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Full Length Research Paper

Optimizing gari quality attributes for different groups of consumers with response surface methodology

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Different groups of consumers prefer different sensory attributes of gari. Therefore it is difficult to produce one stock of the product for all sectors of the market. Fermentation time (h), frying temperature (°C) and resident time (min.) and their interaction effect on quality attributes of gari; swelling capacity, texture, colour, taste and acceptability of gari was investigated. Optimization analysis showed that the optimum quality for all the parameters; 3.51, 3.83, 4.14, 4.70 and 4.70 of swelling capacity, texture, colour, taste and acceptability, respectively were obtained with the fermentation temperature of 12 h, frying temperature of 95°C and resident time of 34.64 h. Other runs in the design were also accepted by some members of the taste panel. The design provides various experimental runs for the production of gari with varying quality attributes to suit the traditional varying market preference.

Key words: Optimization, response surface methodology, CCD.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a major food crop in Nigeria (Kim, 2009). It supplies about 70% of the daily calorie of over 50 million people (Oluwole et al., 2004) and about 500 million people in the world (Abu et al., 2006). Some cassava varieties show high resistance to drought and mosaic disease, high yield, even in agroecological conditions where other starch bearing crops do not thrive. The prevailing climate change, the threatening global warming and the expected negative impact on the yield of less hardy crops highlights further advantages of cassava as the crop of the century. Traditionally, cassava was cultivated by farmers at subsistence levels as the 'poor man's food'. Currently, semi-commercial and commercial farms are available due to increasing awareness and proof of functional versatility of cassava flour especially in the food manufacturing sector (Ernesto et al., 1999; Cardoso et al., 2000; FAOSTAT, 2002). Cassava is a staple crop in Nigeria, some other West African countries and Brazil. It is produced into gari, lafun, tapioca kokote and achke. Gari is an important by-product of cassava, an important item in the menu of most Nigerians. It is particularly popular because of its ready-to-eat (Abu et al., 2006). The importance of gari is also spreading to many countries of West Africa and some of the international markets. Gari is a good source of energy and fiber. Other nutrients are also present in marginally nutritional significance (Ikegwu et al., 2009). The product is consumed dry, smoked with milk, sugar and salt, or in hard paste (eba*)* with soups. Acceptability of gari by all sections of the consumer population is still suffering a set back. This trend is due to its varied sensory attributes and failure to meet the international quality standard (FAO/WHO, 1991; Damadjali et al., 1993; Owuamanam and Achinewu, 2002). Physical, chemical and biochemical processes are employed in the production of gari. Processing factors and ingredients are applied singly or interactively to modify the native cassava starch (Achinewu et al., 1998). The extent of the modification determines the levels of physicochemical and sensory attributes of the final product and consequently, its acceptability. For instance, Oduro et al. (2000), Okafor and Uzuegbu (1987) and Collard and Levi (1987) acknowledged that sensory attributes of gari is determined by level of fermentation, frying temperature, quantity of palm oil added, post-harvest storage of

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Table 1. Levels of dependent and independent variables.

Variable	Unit	Low	Medium	High
Independent variable		**Real (code)**	**Real (code)**	**Real (code)**
X1 - Duration of fermentation	H	12(-1)	24(0)	48(+1)
X2 - Frying temp.	°C	70(-1)	80(0)	100(+1)
X3 - Frying time	min	45(-1)	56(0)	70(+)
Dependent variable				
Y1 - Swelling capacity				
Y2 –Texture				
Y4 – Colour				
Y3 –Taste				
Y4 – Acceptability				

cassava tubers before processing, method of grating, and rate of dewatering of cassava mash during fermentation. Other factors include age of cassava plant at harvest, cassava variety, soil quality of location of farm and storage condition of gari before consumption. In Nigeria, gari quality varies along traditional/cultural lines. The east prefers it creamy of different shades coloured by red palm oil; sweet, imparted by short period of fermentation. The west prefers creamy to slightly-golden colour, varied degrees of sourness imparted by longer period of fermentation. Due to these variations, it is difficult to source the same quality of gari more than once, hence the consumers are forced to consume what is available. For optimum quality attributes, the processing variables must be optimized singly or in combination in order to produce gari of consistent quality and consumer acceptability. The multivariate approach applied in the central composite design of the response surface methodology is the most widely used response surface designs. It reduces the number of experiments, cost and time, improves statistical interpretations and indicates whether parameters interact (Huguo, 2002). The objective of this work was to optimize fermentation time, frying temperature and frying time to produce gari with the optimum values of swelling capacity, texture, colour, taste, and consumer acceptability.

