International Journal of Basic Science et al Technology
August, Volume 10, Number 3, Pages 230 - 237 http://www.ijbst.fuotuoke.edu.ng/231
https://doi.org/ 10.5281/zenodo.13429763 **ISSN 2488-8648**

A Decade Long pH Monitoring of Commonly Consumed Malt Drinks Sold in Nigerian Markets: The Bayelsa Experience

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Article Information

Article # 10035
Received: 16th May. 2024
Revision: 7th Sept. 2024
2nd Revision: 12th Sept 2024
Acceptance:13th Sept. 2024
Available online:
25th Sept 2024.

Key Words
Non-alcoholic drink,
Malt, pH value, Acidity,
Malt-water mix

Abstract

Malt drinks are popular non-alcoholic beverages in Nigeria, commonly consumed during social and festive events like weddings and parties; often perceived as healthier alternatives to carbonated soft drinks, alcoholic beverages and palm wine. In this study, pH values of five malt brands in Bayelsa State, coded as GRM, GNM, MLT, AMS and MTX were assessed over a ten-year period from 2013 to 2024. Annual pH measurements were conducted using a calibrated pH meter following standard procedures. Effect of a common consumer habit (CCH) of diluting malt drinks with water on the pH values was then explored. pH values recorded for the neat (undiluted) malt drinks ranged from 4.49 to 5.02, with mean values of 4.72 ± 0.43 for MLT, 5.02 ± 0.35 for AMS, 4.49 ± 0.16 for GRM, 4.55 ± 0.32 for GNM and 5.00 ± 0.34 for MTX, indicating acidity of the malt brands. Positive and strong correlation coefficients (+ 0.72 to + 0.96) were obtained for pH versus dilution factors. CCH gave 13 to 31-fold reduction in acidity. Study suggested that increased consumption of these acidic drinks exposes consumers to the risk of acidosis and related health challenges. It is recommended that consumers drink responsibly and a survey be conducted to evaluate mitigation potential of CCH focusing on taste preferences, health concerns, economic motivations, product experience and perceived quality. Insights gained from such a survey could inform product design, marketing strategies and public health recommendations, ultimately enhancing the appeal, safety and acceptance of malt beverages among consumers.

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Introduction

Dietary profile of most Nigerians includes non-alcoholic and alcoholic drinks, often consumed by different people for various reasons, including health, faith-based and social inclinations. Malt drinks in Nigeria belong to the non-alcoholic category and commonly consumed by people resident in Nigeria. Serving platforms for these drinks include (i) weddings, (ii) funerals, (iii) parties, (iv) coronations, (v) board meetings and related events. In Nigeria, malt drinks are popularly used as substitutes for alcoholic drinks in many social and faith-based gatherings. They are also perceived as food supplements claimed to be fortified with vitamins (Vitamins A, B1, B2, B3, B5, B6 and C) and elements such as calcium (Ca). In addition, malt drinks are claimed to lower cholesterol and decrease the risk of cardiac diseases. It's content in dietary fiber helps to reduce insulin activity and increase cholesterol absorption and breakdown (Maina *et al*, 2021). Frequency of consumption and quantity consumed vary with individuals, which often times is associated with social/financial status. Malt drinks are often brewed from barley, hops and grains. Water, coloring, and other additives including preservatives that are very effective against microorganisms such as yeasts, bacteria and mold are introduced into the mixture to prolong shelf life and enhance consumer appeal (Lawlor *et al*, 2009).

Despite the acclaimed nutritional and health benefits of malt drink, the report of Obuzor & Ajaezi (2010) that the pH of malt drinks produced in Nigeria varies from 4.4 to 4.6 is quite worrisome. The human body operates under controlled pH levels or values. For instance, the blood, water and other liquids in the body work optimally at certain pH ranges. Blood pH is within neutral range, ranging from 7.35 to 7.45. Human stomach has a pH range of 1.5 to 3.5 (acidic). A low pH is required for digesting of food and destruction of germs. Any activity or substance intake that makes the body too acidic or too alkaline, are associated with blood pH and might result in unfavorable health conditions and medical emergencies. Reduction in blood pH to less than 7.35 is a condition referred to as acidosis (DiNicolantonio and O'Keefe, 2021). The objectives of this study were

https://doi.org/ 10.5281/zenodo.13429763 ISSN 2488-8648

to (i) investigate the pH range of five major brands of malt drinks sold in Bayelsa State from 2013 to 2024 and (ii) explore possibility of ameliorating the acidity of these drinks through dilution with water.

