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Food Research International 33 (2000) 867–873

FOOD
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Optimizing agbelima production: varietal and fermentation effect on product quality

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Received 7 October 1998; accepted 25 March 2000

Abstract

The variety of cassava used for processing has been shown to influence the physico-chemical, functional and other quality characteristics of some cassava products. Thus, the effects of varietal differences and fermentation time on some quality indices of agbelima, a fermented cassava product, was investigated with the objective of optimizing production. Three improved cassava varieties, TMS 4(2)1425, TMS 50395, TMS 30572 and two local varieties, Bosomensia and Biafra were investigated at fermentation times of 0, 24, 48 and 72 h. Quality parameters assessed included total titratable acidity, pH, textural properties and colour characteristics. All the parameters were significantly ($P \leqslant 0.01$) affected by both varietal differences and fermentation time. The interaction between varietal difference and fermentation time were also highly significant ($P \leqslant 0.01$) for all the parameters assessed. The results of this study show that the selection of cassava varieties for processing and the duration for fermentation are critical to the quality of the final agbelima product.

Keywords: Cassava fermentation; Agbelima; Cassava variety; Quality characteristics

1. Introduction

Cassava is grown widely in several parts of the world especially in the tropical regions and constitute a significant proportion of the diet of the population. In Africa, it provides over 50% of the average daily caloric intake in some countries (Oyewole & Odunfa, 1992). In recent times, a number of regional programs have been initiated to breed improved varieties of cassava to increase yield and resistance to diseases which are sometimes associated with the indigenous cassava varieties (Silvestre, 1989).

These new cassava varieties have, however, received varying degrees of acceptability because of their differing responses to the traditional processing methods used in processing cassava into different products. Various studies have shown that the physicochemical, functional and other quality characteristics of fufu, gari, cassava pellets and composite flours from cassava are significantly affected by varietal differences (Cabrera, 1986; Safo-Kantanka & Owusu-Nipah, 1992; Vitti, Leitao, Pizzinato & Campos 1978). Studies have also shown that detoxification occurs during cassava fermentation using traditional methods (Gidamis, O'Brien & Poulter, 1993; Vasconcelos, Twiddy, Westby & Reilly, 1990).

Agbelima is a traditional fermented cassava product, the production of which involves the use of an inoculum locally called 'Kudeme'. Kudeme is made up of predominately *Bacillus* species and lactic acid bacteria (Amoa-Awua, 1996). The main purpose of using this inoculum is to improve the texture, colour and flavour of agbelima (Budu, 1990; Sefa-Dedeh, 1989). Presently, attention is gradually being shifted to the improved varieties of cassava. There is thus the need to investigate the effect these varieties and other process parameters have on product quality in order to effectively optimize agbelima production. Dziedzoave (1996) reported that colour, cohesive, smoothness, aroma and sourness are the first five most important sensory attributes consumers and producers associate with good quality agbelima. He also observed that average particle size, total acidity/pH and metric chroma are the most adequate objective indicators of human evaluation for smoothness, sourness and colour, respectively.

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0963-9969/00/$ - see front matter
PII: S0963-9969(00)00106-X

Thus, the objective of this study was to investigate how differences in cassava variety and fermentation time affect product quality.

2. Materials and methods

2.1. Experimental design

A two-factor, completely randomized design involving five cassava varieties and three fermentation times were used in this study. The varieties constituted one factor and the fermentation time the other factor. This gave 15 experimental units each described by a distinct variety and fermentation time combination. To determine the experimental unit which produced the overall best quality agbelima, the average performance were computed based on the attributes of color (chroma), smoothness (average particle size) and aroma (total titratable acidity). The experimental unit with the lowest value in chroma was given a score of 1 whilst that with the highest value a score of 15. The experimental unit with the highest percent value in total titratable acidity was given a score of 1 and the lowest a score of 15. The experimental unit with the smallest particle size was given a score of 15 whilst that with the highest received a score of 1.

2.2. Source of raw materials

The cassava varieties selected for this study were varieties with low cyanide content, high yielding and disease resistant and were obtained fresh from farms in and around Pokuase, a suburb of Accra in Ghana. They were made up of two local varieties, namely ''Bosomensia'' and ''Biafra'' and three improved varieties, TMS 30572, TMS 50395 and TMS 4(2)1425.