MATERIALS AND METHODOLOGY

About 100 kg of 12 month-old ATM123 cassava variety was obtained from Akwa Ibom State Agriculture Development Project, (AKADEP), Ikot Ekpene, Nigeria. The frying pot was locally fabricated with vulcanized metal with provision to monitor temperature; gas cooker was also locally fabricated. Gari processing was done according to the method adopted by (Ngaba and Lee, 1999; Achinewu et al., 1998) with slight modifications to suit the experimental design and method. The roots were peeled, washed and grated 6 h post-harvest with a locally fabricated grating machine and bagged to dewater the mash to moisture content of about 25%. Fermentation was accomplished according to the design in Table 1.

The dewatered fermented cassava mash was sifted through a local sifter of about 5 mm pore size. Bits of the sifted cassava mash were introduced into hot frying pan with a surface temperature of about 120°C. This was done gradually until mash of about 600 g was introduced; 10 ml of red palm oil was added to the cooking mash cascading gently and steadily with a wooden T stirrer to prevent formation of starch lumps.

Determination of statistical design

The small 3^3 central composite design of the response surface methodology was adopted to study the simultaneous effect of fermentation time, frying temperature and frying time on gari sensory quality. The design is cheap, only a fraction of the experimental runs is required for a full three-level factorial analysis, without compromising accuracy, reproducibility. It is robustness and reliable. It is based on a matrix of multifactor method which measures linear, interaction, quadratic and cubic effects and encompasses the entire multidimensional experimental region (Anderson and Whitcomb, 2007). It is an important tool for a more rapid food process and product development (Huguo, 2002).

$$Y_i = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12}X_1 X_2 + b_{13} X_1 X_3 + b_{23} X_2 X_3 + b_{11} X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 \quad (1)$$

where
Y_1 = measures the predicted response as a result of each factor levels combination; b_o = the intercept, b_1 - b_{33} = regression coefficient determined experimentally, X_1, X_2 and X_3 = independent variables (Box and Behnken, 1960).

The dependent and independent variables for the experimental runs are given in Tables 1 and 2 respectively. The response profile for the 14 experimental runs, analysis of variance and response surface plots optimization analysis were generated with the trial version of Design-Expert (Ver. 7.1.1, Statease, Minneapolis, Mn).

Determination of swelling capacity

Swelling capacity for the samples was determined according to the method adopted by Sanni et al. (2001). A 50 ml measuring cylinder was filled with samples up to the 10 ml mark. Distilled water was added gently up to the 50 ml mark. The mouth of the measuring cylinder was secured tightly covered with a clean plastic cork, the

Table 2. Analysis of variance of models describing effects of fermentation time, frying temperature and resident time on basic qualities of gari.

Variable	Swelling capacity	Texture	Colour	Taste	Acceptability
Model	0.3332	0.0229		0.0229	0.0027
X_1	0.8487	0.0012	0.2908	0.0229	0.0008
X_2	0.5264	0.7332	0.6523	0.7332	0.6682
X_3	0.1943	0.4351	0.5230	0.4351	0.0723
X_1X_2	0.2145	0.1722	1.0000	-	-
X_1X_3	0.3761	0.3226	0.7838	-	-
X_2X_3	0.4473	0.0829	0.5271	-	-
R^2	0.4847	0.8193	0.2814	0.8103	0.7420
Mean	3.30	3.95	3.99	3.95	3.95

Table 3. The responses profile for the 15 experimental runs.

