Consumer Acceptability of Nixtamalized Nigerian Traditional Maize-Based Food – *Tuwo Masara*

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ABSTRACT

Background: *Maize and its products such as Tuwo, an indigenous, commonly consumed staple in northern Nigeria, have low calcium content. Nixtamalization, a process of lime cooking and steeping of cereals, more commonly done in the Americas than other parts of the world, is associated with increased calcium content.*

Objective: *The objective of this research is to evaluate the acceptability of Tuwo masara produced from calcium-improved maize through nixtamalization.*

Methodology: *Maize grains were nixtamalized using lime concentrations of 0% (control), 1.2%, 3%, and 5%, respectively, to produce nixtamalized maize flour tuwo (NMFT). Tuwo samples were prepared using the traditional method. Preference and acceptability of the samples were evaluated by Consumer studies. Questionnaires containing hedonic, just-about-right, and check-all-that-apply tests were administered to 125 untrained, consented respondents.*

Results: *Thirty-six percent of the respondents were female, while 64% were male. Just-about-right results showed that 5% NMFT compared favourably with the control in terms of flavor, taste, hardness, and mouldability. The check-all-that-apply results showed that quality attributes of tuwo samples were smoothness, mouldability, stickiness, sweet taste, good flavor, cream color, and moderate softness. All the samples were accepted by the consumers; however, the sample rated as 'most liked' in terms of flavor, taste, smoothness, mouldability, stickiness, softness/hardness, and color was 5% NMFT, while 3% NMFT was the 'least liked'.*

Conclusion: *The nixtamalized tuwo was acceptable among indigenous consumers. Hence, nixtamalization can be adopted as a food-based approach in incorporating calcium into cereal grains to improve calcium consumption of consumers, thereby reducing calcium deficiency.*

Keywords: Tuwo masara, consumer studies, nixtamalization, maize, Just-about-right, Check-all-that-apply

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INTRODUCTION

Micronutrient deficiency has been a global public health problem affecting vulnerable groups such as young children, breastfeeding mothers, and pregnant women, mostly in developing countries and resource-poor countries (1, 2, 3). Calcium is a micronutrient that is required for several physiological roles in the body, and its deficiency has been reported to have negative health outcomes, including pregnancy complications, maternal bone loss, cancers, cardiovascular disease, and high blood pressure (4). Alleviation of micronutrient deficiencies in low- and middle-income countries where it

is prevalent (5) is therefore important for health improvement, nutritional security, economic growth, and national development (6). Food fortification, diversification, and nutritional supplementation are strategies used to reduce micronutrient deficiencies (1). Maize, one of the dominant cereal crops in Northern Nigeria (7), is widely consumed in various forms, providing nutrients for many households (8). However, maize and its products are fortified with several micronutrients of public health importance, which do not include calcium (9, 10). A food-based approach can be a cheap method of reducing micronutrient deficiencies, especially if the existing technology is accepted by the local processors.

Nixtamalization, a traditional and ancient process (11), involves cooking corn in lime water, steeping in alkaline liquor, and washing to remove the hull (12); the cooked corn is named nixtamal. This traditional process has been reported (13) to increase the nutritional and textural quality of maize food products in different ways. The alkaline solution breaks down the maize's tough pericarp, which makes it easier to grind and increases its nutritional value (14). It also breaks down phytic acid and releases minerals, making them more bioaccessible (15) while reducing aflatoxin concentrations in the process (16). In addition, lime-cooking improves the rheological properties of the dough, thus giving it the preferred quality attributes by the consumers (17). It significantly increases its calcium content (18), releases bound niacin and makes it available, thus increasing the bioavailability of calcium in maize (13) since the lime hydrolyzes the bonds holding the hemicelluloses together in the cell walls, and allows the pericarp to be easily removed. The degraded pericarp, rich in arabinoxylans, acts as a hydrocolloid, imparts desirable textural properties, provides relevant amounts of bioavailable calcium, and improves niacin bioavailability (13).

Tuwo, a traditional, unfermented thick pudding or soft dough, is often prepared from maize (*tuwo masara*) or rice flour (*tuwo shinkafa*). It is one of the favorite and common foods in most Hausa households (9) and is also eaten amongst the Yorubas in the Southwest as well as some communities in West Africa (19). A consumer acceptability test is a type of sensory evaluation method used for product development and marketing research to determine how much consumers or potential consumers like, accept, or prefer a product based on its sensory appeal. It is an effective means of assessing hedonically the degree of liking of a food product. This test involves the use of more than 100 respondents who are usually conversant with the particular food product. It can involve the use of tests such as the "Just-about-right" (JAR) scale, which is used to measure the intensity of sensory characteristics such as color, flavor, taste, or textural quality in a product. The scale typically has endpoints like "Much too little" and "Much too much," with the midpoint labeled "Just-About-Right" which is the ideal level for the sensory characteristics of interest. It helps to understand why consumers may or may not like a product and guides efforts to increase consumer acceptability by serving as a means of feedback. Consumer acceptability tests can also involve the use of a check-all-that-apply (CATA) scale. The CATA involves a sensory test where consumers are presented with a list of attributes to select all applicable terms that can be used to describe the product. Collection of responses from the consumers about the food product, and term citation frequency (or frequency of term selection) is calculated across respondents to derive profiling information (20, 21, 22, 23). It is a simple, reliable, and widely used technique for gathering detailed product profiles from untrained consumers. This test helps to identify key sensory attributes and understand consumer preferences by providing both quantitative and qualitative data on the product sensory attributes. Contextualizing the nixtamalization process in improving calcium content of Nigerian indigenous maize food products while exploring the potentials of local cereal products as vehicles for increasing calcium quantity is essential. The objective of this research was therefore to evaluate the consumer acceptability of Tuwo masara produced from calcium-improved maize through nixtamalization.

MATERIALS AND METHODS

Study Location

Sabo area, Ibadan, Oyo State, Nigeria, was adopted for the consumer acceptability study. This is because the Sabo area is a community of predominantly Hausa migrants, the main *tuwo-consuming* population from the Northern part of Nigeria.