2.3. Inoculant (kudeme) preparation

Five hundred grams of peeled cassava were cut into chunks of 3–5 cm^3 sizes and placed in boiling water for 10 min. They were then removed and wrapped in a wet cheese cloth, placed in a polyethylene bag and tied securely. This was allowed to ferment for 4 days at room temperature (25–27°C) after which the resultant product, the kudeme, was ready for use. This process was carried out for each of the varieties.

2.4. Agbelima preparation

The different varieties of fresh cassava tubers were knife peeled, washed and grated using a motor-driven cassava mill. The grated mash from each variety was divided into four 1-kg batches. Each batch was inoculated with 30 g of kudeme made from the same variety. Inoculated mashes were loaded into polypropylene sacks and left to drain and ferment for 0–3 days, without the application of any external pressure on the sacks. Each 1 kg batch per variety was used for one fermentation time. Fermentation was arrested by freezing of the sample prior to analysis after 0, 24, 48 and 72 h, respectively for each of the four 1-kg batches of each variety.

2.5. pH

Five grams of the agbelima sample was weighed and made into a slurry using 50 ml of distilled water in a beaker. The beaker was placed in a water bath at 40°C for 1 h with occasional shaking. The pH was then measured with the Corning pH meter (model 240, Corning Science products, Corning new York, USA).

2.6. Total titratable acidity

Eighteen grams of agbelima sample was made into a slurry using 200 ml distilled water (CO_2-free) in a flask. The flask which was loosely stoppered was placed in a water bath at 40°C for 1 h and shaken occasionally. The slurry was then filtered using Whatman's No.1 filter paper. One hundred millilitres of the filtrate was titrated against 0.2 M NaOH using phenolphthalein as indicator. The total titratable acidity was calculated as percent lactic acid.

2.7. Colour

The sample colour was determined using the Minolta Chroma meter (Model Cr-200, Minolta Camera Co. Ltd., Japan) on the $L^*C^*H^\circ$ colour space. The agbelima sample was packed into a petri dish and the surface smoothened. The sensor of the chroma meter was then placed on the surface of the sample and the color reading read on the meter. This was carried out on four randomly selected points on the sample surface and the average value determined. The chroma meter was calibrated using a standard white tile [$L^* = +\ 97.63$ (0.00); $C^* = 2.10$ (0.01); $H^\circ = 1.27$ (0.00)].

2.8. Average particle size

A modification of the method proposed by Henderson and Perry (1979) for dry flours was used. The modification was made to suit the sample under investigation which was a wet sample. One hundred grams of agbelima sample was washed down a set of graded Tyler sieves with 10 l of water. The aperture sizes of the sieves used were 1.00, 0.50, 0.25 and 0.125 mm. Fractions retained on each sieve were oven-dried at 120°C for 2 h, cooled and weighed. The dry matter content of the agbelima (cassava dough) was deter-

mined and used to estimate the amount of the sample that would otherwise have collected in the pan. The results were used to calculate the fineness modulus from which the average particle size (D) in ml was calculated according to the method of Henderson and Perry.

2.9. Statistical analysis

Statistical analysis (ANOVA) on the data obtained was carried out using the Microsoft Excel program. All analyses were carried out in triplicate.

3. Results and discussion

Figs. 1 to 6 show the changes in the chemical, textural and colour characteristics of the cassava varieties with fermentation time. Significant differences ($P<0.01$) were observed for all the varieties, different fermentation times and the interaction between these two parameters for each of the factors assessed. There was a rapid increase in total titratable acidity for all the cassava varieties during the first 24 h of fermentation. The increase continued during the second day of fermentation but at a reduced rate. However, after 48 h of fermentation, total acidity decreased for all the varieties with Bosomensia and TMS 4(2)1425 being more pronounced (Fig. 1).