Run	Std	X_1 (H)	X_2 (H)	X_3 (H)	S. C.	Texture	Colour	Taste	Accept
1	5	12.00	95.00	30.00	3.44	3.30	4.30	4.70	4.00
2	13	30.00	95.00	40.00	3.20	4.00	4.00	3.30	3.30
3	12	30.00	120.00	50.00	3.37	3.67	4.70	4.70	4.00
4	1	12.00	70.00	40.00	3.45	3.30	4.70	4.00	4.00
5	11	30.00	70.00	50.00	3.41	4.70	4.00	4.00	4.30
6	14	30.00	95.00	40.00	3.40	4.30	4.30	4.00	4.00
7	7	12.00	95.00	50.00	3.21	3.30	3.30	4.30	4.70
6	9	30.00	70.00	30.00	3.22	4.00	4.00	3.00	3.00
9	10	30.00	120.00	30.00	3.41	4.30	4.00	2.60	3.30
10	3	120.0	120.00	40.00	3.22	3.00	4.00	4.30	4.70
11	4	48.00	120.00	40.00	3.27	4.70	3.30	2.60	3.30
12	8	48.00	95.00	50.00	3.01	4.70	3.30	3.30	3.30
13	2	48.00	70.00	40.00	3.11	4.00	4.00	2.30	3.00
14	6	48.00	95.00	30.00	3.51	4.00	4.00	2.60	3.00

X_1 = Fermentation time, X_2 = Frying temperature, X_3 = Resident time, S. C = Selling capacity.

content was mixed by inversion at 2 min intervals, the cylinder was left to stand for 3 min before the final volume of the gari in the cylinder was read. The swelling capacity was determined by dividing the volume of sample in water by initial volume of sample.

$$\text{Swelling capacity} = \frac{\text{Final volume of sample in water}}{\text{Initial volume of sample in water}}$$

Sensory evaluation

A descriptive sensory evaluation of the samples in terms of texture, colour, taste, and overall acceptability was carried out on a 5-point hedonic scale, where 1 = poor, 2 = fair, 3 = satisfactory, 4 = good, and 5 = excellent (Venet and Nyla, 2001). A 30-member semi-trained panel from National Youth Service Corp (NYSC) members comprising 15 females and 15 males from the northern, southern and eastern and western regions of Nigeria who are regular gari consumers were used for the sensory evaluation. Samples were coded and randomly presented in clean ceramic plates all at the same time and were assessed in dried and reconstituted forms, cold and hot water was supplied for personal reconstitution of samples. Data collected from the sensory evaluation were subjected to ANOVA, regression analysis and response surface plots.

RESULTS AND DISCUSSION

Table 2 is a summary of analysis of variance and multiple regression analysis showing p-values of models for the parameter and of the processing variables at linear and interactive levels, their corresponding coefficient of determinations and means obtained by fitting the data to the 2nd order response model.

Bold face characters in the models 2 to 6 are not significant in statistics, but there are retained since sensory differences in the products may be hidden by the apparently insignificant terms.

The table shows that the developed models for swelling capacity, texture, texture colour appeared to be inadequate ($p>0.05$, R^2 = 0.4646). However, the developed models for taste and acceptability were significantly appropriate ($p<0.05$). Table 3 shows that the