Materials

White maize variety and a food-grade hydrated lime ($Ca(OH)_2$), 95-97% calcium hydroxide, were purchased from a reputable supplier.

Sample Preparation

Production of Nixtamalized Maize Flour (NMF)

Maize kernels were cleaned by sorting, winnowing, and removing extraneous materials. Nixtamalized maize flour (NMF) was prepared using the method

described (24). Maize grains (1 kg) were cooked for 60 min at 90°C with 10 L of water and calcium hydroxide (0%, 1.2%, 3%, and 5%). The control sample (0%) was prepared by cooking maize kernels without the addition of calcium hydroxide. The cooked maize (nixtamal) was left in the cooking liquor (nejayote) for 6 hrs. The nejayote was then drained off; each sample was washed twice in water (1:2 w/v ratio) to remove excess lime. After washing and draining, the nixtamal samples were ground and dehydrated at 50°C for 24 hrs. The dried samples were milled into fine flour using a hammer mill to pass through a sieve size of <250 μm. Nixtamalized maize flour samples were stored in Ziploc bags prior to the preparation of *tuwo*.

Tuwo preparation

Tuwo samples were prepared from the nixtamalized maize flour by the local Hausa women who prepare *tuwo* at Sabo, Ibadan, using the traditional method as described (19).

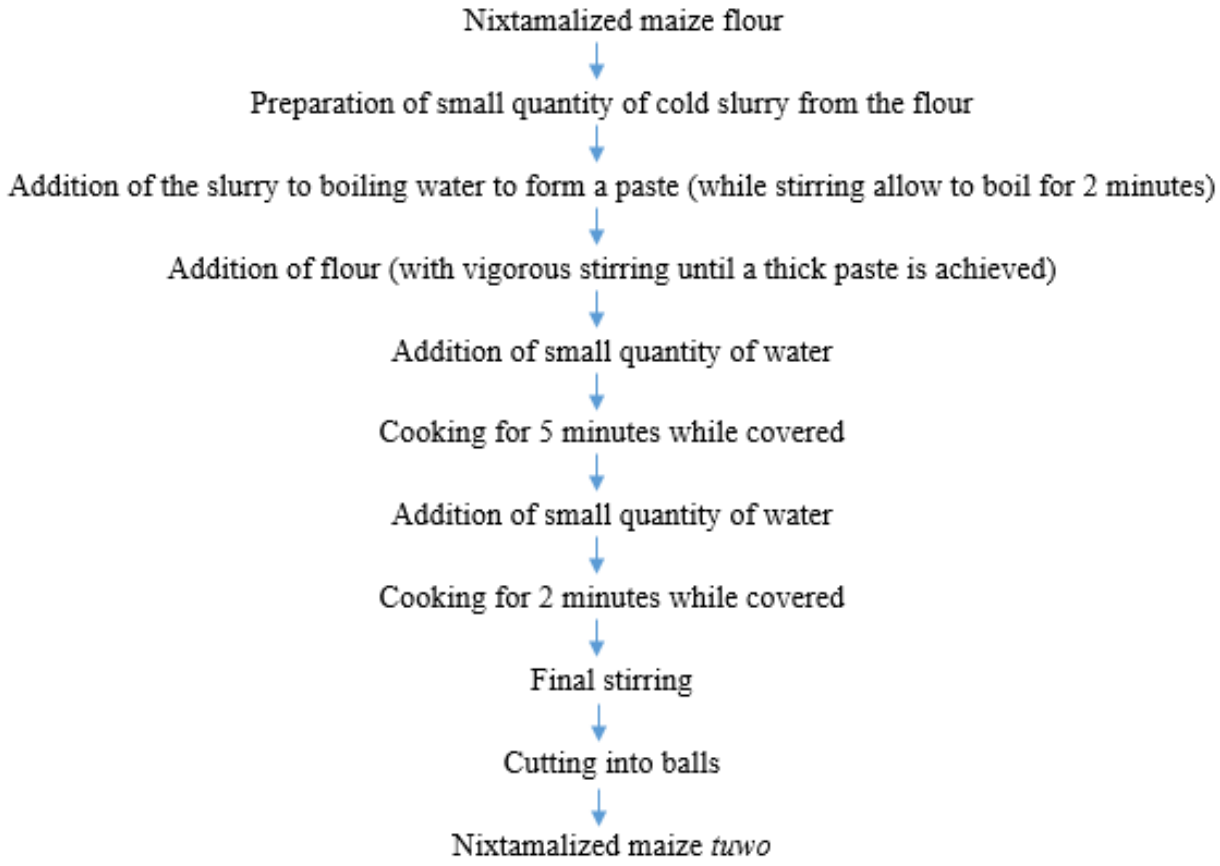

Figure 1. Preparation of *tuwo* from Nixtamalized Maize Flour

Consumer Acceptability Study

Consumer acceptability of *tuwo* was conducted by adopting the method of Fliedel et al (25) using 125 consented untrained consumers of *tuwo*. The consumers' preference and acceptability of the *tuwo* samples (Nixtamalized maize flour *tuwo* (NMFT)) were assessed in comparison to the usual maize *tuwo* (control sample). The sensory descriptors of the improved maize *tuwo* samples, as perceived by the consumers, were also evaluated. An interviewer-administered questionnaire was used to assess the socio-demographic characteristics and the consumption habits of the respondents. Hedonic, JAR, and CATA tests were conducted on the *tuwo* samples. The quality attributes of *tuwo* assessed were flavor, taste, color, softness, smoothness, stickiness, and mouldability. The samples were presented to the consumers to score the overall liking for the taste and touch, respectively, using a nine-point hedonic scale, where 1 = Extremely dislike and 9 = Extremely like. The 3-point JAR scale, which shows the extent to which the quality attributes of the *tuwo* samples are, was also used, where "1 is 'not enough', 2 is 'just-about-right or as-I-like,' and 3 is 'too much' and used as applicable to the sensory quality attribute. To also describe the *tuwo* sample itself, a CATA test that indicates the sensory descriptors of each sample as perceived by

the respondent was done. All the sensory quality attributes that describe each sample were checked and ranked.