The trend in pH was directly opposite that observed for total acidity. There was a rapid decrease in pH during the first 24 h after which pH remained within a fairly constant range (Fig. 2). Analysis of variance (ANOVA) showed that Bosomensia and Biafra had significantly higher pH values ($P < 0.01$) than TMS 50395 and TMS 30572. TMS 4(2)1425 even though significantly higher ($P < 0.01$) in pH than TMS 30572 did not show any significant difference from that of Biafra and TMS 50395. With respect to fermentation time, pH at 0 h was significantly different ($P < 0.01$) from that of the other fermentation times.

The observed changes in total titratable acidity and pH with fermentation time are in agreement with observations made by Collard and Levi (1956) and Akinrele (1964). They observed that cassava fermentation proceeds with the production of a variety of organic acids such as lactic and formic acids during the first 48 h of fermentation. However, during the course of fermentation some of these acids are used for the production of various aldehydes and esters which give the fermenting mash its characteristic aroma. This may therefore account for the decrease in total acidity after 48 h of fermentation for all the varieties.

Considering the fact that for both total acidity and pH, there were no significant differences after 24 h of fermentation, shows that if the purpose of fermentation is to increase acidity then fermentation beyond 24 h would not be necessary. However, the fact that texture was at its worst at this fermentation time suggests that fermentation beyond 24 h is a necessary requirement for texture improvement.

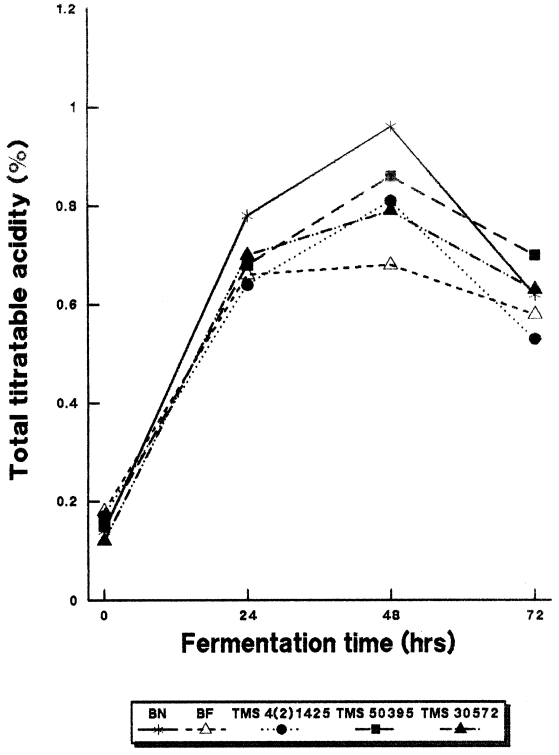

Fig. 1. Change in titratable acidity with fermentation time.

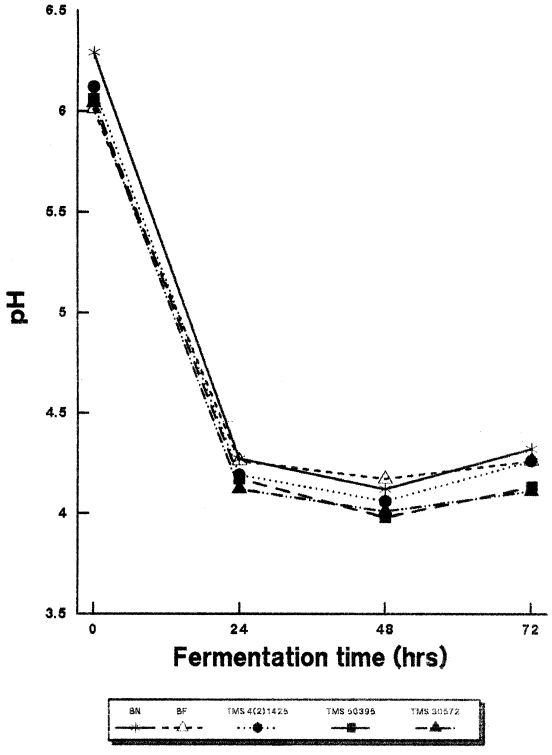

Fig. 2. Change in pH with fermentation time.