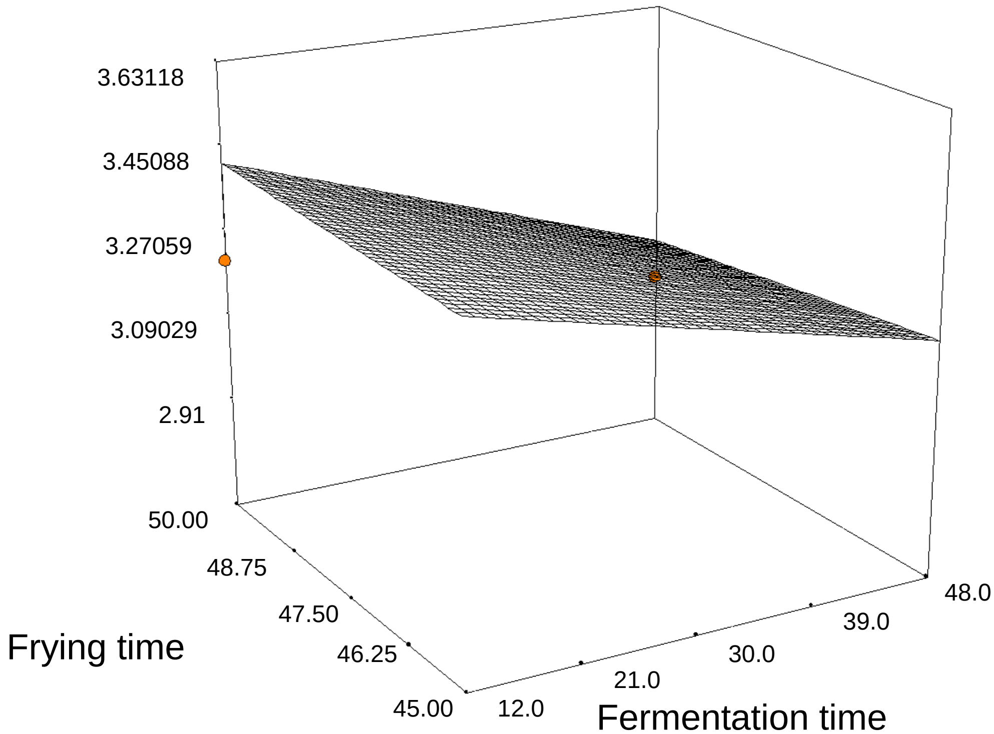

Figure 1. Response surface plot of frying time and fermentation time on swelling capacity.

swelling capacity of the samples ranged from 3.01 to 3.51.

Run 6, corresponding to 48 h, 98°C and 30 min of fermentation time, frying temperature and time respectively showed the highest value (3.50) while Run 8 with 48 h, 95°C and 50 min of fermentation time, frying temperature and time respectively showed the least value (3.01) with a low range of (0.50). This observation was in agreement with those reported by Achinewu et al. (1998) and the recommended value of 300 and 500% for good quality gari (Achinewu et al., 1990). Swelling capacity, the ability of gari particles to absorb water and swell, a very important sensory and mechanical attribute which determines the engineering property including the mouldability of eba and the flow of gari for 'smoking'. According to Sanni et al. (2005), swelling capacity depends on the free amylose and associative forces within the starch granules and moisture content (Achinewu et al., 1998) availability of hydrophilic substituent groups (OH_-, $O_=$) may also be a factor and time of contact with water (Igathinathane et al., 2007). Supporting the trend, Figure 1 shows that swelling capacity (S.C) decreases with fermentation period and a decrease in frying time.

$$\text{Swelling capacity} = 2.002X_1 + 0.0085X_2 + 0.0099X_1X_2 + 0.0415X_1X_3 \quad (2)$$

$$\text{Texture} = 2.3767X_1 - 0.04856X_2 + 0.0432X_3 + 0.0007X_1X_2 - 0.0014X_1X_3 + 0.0006X_2X_3 \quad (3)$$

$$\text{Colour} = 8.7534 - 0.0588X_1 - 0.0363X_2 - 0.0793X_3 + 0.000325X_1X_2 \quad (4)$$

$$\text{Taste} = 6.63 - 0.0.0780X_1 + 0.\ 0713X_2 + 0.124X_3 + 0.0011X_1X_2 - 0.0011X_1X_3 + 0.0009\ X_2X_3 \quad (5)$$

$$\text{Acceptability} = 1.9465 - 0.0136X_2 - 0.0251X_2 + 0.1078X_3 + 0.00091X_1X_2 - 0.0021X_1X_3 \quad (6)$$

Texture is an important attribute which influences level of acceptability of eba. Texture is a complex sensory parameter which is difficult to describe in isolation of swelling capacity, bulk density (not shown here), moisture content (water activity). According to Ikegwu et al. (2009). Variety of the tuber is a major influence on the kinetics of cassava mash during fermentation.

The result of sensory evaluation of texture is presented in Table 2. The table shows that contribution of linear and interaction of the factors on the parameter were not significant ($p>0.05$) except frying temperature, ($p<0.05$), however, the model was appropriate ($R_2 = 0.9222$).