Consumer acceptability was carried out on the nixtamalized *tuwo* samples made from white maize at different calcium concentrations: control (0%), 1.2%, 3%, and 5%. The consumers' interviews were conducted with 125 consumers who are familiar with and consume *tuwo* in the Sabo area, where Hausas from the northern part of Nigeria, who are the major consumers of *tuwo*, reside in Ibadan. Individual interviews conducted included the collection of demographic information and consumption habits of the participants. The participants were requested to taste and touch the *tuwo* samples. The samples were presented to the consumers one after the other and also to rank the overall liking by means of a nine-point hedonic scale, where 1 = Extremely dislike while Extremely like represents 9. The 3-point 'Just About Right' scale was used to show the extent to which the quality attributes of the *tuwo* samples were perceived. Also, in order to describe the *tuwo* samples in themselves, the 'Check-All-That-Apply' test was employed to point out the sensory and perception descriptors of each sample.

Statistical Analysis

Statistical analysis was carried out using SPSS version 20 and XLSTAT 2014 statistical packages to analyse JAR and CATA data as well as Principal Component Analysis (PCA).

Ethical Consideration

Ethical approval was obtained from the UI/UCH Ethics Committee, IAMRAT, College of Medicine, University of Ibadan, with approval number UI/EC/24/0265.

RESULTS

Socio-Demographic Characteristics of Respondents

Socio-demographic characteristics of respondents (Table 1) showed that 36% were female, while 64% were 64%. Ethnicity results showed that 75.2% were Hausa from the northern part of Nigeria who now live in Ibadan, 4% Yoruba, and 20% from other ethnic groups. The respondents between 18-25 years were 26.4%, 26- 35 years were 22.4%, 36- 45 years were 11.2%, and the remaining 40% were > 46 years. Most of the respondents (42.4%) were traders, students 26.4% while 17.6% were artisans. Only 1.6% of the respondents were civil servants, and 2.4% were unemployed. Their marital status showed that 54.4% of the respondents were single, while 41.6% of the respondents were married and 4.0% were widowed.

Consumption Habits

The frequency of *tuwo* consumption showed that 49.6% of the respondents (n = 125) consume *tuwo* several times a week (Table 1), while only 25.6% consume *tuwo* daily. About 13.6% of the respondents consume *tuwo* once a week. The mode of *tuwo* consumption showed that the majority (83.2%) of the respondents consume *tuwo* with soup such as *miyan taushe*, which is native to Northerners, *egusi* and *gbegiri,* common among the Yorubas, and vegetable soup, okra, or peanut soup among some other Hausa consumers. The consumption pattern of *tuwo* among the respondents showed that out of the 76% overall consumers of *tuwo,* only 54.4% consume *tuwo* only at dinner, 5.6% can consume it either as breakfast, dinner, or lunch, while 15.2% prefer to consume *tuwo* either as breakfast or dinner. Only 16% of the respondents prefer to consume it as breakfast only and 8% as lunch only.

Table 1a: Socio-Demographic Characteristics of Respondents

Variable	Frequency (125)	Percentage (%)
Gender		
Male	80	64
Female	45	36
Ethnic		
Hausa	94	75.2
Yoruba	5	4.0
Others	26	20.8
Age (years)		
18-25	32	25.6
26-35	28	22.4
36-45	14	11.2
46-55	11	8.8
>56	40	32.0

Table 1b: Socio-Demographic Characteristics of Respondents

Variable	Frequency (125)	Percentage (%)
Occupation		
Student	33	26.4
Artisan	22	17.6
Civil service	2	1.6
Trader	53	42.4
Employed	3	2.4
Unemployed	5	4.0
Others (e.g. farmer)	7	5.6
Marital status		
Single	68	54.4
Married	52	41.6
Widower	5	4.0
Consumption frequency of *tuwo*		
Everyday	32	25.6
Several times a week	62	49.6
Once a week	17	13.6
Several times a month	7	5.6
Once a month	7	5.6
Time of consumption		
Breakfast	20	16.0
Lunch	10	8.0
Dinner	68	54.4
Breakfast; Lunch; Dinner	27	21.6
Mode of Consumption		
With Soup (Miyan Taushe, Egusi, Gbegiri, Vegetable Soup, Okra, Peanut Soup, etc.)	98	78.4
With Stew only (omi obe)	6	4.8
Eat without soup/stew	15	12.0
With Soup (Miyan Taushe, Egusi, Gbegiri, Vegetable Soup, Okra, Peanut Soup, etc.); With Stew only (omi-obe)	6	4.8

Perception of Consumers on Nixtamalized *Tuwo*

Figures 2a and 2b show the ranking for *tuwo* in terms of taste and texture (touch). All the samples were liked; however, among the NMFT samples, 5% NMFT (76.8%) was ranked next to the control (81.6%) in terms of taste. The 3% NMFT sample was liked by 69.6%. This same trend was observed for the texture of *tuwo* samples; hence, among the NMFT samples, 5% NMFT was the most acceptable in terms of taste and texture.