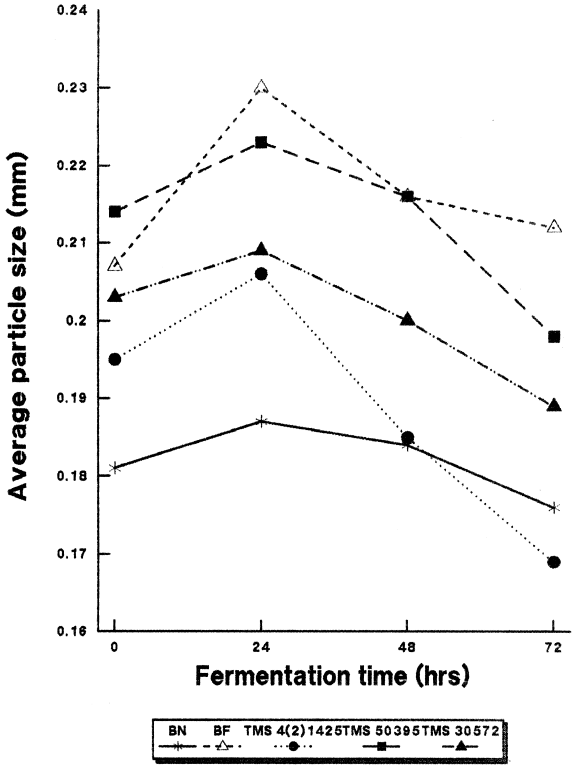

Fig. 3. Change in average particle size with fermentation time.

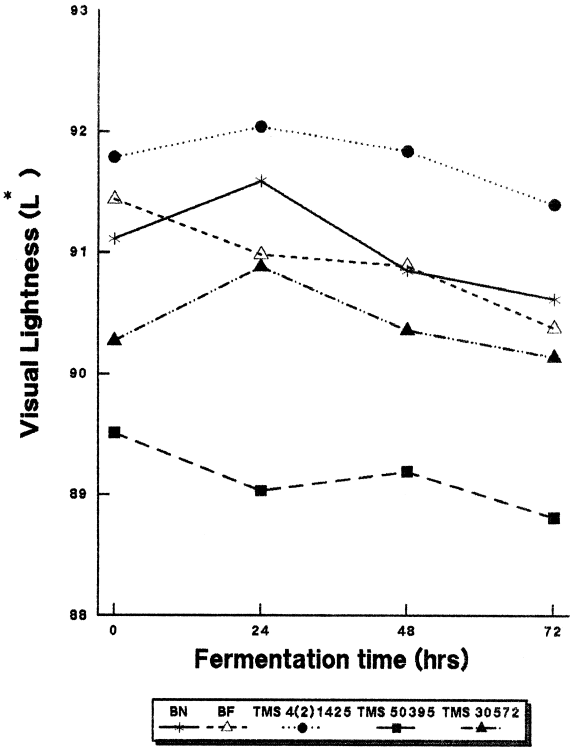

Fig. 4. Changes in visual lightness with fermentation time.

For all the varieties, there was a similar trend in the changes in particle size and fineness modulus with fermentation time. There was an increase in particle size of all the varieties during the first 24 h of fermentation after which there was a significant decrease ($P < 0.01$) (Fig. 3). Bosomensia and TMS 4(2)1425 showed a significantly lower ($P < 0.01$) average particle size compared to Biafra and TMS 50395 varieties. TMS 30572 although significantly different from Bosomensia and Biafra showed no difference from TMS 4(2)1425 and TMS 50395. Even though particle size was significantly affected by fermentation time ($P < 0.01$), there was no difference between the 0 h and the 48 h fermented samples. However, the 72 h fermented samples differed significantly from the 24 h and 48 h fermented samples.