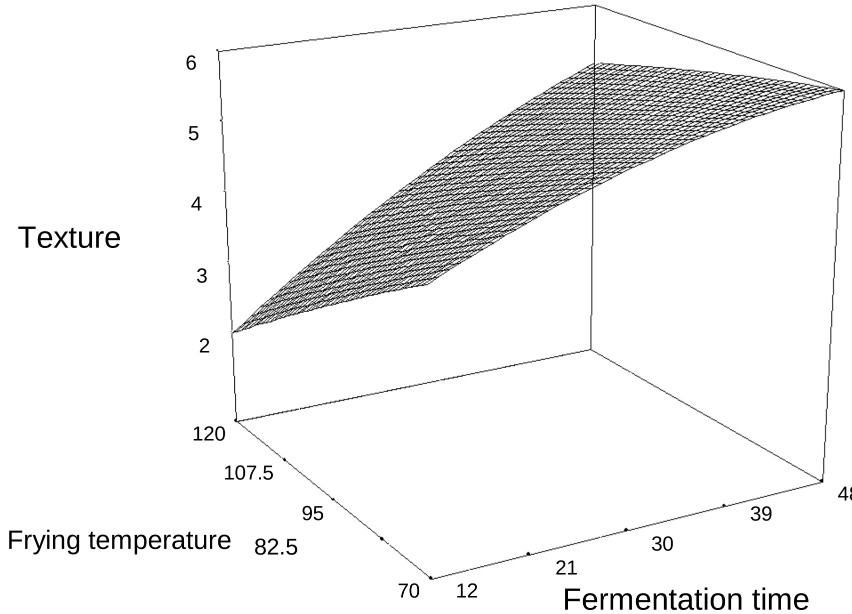

Figure 2. Response surface plot of frying temperature.

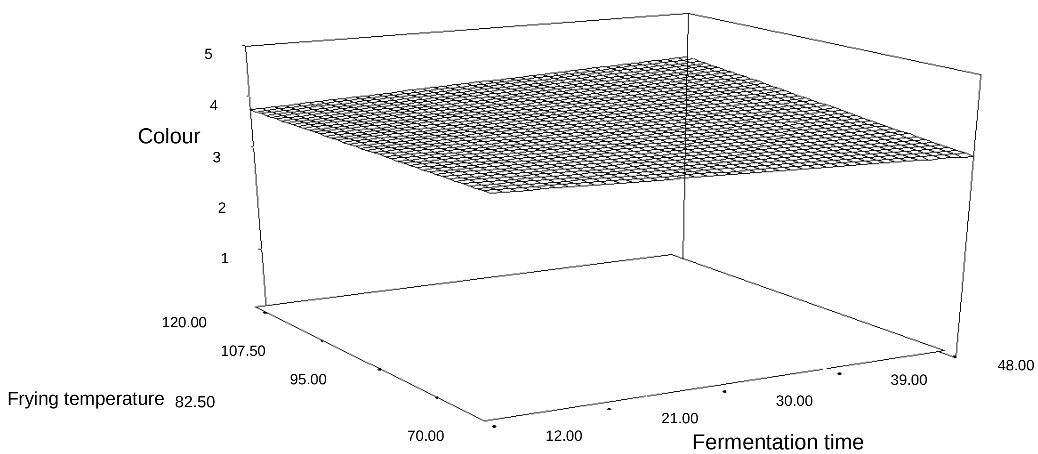

Figure 3. Response surface plot of frying temperature and fermentation time on colour and fermentation time on texture.

According to Table 3, texture sensory score ranged between 3.30 and 4.70. The highest was observed at 48 h, 95°C and 50 min of fermentation time, frying temperature and time respectively while the lowest was observed at 120 h, 20°C and 40 min of fermentation time, frying temperature and time respectively. Figure 2 shows that value of the parameter is increased with increasing fermentation time, and decreasing frying temperature. This observation may be due to the depletion of amylose of the cassava mash during fermentation, slow cooking of the mash with low temperature, this trend is in agreement with was reported by Cadoso et al. (1987) and Eresto et al. (2002), the slight variation may be due to varietals, procedural and idiotic differences of the experimenters.

Colour of gari is normally white or cream. Traditionally, different shades of redness is obtained by addition of palm oil. Although an important sensory parameter in the choice of gari, in our study, the model of processing variables on colour of gari was not significant ($p>0.05$,) and appeared to be reliable ($R^2 = 0.7490$), showing that colour may not be a major determining factor of gari acceptability compared to texture and taste. Figure 3 shows a near flat response surface to support the observation.