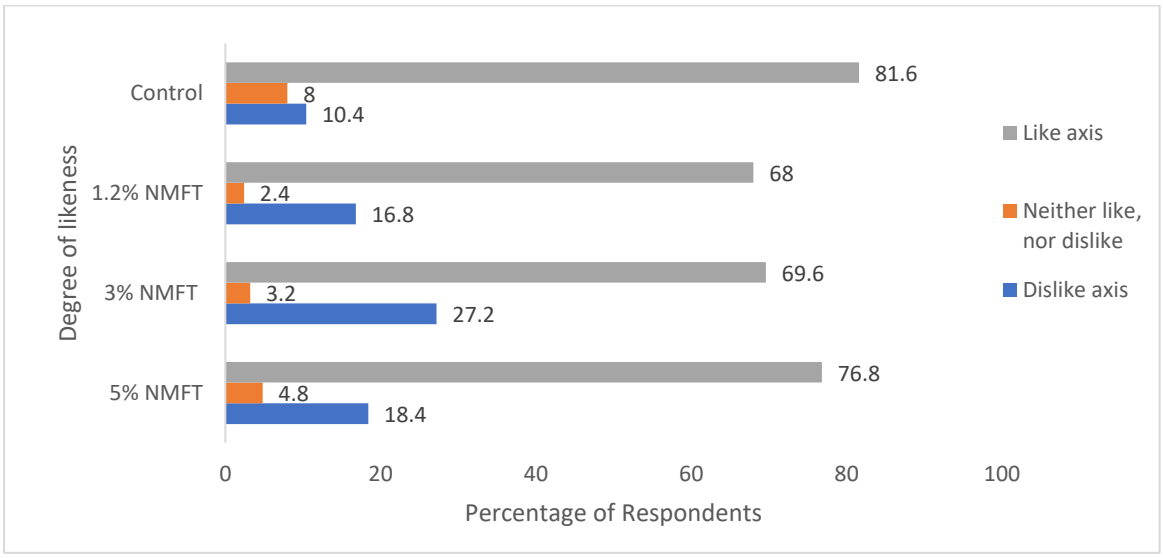

Figure 2a. Perception of Overall Liking of *tuwo* in Terms of Taste

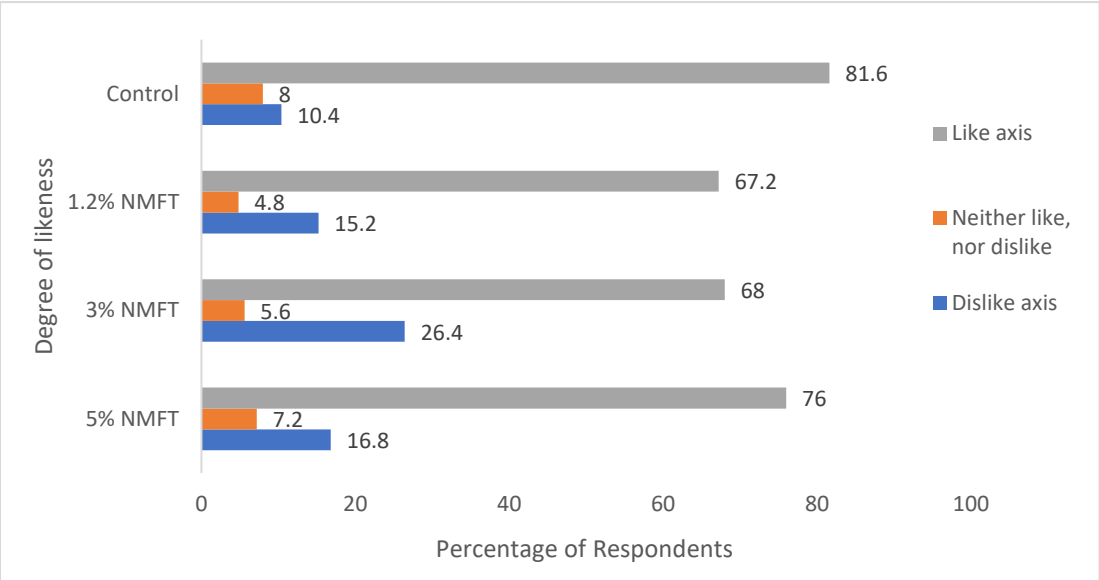

Figure 2b. Perception of Overall Liking of Texture (Touch) of *tuwo*

Description of Quality Attributes of *Tuwo* Samples

The JAR result (Table 2) showed that the flavor of 5% NMFT was most preferred, having the highest 'as-I-liked' rating by 65.6% of the consumers, followed by the control sample and 3% NMFT with 56% and 54.4%, respectively. Sample 1.2% NMFT was rated the least, with 51.2%. In terms of taste, about 61.6% rated *tuwo* from 5% NMFT sample as 'as-I-like' while the control sample was rated next by 55.2%. Samples 1.2% NMFT and 3% NMFT were rated 'as-I-like' by 53.6% and 46.4%, respectively. The color of the control sample, 5% NMFT, 3% NMFT, and 1.2% NMFT was rated 'as-I-like' by 69.6%, 68%, 60%, and 56% of the respondents, respectively. The color was perceived as 'too dark' by 12.8%, 14.4%, 21.6%, and 12% of the respondents, respectively, while 17.6% rated both control and 5% NMFT as 'not dark'.

The softness of the *tuwo* samples showed that control was rated 'as-I-like' by 48.8% of the respondents and 'too hard' by 3.2%. About 48% of the respondents rated the control sample as 'too soft'. Sample 3% NMFT was rated 'too hard' by 56%, and 'as-I-like' by 37.6%. Samples 1.2% NMFT and 5% NMFT were rated 'as-I-like by 44.8% of the respondents for softness; however, both samples were rated as 'too soft' by 10.4% and 11.2%, respectively, while 27.2% rated sample 1.2% NMFT as 'too hard'.

In terms of smoothness, the 5% NMFT had the highest 'as-I-like' rating by 50.4% of the respondents, and the 3% NMFT had the least by 40.8%. The control sample had the highest percentage of 'as-I-like', 54.4%, in terms of stickiness, while the 3% NMFT had 43.2%. The 5% NMFT was rated by 41.6% as 'as-I-like' in terms of stickiness, 29.6% as 'very sticky' then 'not sticky' by 28.8% of the respondents. Sample 1.2% NMFT had 40.8% 'as-I-like' rating, the least percentage 20% as 'very sticky', and 23.2% as 'not sticky'.

About 48.8% of the respondents described the control sample as 'very mouldable' and 5% NMFT, with 45.6%. Only 32% rated 3% NMFT as 'not mouldable', while 35.2% and 34.4% rated the control sample and 5% NMFT 'as-I-like'. Samples 1.2% NMFT and 3% NMFT were rated 'as-I-like' by 30.4%, respectively.