The increase in particle size during the first 24 h of fermentation may be due to the large volume of exudate around the tissues which may have resulted in a reabsorption of some water by the intact cells thereby causing them to swell and become more turgid and consequently increasing in size. However, the decrease in particle size after 24 h of fermentation is attributed to the activity of tissue degrading enzymes in the fermenting mash. Some enzymes identified to be associated with cassava fermentation are amylases, pectin methyl esterase and cellulase (Oyewole & Odunfa, 1992). Amoa-Awua and Jakobson (1995) in their studies on cassava fermentation have also shown that the microflora of the inoculum is dominated by *Bacillus* spp. which through the activities of their cellulase enzymes cause the breakdown of the texture of cassava dough. The fact that the 72 h fermented samples had a significantly lower particle size than both the 24 h and 48 h fermented samples indicates that fermentation must be carried beyond 48 h if any improvement in smoothness is to be achieved. The overall decrease in particle size for all the five varieties with fermentation time is of significant importance. This is because such a decrease would result in an increased smoothness of the product, an effect confirmed to be very desirable in good quality agbelima (Dziedzoave, 1996).

From the interaction between varietal difference and fermentation time, the agbelima sample with the best smoothness may be obtained from TMS 4(2)1425 at 72 h of fermentation and Bosomensia at 72 and 48 h fermentation times respectively in descending order of smoothness.

With the exception of the Biafra variety which showed an increase after 48 h of fermentation, the trend in uniformity index for all the varieties was similar to that of the particle size and fineness modulus. The uniformity index being a ratio of medium size particles to small size particles reflects the uniformity of the sample more than the smoothness, even though it does reflect smoothness to a reasonable extent. The closer the value is to zero, the more uniformly smooth is the product,

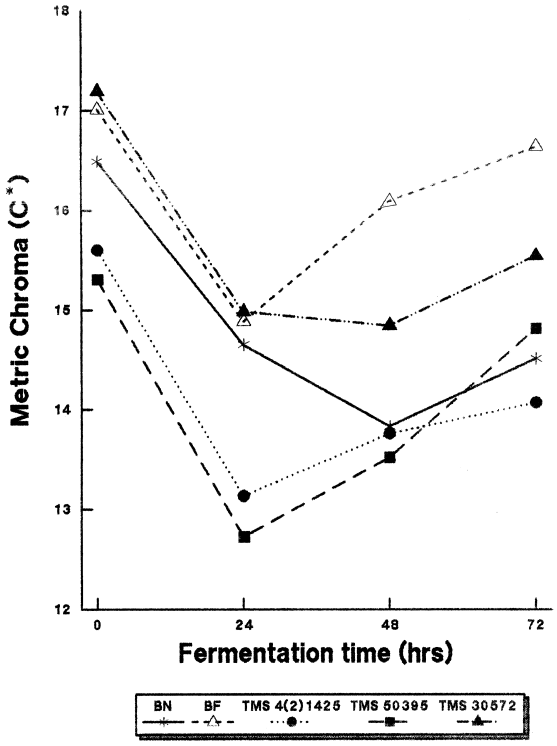

Fig. 5. Change in metric chroma with fermentation time.

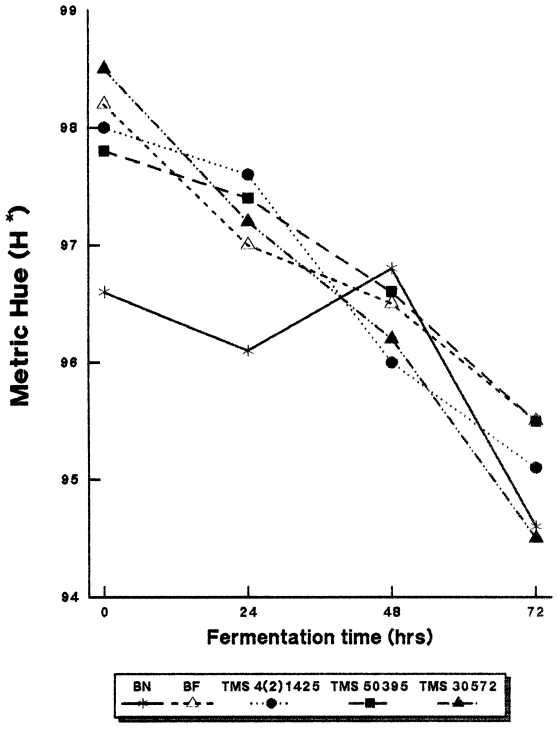

Fig. 6. Change in metric hue with fermentation time.

whereas the closer the value is to 1 the more non-uniform is the product. All the varieties yielded products that were uniformly smooth at all fermentation times. Differences in uniformity index between the different fermentation times were similar to that of the fineness modulus and particle size.