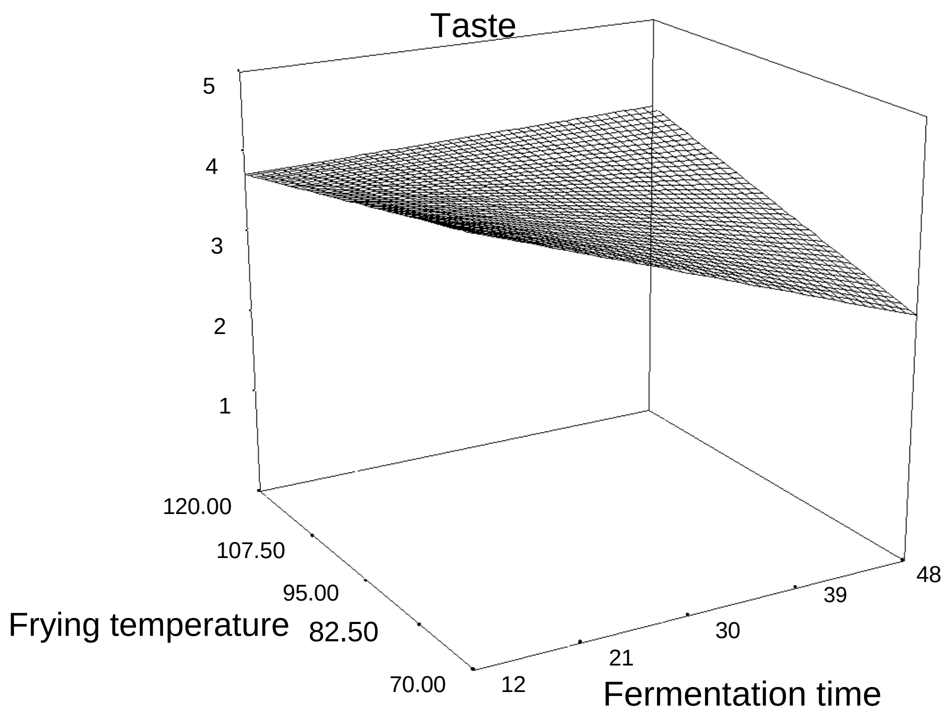

Figure 4. Response surface plot of frying temperature and fermentation time on taste.

Effect of resident time of cassava mash during frying is minimally significant (p>0.05). Taste sensor score ranged between 2.30 to 4.70, the highest scores were observed in products with fermentation period of between 12 and 30 h with interaction of frying temperature of between 70 to 95°C, the lowest were observed for samples from fermentation period of more than 30 h and frying temperature of more than 95°C (Table 3).

Figure 4 further elucidates the observation. This observation is not in agreement with that reported by Achinewu et al. (1998), the high acceptability of gari of 60 h of fermentation in his study may have been be due to the composition of the taste panel. Due to the high pH value of the product a few consumers would accept and make limited use of the product. Taste of gari emanates cassava fermentation, production, accumulation and breakdown of metabolites (aldehydes, ketones and organic acids) is a factor of fermentation period which in turn is proportional to the taste quality of the final product. Besides, prolornged fermentation of cassava mash introduces an unhygenic problem into gari production. In our study, it was observed that some panelists preferred the sour to the sweet sweet sample, this pattern of preference shows that one run of gari cannot satisfy the organoleptic requirement of all consumers.

Our experience shows that acceptability of a product reflects its preference and ready-to-buy attitude of consumers in the presence of close substitutes. The level of acceptability depends on the general product sensory properties, familiarity, attractiveness and traditional values. Non-availability of the desired quality product forces consumers to buy and consume what is available, with limited satisfaction. In this study the optimum quality for all the parameters of 3.51, 3.83, 4.14, 4.70 and 4.70 of swelling capacity, texture, colour, taste and acceptability, respectively were obtained with the fermentation temperature of 12 hours, frying temperature of 95°C and resident time of 34.64 h.

Conclusion

The work revealed that the organoleptic attributes and preference of gari is relative to the levels of processing factors used and the psychology of the consumer (Wayne and Macinnis, 1997). Therefore, in the production of gari, adequate attention should be paid to the effect of traditional preference of the target consumer population.