Citation Frequency of *Tuwo* Sensory Attributes

The CATA result revealed the quality attributes of the *tuwo* samples as described by the respondents. The control sample was described as smooth and without lumps by 77.6%, swallowable (66.4%), cream in color (40%), sweet taste (48%), soft (40%), sticky (32%), and with good flavor (56%). However, out of the NMFT samples, 5% NMFT was rated highest (81.6%) in terms of smoothness (no lumps), swallowability (60.8%), mouldability (52.8%), sweet taste (48.8%), good flavor (50.4%), and cream color (44.8%). The quality attributes of 1.2% NMFT were 'no lumps' (84.4%), swallowable (62.9%), sweet taste (53.3%), mouldable (46.7%), cream in color (45.7%), and having good flavor (58.1%). Sample 3% NMFT had no lumps (80.8%), was rated swallowable by 62.4%, had a sweet taste (49.6%), was mouldable (43.2%), was cream-colored (55.2%), and had good flavor (58.4%).

All the nixtamalized *tuwo* samples had high citations with descriptions such as 'no lumps', 'swallowable', 'good flavor', 'sweet taste', 'mouldable', as shown in Figure 3. Sample 5% NMFT had the highest citations for descriptors such as 'no lumps' (102), 'sweet taste' (61), and 'mouldable' (66), while the control sample had the highest citations for 'smooth' (34), 'swallowable' (82), and 'soft' (47). It was further described as having 'good flavor' (70), 'cream' in color (50), and 'mouldable' (60), but was found 'sticky' (40). Sample 1.2% NMFT had descriptors such as 'no lumps' (89), 'swallowable' (66), 'sweet taste' (56), 'mouldable' (49), 'smooth' (23), 'cream' in color (48, as against 'white' with 11 citations), in addition to 'good flavor (61). Sample 3% NMFT was described as 'no lumps', not sticky, swallowable, sweet taste, smooth, cream in color, good flavor, and mouldable, with 101, 45, 78, 60, 33, 69, 73, and 54 mentions, respectively. However, it was described as hard and too hard.

Table 2: JAR Test Results on Sensory Quality Attributes of NMFT Samples

Variable	Control	1.2%NMFT	3%NMFT	5%NMFT
Flavor				
As-I-like	56.00	51.20	54.40	65.60
Not pleasant	9.60	10.40	16.80	10.40
Very pleasant	34.40	21.60	28.00	24.00
Taste				
As-I-like	55.20	53.60	46.40	61.60
Not pleasant	14.40	10.40	21.60	16.80
Very pleasant	30.40	20.00	32.00	21.60
Colour				
As-I-like	69.60	56.00	60.00	68.00
Not dark	17.60	16.00	18.40	17.60
Too dark	12.80	12.00	21.60	14.40
Softness				
As-I-like	48.80	46.40	37.60	44.80
Too hard	3.20	27.20	56.00	44.00
Too soft	48.00	10.40	6.40	11.20
Smoothness				
As-I-like	46.40	42.40	40.80	50.40
Not smooth enough	16.80	20.00	31.20	23.20
Very smooth	36.80	21.60	28.00	26.40
Stickiness				
As-I-like	54.40	40.80	43.20	41.60
Not sticky	18.40	23.20	25.60	28.80
Very Sticky	27.20	20.00	31.20	29.60
Mouldability				
As-I-like	35.20	30.40	30.40	34.40
Not mouldable	16.00	20.00	32.00	20.00
Very mouldable	48.80	33.60	36.80	45.60

Key: JAR - Just-about-right"; NMFT - Nixtamalized maize flour tuwo

Principal Component Analysis (PCA)

PCA was used to summarize the associations between the measured CATA sensory attributes in order to describe the nixtamalized *tuwo* samples and the mean overall liking score of each sample, as evaluated by the respondents. The PCA plot (Figure 4) described 85.24% of the variance of the NMFT sensory attributes by means of both the first and second axes, representing 47.34% and 37.90% correspondingly. The variance shows the pattern of the related variables in the quadrant used to describe each NMFT sample. The control sample was described distinctly on the right axis in terms of the variables when compared with 5% NMFT and 3% NMFT, though 5% NMFT, 3% NMFT, and 1.2% NMFT were all on the left axis.