Materials and Methods

Malt Sample Collection

Commonly consumed malt drinks in Nigeria were purchased from different reputable markets located in different parts of Bayelsa State from 2013 to 2024. Five different popular commercial brands were purchased for this study. In line with best practices in research ethics, the real brand names were withheld and the drinks coded as GRM, GNM, MLT, AMS and MTX. An average of fifteen samples per brand were sampled per annum, making a total of seven hundred and fifty (15 samples x 5 malt brands x 10 years). All malt samples collected from the market were immediately conveyed to Chemical laboratory of Chemistry Department, Faculty of Science, Federal University Otuoke.

Determination of Malt pH in Neat Samples

Determination of pH for the malt samples was carried out following standards procedure as described in the reports of Adekunle and Isaac (2019) and Lawn and Prichard (2003) with slight modification. Exactly 40 ml of sample was measured using a Pyrex measuring cylinder and transferred into a 100 mL Pyrex beaker. The probe of a pH meter (Model: Hanna HI 96107), standardized using appropriate buffer solutions (4, 7 and 10) was inserted into the sample contained in the beaker and readings were taken. The probe of the pH meter was rinsed using deionized water after each measurement before taking reading of the next aliquot. Measurements were taken for neat malt samples.

Assessing the Effect of Common Consumer Habit (Water Dilution) on Malt acidity

Common consumer habit (CCH) of adding water into the malt before taking was studied via Focused Group Discussion (FGD) and interaction with relevant stakeholders cutting across age groups. The habit was more common with consumers of 50 years of age and above who expressed concern about sugar content with respect to health issues. Dilution with water was done at malt to water ratios of 1:1, 1:2, 1:3 and 1:4 corresponding to dilution factors of 1, 2, 3 and 4 respectively and percent compositions of 50:50, 33:67, 25:75 and 20:80 respectively. pH measurements were carried out as obtained for the neat sample. The total number of samples analyzed was 9,000 as described in Table 1. For example, 15 sample for a given brand malt has different dilution factors of 1, 2, 3, 4 with each dilution factor replicated 3 times giving a total of 180 (15 samples x 4 dilution factors x 3 replicates) samples per annum and 1,800 samples in 10 years. This procedure was repeated for all the samples, giving a total sample population (n) of 9,000 (1800 samples x 5 malt brands) as described in Table 1.

Table 1: Detailed information on the total number of samples for a given malt brand malt to water percent composition

S/N	Code for malt brand	Percent water in the Malt-Water Mixture				Total Sample population
		50	67	75	80	
1.	GRM	450	450	450	450	1800
2	GNM	450	450	450	450	1800
3	MLT	450	450	450	450	1800
4	AMS	450	450	450	450	1800
5	MTX	450	450	450	450	1800
Total Sample population		2,250	2,250	2,250	2,250	9,000

Quality Assurance and Quality Control

The pH meter used in these determinations was properly calibrated and the probes rinsed with double distilled-deionized water before use. All glassware (Pyrex) were thoroughly washed with detergent, rinsed with distilled water followed by soaking overnight with acidified water and then properly rinsed with double distilled – deionized water. Each glassware was dried in the oven at 105^0C before use. The pH probe was properly rinsed after each determination.

Statistical Analysis

In this study, IBM SPSS 21.0 for Windows® was used for statistical processing of data, which were subjected to descriptive statistics to give minimum, maximum,

https://doi.org/ 10.5281/zenodo.13429763 ISSN 2488-8648

mean, standard deviation; paired sample T-test and One-way Analysis of Variance (ANOVA) to evaluate differences in means; Pearson correlations, to establish useful relationships.