The results also indicated that agbelima colour is basically a blend of white, yellow and green in decreasing order of intensity. The trend in visual lightness (L^*) with fermentation time shows that whilst TMS 4(2)1425 had the highest L^* value, TMS 50395 had the least. For all the five varieties, the L^* value decreased to a minimum after 48 h of fermentation (Fig. 4). Analysis of variance showed that the L^* values of the five varieties differed significantly ($P < 0.01$) from each other during the course of fermentation. The trend for metric chroma (C^*) with fermentation time was similar for all the five varieties. Metric chroma decreased during the first 24 h of fermentation after which there was an increase throughout the fermentation period (Fig. 5). Metric chroma indicates the overall colour purity of the product and the rate of change in C^* for each fermentation time was different for each variety. TMS 30572 showed a significantly higher C^* value than TMS 4(2)1425 and TMS 50395 but did not differ significantly from the two local varieties. The increase in metric chroma after 24 h of fermentation indicates a brightening of the colour of the product, which is very desirable in agbelima. However, the final C^* values at 72 h of fermentation were lower than the initial value at 0 h (Fig. 5). This implies that the fermentation did not really result in any overall improvement in the brightness of the colour. Since the C^* colour parameter is the most adequate objective indicator of human evaluation of colour (Dziedzoave, 1996), any changes observed in C^* must be considered more critical to quality than changes in L^* and H°.

The trend in the metric hue values (H°) were similar for all the varieties, decreasing throughout the fermentation period (Fig. 6). However, the Bosomensia variety showed an increase during the first 24 h of fermentation followed by a rapid decrease after 48 h. The general decrease in H° indicates an overall decrease in the yellow–green colour of the products. This may be due to the isomerisation of carotenoids at the onset of acid formation during the course of fermentation. Adewusi and Bradbury (1992) reported the identification of β-carotene, lutein and other carotenoids in the tubers of some cassava varieties and these are likely to be responsible for the colour of cassava.

According to Eskin (1990), acids catalyze isomerization of carotenoids from the all-*trans* form to the corresponding *cis*-isomer. The change in shape associated with the *cis*-isomer reduces the resonance in the molecule as well as the colour intensity. The increase in acidity with fermentation time may have caused an increase in isomerisation of the carotenoids present resulting in the observed reduction in H°. The loss in colour may also be due to enzymatic oxidation (Arens, Seilmeier, Weber, Kloos & Grosch, 1973; Eskin, Grossman & Pinsky, 1977). The overall reduction in H° is a desirable effect

because in the production of agbelima, the objective of adding the traditional inoculant, 'kudeme' is to improve the whiteness and smoothness of the product (Budu, 1990; Sefa-Dedeh, 1989) and a reduction in the colour hue would indirectly improve whiteness.

The summary presented in Table 1 indicates that whereas the Biafra and the TMS 30572 varieties seem to be very good for producing agbelima with a bright colour, TMS 30572, TMS 50395 and Bosomensia varieties produce agbelima with a relatively high acidity. How-

Table 1
Cassava varieties and corresponding fermentation times that give the best agbelima samples in relation to parameters assessed