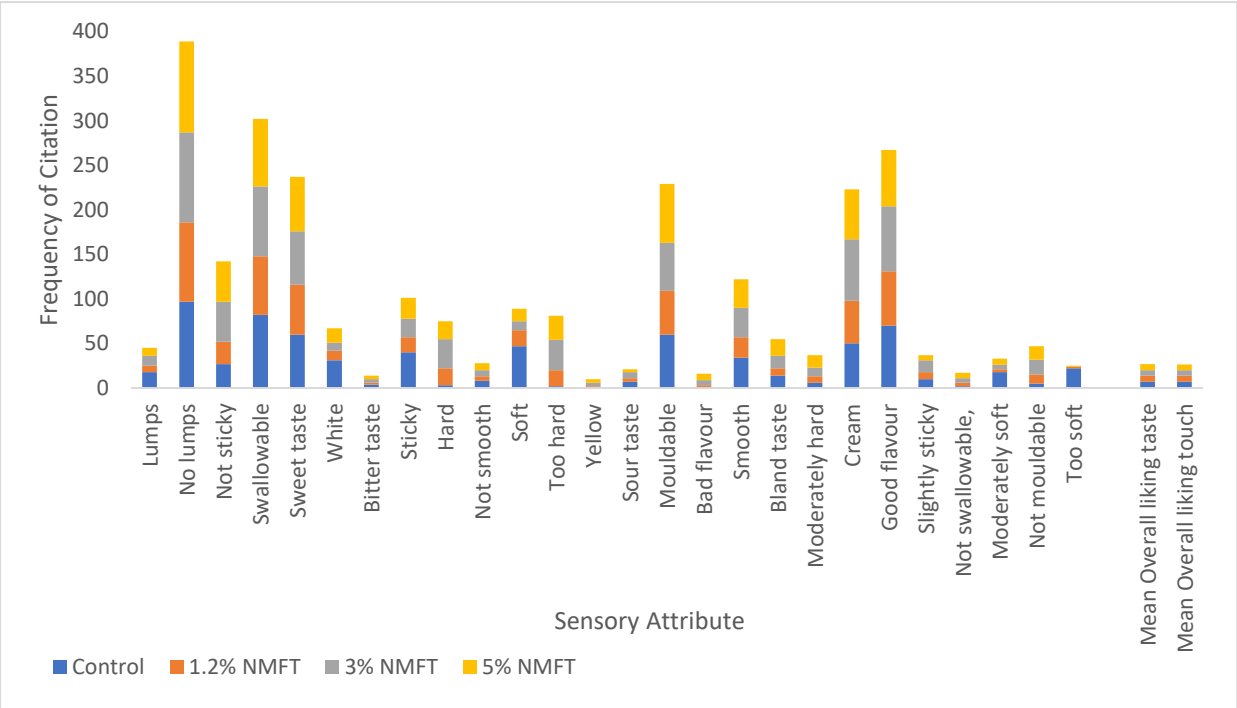

Figure 3: Citation Frequency of Sensory Attributes Used in Describing *tuwo*

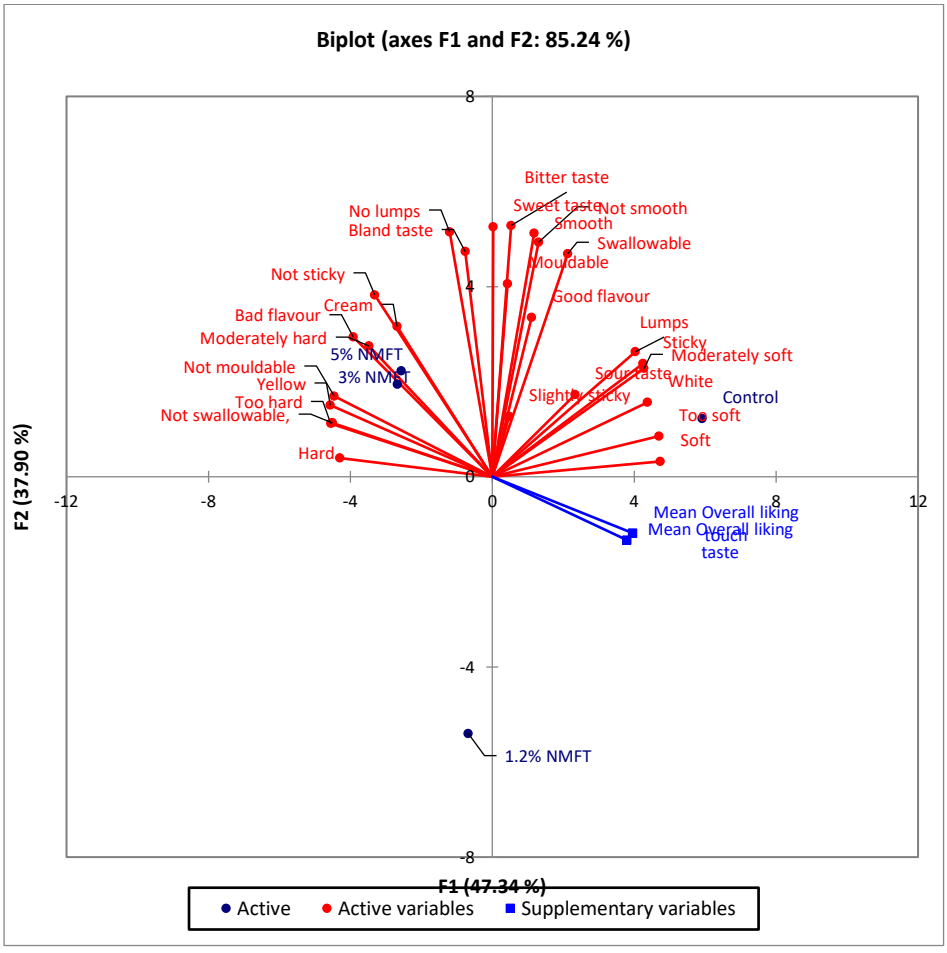

Figure 4: Display PCA Biplots for the Nixtamalized *tuwo* Samples

DISCUSSION

Socio-demographic characteristics of the respondents showed more males than females. This is contrary to the study (26) conducted on *tuwo*, which reported a higher percentage of female respondents; however, both genders were used from the community. The lower number of female respondents could be due to the culture of the ethnic group, where most of the women are in purdah (female seclusion). The age distribution shows that the respondents were mostly adults who would prefer not to declare their age. Most of the respondents were traders in various businesses and artisans with different specializations such as tailoring, mechanics, etc.

About half of the respondents consume *tuwo* several times a week, with a few others consuming *tuwo* daily or once a month. The majority consume *tuwo* with soup, while more than half consume it only at dinner. A report (26) stated the frequency of *tuwo* consumption as two or three times a day (12.8% and 26.2%, respectively), three times a week (39.7%), and when desired by only 6.6%. Consumption habits of a *tuwo* consumer can be influenced greatly by the family head, decision maker, or the person who prepares the *tuwo* in the family. This is supported by a report (26) which stated that "the person directly responsible for *tuwo* preparation in the house influences the eating habit of the family".

Generally, both the taste and texture of the control sample were more liked than the nixtamalized samples. This observation is expected since the control sample is similar to the usual *tuwo* product the respondents are familiar with. This is similar to the reports (27, 28) on *tuwo* made from rice and tigernut flour and *tuwo* from rice, soybean, and plantain flour, respectively, that the familiarity of consumers with traditional *tuwo shinkafa led to more of its acceptance than any other variant.* However, among the nixtamalized samples, 5% NMFT was the most acceptable. According to a study (26), the texture preference for *tuwo* can be influenced to a great extent by an individual's choice and practice of the community, and acceptability of a product depends majorly on how the sensory attributes are perceived.

The JAR result helped to describe the extent to which the consumers liked each of the various NMFT attributes when compared with the control. Sample 5% NMFT was more preferred in terms of the flavor. It must, however, be noted that the flavor of all the *tuwo* samples was generally accepted. The *tuwo* samples were cream in color, mouldable and swallowable. The sensory quality attributes normally adopted by the consumers in evaluating maize *tuwo* are color (white to creamy), texture (ease of mouldability and swallowability) and pleasant taste, which agrees with the findings (29). According to studies (26, 28) the taste of *tuwo* depends on the type of grain and the method used in preparing the flour; though the actual taste of *tuwo* is usually concealed by the taste of the soup with which it is consumed.