The models produced in this study are not final to the production of consistently high quality of gari, effects of other variables on the quality and acceptability of the product should be studied.

REFERENCES

Achinewu SC (1990). Toxic components of food and their mode of removal. Public lecture Rivers State University of Science and Technology, Port Harcourt, pp. 69-70.

Achinewu SC, Barber LI, Ijoma IO (1998). Physicochemical properties and garification (gari yield) of selected cassava cultivars in Rivers State, Nigeria. Plant Foods Hum. Nutri., 52: 133-140.

Anderson M, Whitcomb P (2002). RSM simplified: Optimizing processes method for design of experiments. Productivity Press, New York.
Box GEP, Behnken DW (1960). Some new 3-level design for the study of quadratic variables. Technometrics, 2: 455-475.
Cardoso AP, Cliff J, Bradbury JH (2000). Cyanogens in cassava flour and roots and urinary thiocyanate concentration in Mozambique. J. Food Consumption Anal., 13: 1-12.
Collard P, Levi S (1959). A two stage fermentation of cassava. Nature, London, (183): 620-621.
Damadjali DS, Widowate S, Rachin A (1993). Cassava flour production and consumers acceptance at village level in Indonesia. Indonesian Agric. Res. Dev. Lurnal, 15: 16-25.
Ernesto M, Cardoso AP, Cliff J, Bradbury JH (1999). Cyanogenic potential of cassava flour; field trial in Mozambique of a simple kit. Int. Food Sci. Nutr., 49: 93-99.
FAO/WHO (1991). Joint food standards programme Rome: Codex Alimentarius Commission XII, Supplement 4, FAO, p. 145.
FAO STAT (2002). The world production of cassava roots in 2001. http://www.fao.org.
Huguo GN (2002). Food product design: A computer-aided statistical approach. CRC Press, pp. 56-63.
Igathinathane C, Pdessimo LO (2007). Moisture sorption thermodynamic properties of corn stover fractions. Am. Soc. Agric. Biol. Eng., 50(6): 2151-2160.
Ikegwu OJ, Nwobasi VN, Odoh MO Lledinma NU (2009). Evaluation of pasting and some functional properties of staqarch isolated from some improved cassava varieties in Nigeria. Afr. J. Biotechnol., 8(10): 2310-2315.
Jenet S, Nyla T (2001). Eating qualities of muffins prepared with 10% and 20% soy flour. J. Nutr. Recipe Menu Dev., 3(2): 25-33.
Kim HS (2009). Cassava: Gabon seeks Nigeria's help; http://cassavamews/ blogspot.com/2009/02/cassava-gabon-seeks-nigerias-help.html.
Ngaba RR, Lee JS (1999). Fermentation of cassava (*Manihot esculenta* Crantz). Am. J. Food Sci., 44: 1570-1571.
Oduro I, Ellis WO, Dziedzoave NT, Nimaakoyeboah K (2000). Quality of gari from selected processing zones in Ghana. Food Control, 11: 297-303.
Okafor N, Uzuegbu JO (1987). Studies on the contributions of microorganisms to the organoleptic properties of gari: a fermented food derived from cassava. (*Manihot esculenta* Crantz). Nig. J. Food Agric., 2(13): 39-41.
Sanni LO, Adebaoale AA, Awoyale W, Fetuga GO (2008). Quality of gari (roasted cassava mash) in Lagos State, Nigeria. Nig. Food J., 26(2): 125-130.
Sanni LO, Ikuomola DP, Sanni SA (2001). Effect of length of fermentation and varieties on the qualities of sweetpotato garri. Proc. 8th Triennaial Symposium of the International Society for Tropical Root Crop- Africa Branch (ISTRC-AB), Ed. M. O. Akoroda, IITA, Ibadan, Nigeria, 12-16 November, 2001, pp. 208-211.
Janet S, Nyla T (2001). Eating qualities of muffins prepared with 10% and 20% soy flour. J. Nutr. Recipe Menu Dev., 3(2): 25-33.
Wayne D, Hoyer JM, Deborah JM (1997). Regional, ethnic, and religious influences on consumer behaviour. In: Consumer behaviour. Houghton Mifflin Company, USA, 1: 296-336.