Parameter	Best variety with corresponding fermentation time[a]	Other comparable combinations
Total titratable acidity	BOSOMENSIA (48 h)	TMS 30572 (48 h)
	TMS 50395 (48 h)	BOSOMENSIA (24 h)
	TMS 4(2)1425 (48 h)	
pH	TMS 50396 (48 h)	TMS 30572 (72 h)
	TMS 30572 (48 h)	TMS 30572 (24 h)
	TMS 4(2)1425 (48 h)	BOSOMENSIA (48 h)
		TMS 50395 (48 h)
Particle size	TMS 4(2) 1425 (72 h)	TMS 4(2)1425 (48 h)
	BOSOMENSIA (72 h)	
	BOSOMENSIA (48 h)	
Fineness modulus	TMS 4(2)1425 (72 h)	TMS 4(2)1425 (48 h)
	BOSOMENSIA (72 h)	BOSOMENSIA (24 h)
	BOSOMENSIA (72 h)	
Uniformity index	TMS 4(2)1425 (72 h)	BOSOMENSIA (24 h)
	BOSOMENSIA (72 h)	TMS 4(2)1425 (48 h)
	BOSOMENSIA (48 h)	
Visual lightness (L^*)	TMS 4(2)1425 (24 h)	BOSOMENSIA (24 h)
	TMS 4(2)1425 (48 h)	TMS 4(2)1425 (72 h)
	BOSOMENSIA (48 h)	
Metric chroma (C^*)	BIAFRA (72 h)	TMS 30572 (24 h)
	BIAFRA (48 h)	BIAFRA (24 h)
	TMS 30572 (72 h)	TMS 30572 (48 h)
Metric hue (H°)	TMS 30572 (72 h)	BIAFRA (72 h)
	BOSOMENSIA (92 h)	TMS 50395 (72 h)
	TMS 4(2)1425 (72 h)	

[a] For each parameter, the list is in descending order of quality.

Table 2
Ranking of cassava variety/fermentation time combinations according to the overall quality of agbelima obtained

Variety	Fermentation time (h)	Properties scored						Sum of scores	Overall rank order
		Total acidity (%)		Average particle size (mm)		Chroma (C^*)			
		Average value	Score	Average value[a]	Score	Average value[a]	Score		
TMS 4(2)1425	72	0.53 (0.01)	13	0.169 (0.001)	14	14.07 (0.38)	6	33	1
TMS 30572	72	0.63 (0.01)	10	0.189 (0.003)	9	15.54 (0.18)	12	32	2
Biafra	72	0.58 (0.03)	12	0.212 (0.006)	4	16.64 (0.51)	15	31	3
Bosomensia	72	0.62 (0.03)	11	0.176 (0.003)	13	14.51 (0.14)	7	31	3
Biafra	48	0.68 (0.01)	7	0.216 (0.005)	3	16.09 (0.23)	14	24	4
Bosomensia	24	0.78 (0.03)	5	0.187 (0.001)	11	14.65 (0.50)	8	24	4
TMS 50395	72	0.70 (0.03)	6	0.198 (0.002)	8	14.81 (0.45)	9	23	5
TMS 30572	24	0.70 (0.03)	6	0.209 (0.000)	5	14.98 (0.25)	12	23	5
TMS 30572	48	0.79 (0.01)	4	0.200 (0.002)	7	14.84 (0.32)	10	21	6
Biafra	24	0.66 (0.01)	8	0.230 (0.001)	1	14.88 (0.18)	11	20	7
Bosomensia	48	0.96 (0.03)	1	0.184 (0.001)	12	13.83 (0.45)	5	18	8
TMS 4(2)1425	48	0.81 (0.01)	3	0.185 (0.001)	11	13.76 (0.18)	4	18	8
TMS 4(2)1425	24	0.64 (0.03)	9	0.206 (0.003)	6	13.13 (0.29)	2	17	9
TMS 50395	24	0.68 (0.03)	7	0.223 (0.003)	2	12.72 (0.42)	1	10	10
TMS 50395	48	0.86 (0.00)	2	0.216 (0.003)	3	13.52 (0.24)	3	8	11

[a] Standard deviation given in paretheses.

ever, TMS 4(2)1425 and Bosomensia produced agbelima with the best texture. Ranking the different agbelima samples with respect to chroma, particle size and total acidity, the three important objective indicators of human evaluation of colour, smoothness and taste of agbelima, respectively (Table 2) showed that the cassava varieties and fermentation times which gave the overall best quality agbelima were TMS 4(2)1425 at 72 h, TMS 30572 at 72 h, Biafra at 72 h, Bosomensia at 72 h and TMS 50395 at 72 h fermentation times, respectively.

4. Conclusion

It may be concluded from this study that cassava varietal difference, fermentation time and the interaction between these two parameters significantly affect the quality of agbelima produced. The optimum fermentation time is 72 h, at which there is no significant difference between the performances of TMS 4(2)1425, TMS 30572, Biafra and Bosomensia. However, the performance of TMS 50395 differed significantly.

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