Results and Discussions

pH Values of the Malt Drinks

Results obtained from this study generally showed that the pH values of the five malt brands (MTX, MLT, GNM, GRM, and AMS) were below 5.5. Specifically, the pH values ranged from 4.5 to 5.0 with mean values as 4.5 ± 0.2 (0.04) for GRM, 4.6 ± 0.7 (0.15) for GNM, 4.7± 0.1 (0.02) for MLT, 5.0 ± 0.6 (0.12) for MTX and 5.0 ± 0.1(0.02) for AMS as presented in Fig.1. Note that each mean value was obtained from a sample population (n) of 750. The coefficient of variation (CV) is contained in the parenthesis. Coefficient of variation is a statistical measure of the relative variability of data points in a data set. Lower CV indicates that the data points are closer to the mean with the implication of less variability relative to the mean. A higher CV indicates greater dispersion around the mean while a lower CV suggests that the data points are more closely clustered around the mean (Kreyszig, 2011). Coefficients of variations (CVs) obtained in this study (2.0 to 12%), therefore, showed very reduced dispersion of data, indicating consistency of data set.

The pH range (4.5 to 5.0) obtained in this study from 2014 to 2024 is in concordance with the values (4.4 to 4.9) reported by Obuzor and Ajaezi (2010), Akonor *et al*, (2014), Cozzolino, (2016), Barku *et al.*, (2019), Samuel and Atanda (2020), for malt drinks produced and sold in Nigeria and Ghana. Acceptable pH values for malt drinks provided by International Organization for Standardization (ISO), Food and Agriculture Organization (FAO), National Agency for Food and Drug Administration and Control (NAFDAC) in Table 2. Based on these standards, data on malt pH values generated in this study were largely below recommended values. It is worthy to note that even with Nigerian based regulatory agency (NAFDAC), the pH range (4.5 to 5.0) of the malt brands investigated in this study fell short of acceptable values of 5.0 to 6.5. The mean values of three malt brands were below the lower limit of safety (5.0) while the remaining two brands were just at the lower limit of safety as stipulated by the Nigerian Regulatory Agency (NAFDAC) in addition to ISO and FAO

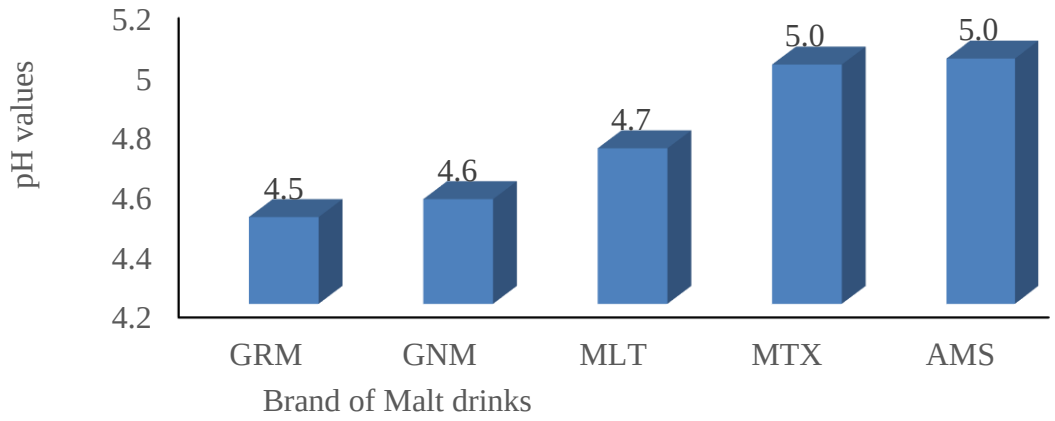

Fig. 1: Mean pH values of five bret als of malt drinks

Table 2: Guidelines or Standardization pH values for malt drinks

S/N	Regulatory Agency	Recommended pH range	pH from this Study
1	International Organization for Standardization (ISO)	5.0 – 6.5	4.5 to 5.0
2	Food and Agriculture Organization (FAO)	5.5 – 6.5	
3	National Agency for Food et al Drug Administration and Control (NAFDAC)	5.0-6.5	