The appearance of a product attracts or dispels a consumer from accepting it, and this can be influenced by the color of the raw material used, especially the color of the maize grain (30). The color of the *tuwo* samples in this study is in agreement with the result of a study (26), which reported that 51% of the respondents preferred the color of the *tuwo* to be white, 31.4% indicated that the color of *tuwo* does not matter to them, while 13.8% preferred a yellow color. The hardness or softness of *tuwo* can be influenced by consumer preference. The softness of the *tuwo* in this study implies that respondents do not like or accept tuwo that is too soft or too hard. Hence, a moderately soft *tuwo* is preferred.

Smoothness, which indicates the absence of lumps or grittiness between fingers when touched, was highest in sample 5% NMFT. Stickiness, which is the tendency of the *tuwo* to stick to the fingers when touched, was liked the most in the control sample. Generally, a non-sticky *tuwo* with moderate hardness is preferred, with the dough being stiff but not dense. According to the consumers, it is expected that when the fingers are dipped into *tuwo*, a morsel should be easily scooped out and manipulated between the forefinger and thumb without the dough sticking to the fingers. Report (26) also corroborated this observation. The level of stickiness in *tuwo* samples can affect the ability to swallow in the mouth and molding into morsels in the hand. If the product is very sticky, it can make it uneasy to swallow. Mouldability is the ability of the morsel cut with fingers from the *tuwo* dough to be mouldable. The Hausa people check the mouldability with the fingers, whereas the Yorubas check with the palm. In this study, the mouldability of the control was more liked, followed by 5% NMFT.

All the nixtamalized samples had high citations with descriptions such as 'no lumps', 'swallowable', 'good flavor', 'sweet taste', 'mouldable', which are the attributes for a good quality *tuwo*. However, there were differences in terms of smoothness.

The PCA plot variance was mainly interpreted by the axes. Biplots are simultaneous variable and observation representations in the PCA space, while the PCA summarized the relationship between the CATA sensory attributes used to describe the NMFT samples and the mean overall liking score. The variance in the sensory attributes of the NMFT samples along the axis of the PCA plot described the control sample differently compared to the other *tuwo* samples.

CONCLUSION

The nixtamalized *tuwo* sample (5%NMFT) was highly acceptable by the indigenous consumers in terms of flavor, taste, smoothness, mouldability, stickiness, softness/hardness, and color. Nixtamalizing maize grain up to 5% lime concentration can produce acceptable *tuwo,* which could improve micronutrient (calcium) availability of *tuwo masara* since it compared favourably with the sample produced traditionally. Awareness and training on the nixtamalization method should be done among the locals to aid production of nixtamalized maize flour in order to possibly improve calcium content of Nigerian indigenous maize food products such as *tuwo*. This can also be explored on other cereal grains used for production of indigenous foods.

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REFERENCES

1 Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., & Uauy, R. (2013). Maternal and Child Undernutrition and Overweight in Low-Income and Middle-Income Countries. *The Lancet*, *382*(9890), 427-451.

2 Looman, M., Geelen, A., Samlal, R. A., Heijligenberg, R., Klein Gunnewiek, J. M., Balvers, M. G., & Feskens, E. J. (2019). Changes in Micronutrient Intake and Status, Diet Quality and Glucose Tolerance from Preconception to the Second Trimester of Pregnancy. *Nutrients*, *11*(2), 460.

3 Aigbedion, G., Tseng, P. C., & Puthussery, S. (2025). Micronutrient Deficiencies and Determinants Among Pregnant Women and Children in Nigeria: Systematic Review and Meta-Analysis. *Nutrients*, *17*(14), 2338. https://doi.org/10.3390/nu17142338

4 Shlisky J., Mandlik R., Askari S., Abrams S., Belizán J. M., Bourassa M. W., Cormick G., Driller-Colangelo A., Gomes F., Khadilkar A., Owino V., Pettifor J. M., Rana Z. H., Roth D. E. and Weaver C. 2022. Calcium deficiency worldwide: prevalence of inadequate intakes and associated health outcomes. *Annals of the New York Academy of Sciences,* 1512(1): 10–28.

5 Method, A., & Tulchinsky, T. H. (2015). Commentary: Food Fortification: African Countries can make more progress. *Advance Food Technology and Nutrition Science Open Journal*, (1), 22-28.

6 Mishra, R. (2011). Current Approaches in Food Fortification for Overcoming Micronutrient Deficiencies. *Research in Environment and Life Sciences*, (4), 39–48.

7 Kamara A. Y., Kamai N., Omoigui L. O., Togola A., & Onyibe J. E. (2020). Guide to Maize Production in Northern Nigeria: Ibadan, Nigeria. 18 pp.

8 Hossain F., Muthusamy V., Bhat Jayant S., Jha Shailendra K., Zunjare R., Das A., Konsam S., & Rajesh K. (2016). Maize. M. Singh, S. Kumar (eds.), *Broadening the Genetic Base of Grain Cereals*, 67-88. DOI 10.1007/978-81-322-3613-9_4

9 Arise K. A., Akintayo A. O., & Akintoye F. N. (2019). Proximate Composition, Functional and Sensory Properties of '*Tuwo*' Prepared from Maize (*Zea Mays*) and Bambara Groundnut (*Vigna subterranea*). *Applied Tropical Agriculture 24* (1), 218-222

10 Joshua Z. P., Mariam I. S., Goje E. A., Suleiman M. M. & Dallhatu R.Y. (2021). Formulation and Evaluation of Maize (*Zea Mays*) Flour Fortified with Carrot (*Daucus Carota*) Powder. *Science World Journal 16*(3) ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)

11 Matendo, R. E., Imathiu, S., Udomkun, P., & Owino, W.O. (2023). Effect of Nixtamalization of Maize and Heat Treatment of Soybean on the Nutrient, Antinutrient, and Mycotoxin Levels of Maize-soybean-based Composite Flour. *Frontiers in Sustainable Food Systems*, (7), 1–12. https://doi.org/10.3389/fsufs.2023.1057123

12 Escamilla-Urbina, I., Totosaus-Sánchez, A., Rodríguez-Huezo, M.E., Vernon-Carter, J., & Álvarez-Ramírez, J. (2025). Effect of Calcium Hydroxide and Nixtamalization Time on the *In Vitro* Starch and Protein Digestibility of Traditional Maize Tortillas. *Plant Foods for Human Nutrition* (80), 61. https://doi.org/10.1007/s11130-024-01245-z

13 Castro, C. M. E., Torres-Chávez, P. I., Ramírez-Wong, B., Ledezma-Osuna, A. I., Quintero-Ramos, A., López-Cervantes, J., & Silvas-García, M. I. (2017). Physicochemical and Rheological Changes of Starch in Nixtamalization Processes: Extrusion as an Alternative to Produce Corn Flour. In *Extrusion of Metals, Polymers and Food Products*. Intech Open.

14 Schaarschmidt S. & Fauhl-Hassek C. (2019). Review: Mycotoxins during the Processes of Nixtamalization and Tortilla Production. *Toxins* (11), 227; doi:10.3390/toxins 11040227 www.mdpi.com/journal/toxins pp 1-27

15 Ocheme B. O., Oloyede O. O., & Mikailu E. G. (2010). Effect of Lime Soaking and Cooking (Nixtamalization) on the Proximate, Functional and Some Anti-nutritional Properties of Millet Flour, AU J.T. *14*(2): 131-138, *Technical Report* 131

16 Maureen, N., Kaaya A.N., Kaffman J., Narrod C. & Atakwase A. (2020). Enhancing Nutritional Benefits and Reducing Mycotoxin Contamination of Maize through Nixtamalization. *Journal of Biological Science*, (20), 153-162

17 Musita N., Nurdjanah S. & Oktiani D. (2019). Nixtamalization Application as A Quality Improvement of Corn Flour**.** AIP Conference Proceedings 2085, 020037; https://doi.org/10.1063/1.5095015 *The 11th Regional Conference on Chemical Engineering (RCChE 2018)*

18 Pandey S., Rakesh G., Deodatt S., & Roji W. (2022). Evaluation of Physio-Chemical Characteristics and Acrylamide Content in Crisp Fried Dough Wafers Made from Nixtamalized Pearl Millet. *Journal of Microbiology, Biotechnology, and Food Science, Article* e3186. https://doi.org/10.55251/jmbfs.3186

19 Bolade M. K., Usman M. A., Rasheed A. A., Benson E. L., & Salifou I. (2002). Influence of Hydrothermal Treatment of Maize Grains on the Quality and Acceptability of *Tuwo Masara* (traditional maize gel). *Food Chemistry*, (79), 479-483.

20 Fiorentini, M., Kinchla, A. J., & Nolden, A. A. (2020). Role of Sensory Evaluation in Consumer Acceptance of Plant-Based Meat Analogs and Meat Extenders: A Scoping Review. *Foods*, *9*(9), 1334. https://doi.org/10.3390/foods9091334

21 Jaeger, S. R., Beresford, M. K., Paisley, A. G., Antúnez, L., Vidal, L., Cadena, R. S., Giménez, A., & Ares, G. (2015). Check-all-that-apply (CATA) Questions for Sensory Product Characterization by Consumers: Investigations into the Number of Terms used in CATA questions. *Food Quality and Preference*, (42), 154-164.

22 Jaeger, S. R., & Ares, G. (2022). Measuring Consumer Attitudes using Text Highlighting: Methodological Considerations. *Food Quality and Preference, 96,* Article 104422. https://doi.org/10.1016/j.foodqual.2021.104422

23 Jaeger, S. R., Chheang, S. L., Jin, D., Ryan, G. S., & Ares, G. (2023). How do CATA Questions Work? Relationship between Likelihood of Selecting a Term and Perceived Attribute Intensity. *Journal of Sensory Studies*, *38*(4), e12833.

24 Gutiérrez-Cortez, E., Rojas-Molina, J. I., Zambrano-Zaragoza, M. L., Quintanar-Guerrero, D., González-Reza, R. M., Rojas-Molina, A., & Espinosa-Arbeláez, D. G. (2013). Effect of Processing Conditions on the Production of Nixtamalized Corn Flours by the Traditional Method. *CyTA-Journal of Food*. (1), 46–53. DOI: 10.1080/19476337.2013.778904.

25 Fliedel, G., Kleih, U., Bechoff, A., & Forsythe, L. (2018). RTBfoods Step 4: Consumer Testing in Rural and Urban Areas. Montpellier, France: *CIRAD-RTBfoods Project*, 29 p. DOI: https://doi.org/10.18167/agritrop/00571

26 Bagirei, S. Y. (2021). Tuwo Consumption and Preferences in Cosmopolitan Cities of Nigeria: A Consumer Response Survey, *International Journal of Science for Global Sustainability*, *7*(1), 34 - 43. ISSN: 2488-9229.

27 Alabi, B. E., Adejuyitan, J. A., & Oyedele, E. O. (2026). Production and Quality Evaluation of *Tuwo-shinkafa* from Rice with Tigernuts Blends. *Ceylon Journal of Science*, *55*(1), 247-252. DOI: https://doi.org/10.4038/cjs.v55i1.8797

28 Noah, A. A., & Omoyeni, S. E. (2020). Evaluation of nutritional, microbial and sensory attributes of rice tuwo flour fortified with soy and

plantain flour blends. *Journal of Advances in Microbiology*, *20*(9), 121-129.

29 Bolade, M. K., Adeyemi, I. A., & Ogunsua, A. O. (2009). Influence of Particle Size Fractions on the Physicochemical Properties of Maize Flour and Textural Characteristics of a Maize-based Non-fermented Food Gel. *International Journal of Food Science and Technology*, (44) 646-655.

30 Sunmonu, B. A. O., Abraham, I. O., & Folakemi, O. D. (2021). Quality Assessment of "Tuwo" (Maize Dumpling) Made from Maize Flour Modified with Maize and Cassava Starch. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, *14*(6), 15-29.