https://doi.org/ 10.5281/zenodo.13429763 ISSN 2488-8648

Scientifically, pH is defined as the negative log in base 10 of molar hydrogen ion concentration ($pH = - Log_{10} [H^+]$). It is known that pH is the measure of acidity or basicity of a medium, scientifically based on a logarithmic scale of 0 to 14 with neutral point at 7.0. Values below 7.0 are in the acidic range with acidity increasing down the scale. On the contrary, values above 7.0 reflect the basic range with basicity increasing up the scale (Atkins and de Paula, 2010). Results from this study, therefore, revealed that these brands of malt drinks are acidic. The acidic range of pH value recorded in this study could have been for the purpose of preservation and maintaining the flavor profile of the malt drink (Fellows, 2009).

Potential Health Implications of Consuming Acidic Malt Drinks

The ideal pH range for human body is 7.35 to 7.45 (Marieb and Hoehn, 2019), human stomach is 1.5 to 2.0 (Fujimori, 2020) and human urine is 6.0 to 7.5 (AUA, 2020). A buildup of acid in the bloodstream or body fluid results in health condition known as acidosis. According to the American Association for Clinical Chemistry, acidosis is characterized by body pH less than 7.35 (Kima *et al*, 2023). Drawing from this, continued consumption of acidic drinks might be an exposure route for acidosis. Symptoms of acidosis include but not limited to rapid and shallow breathing, headache, increased heart rate, fatigue, sleepiness and loss of appetite. More detailed discussion on key health effects is presented as follows (Damjanov, 2008; Thompson and Morgenstern, 2023; Magalhães, 2009; Kanzow *et al*, 2016; Søvik *et al*., 2016).

Dental Erosion and Sensitivity: Tooth enamel (the hard, protective outer layer of the teeth) damage or eroding of tooth enamel increases the risk of cavities, tooth sensitivity and decay, increased risk of cavities with the enamel weakened, the teeth are more susceptible to decay (Kato and Nakano, 2015; Rechmann *et al*., 2013). Acidic beverages, especially those high in sugar such as the malt drinks, can promote the growth of bacteria that cause cavities. Increased sensitivity due to acidic beverages wear down enamel, teeth can become more sensitive to hot, cold, and sweet stimuli, leading to discomfort and pain when eating or drinking (Lussi and Hellwig, 2008). Severe enamel erosion can expose the dentin (the layer beneath the enamel) to further sensitivity and vulnerability to decay (Marshall *et al*., 2007).

Gastrointestinal Issues: Acid reflux and gastroesophageal reflux disease [GERD] - consuming acidic drinks can exacerbate GERD, the acid in these beverages can irritate the esophagus, leading to heartburn and other symptoms of acid reflux), stomach irritation (frequent consumption of acidic drinks can irritate the lining of the stomach, potentially leading to gastritis or worsening symptoms in those with existing stomach conditions such as ulcer).

Bone Health: Calcium Leaching (some studies suggest that excessive consumption of acidic beverages, particularly those containing phosphoric acid, may affect bone health by leaching calcium from bones, potentially increasing the risk of osteoporosis over time), lower bone density (there is some evidence to suggest that high intake of acidic drinks is associated with lower bone mineral density, especially in individuals with low calcium intake) (Tucker *et al*., 2006; Heaney, 2002).

Kidney Health: Blood acidity increases when people ingest substances that contain or produce acid or when the lungs do not expel enough carbon (IV) oxide commonly referred to as carbon dioxide (CO_2). Increased consumption of these drinks under investigation could bring consumers at risk of lung and kidney impairments. Lungs and kidneys compensate for slight pH imbalances but problems with these organs can lead to excess acid accumulating in the body. This is of importance particularly for persons living with health conditions related to these two organs. Increased risk of kidney stones (acidic beverages, especially those high in sugar or fructose, can increase the risk of developing kidney stones. The acid and sugar content may contribute to the formation of uric acid stones and other types of kidney stones), potential kidney damage (regular consumption of sugary, acidic drinks has been linked to an increased risk of chronic kidney disease, particularly when these drinks replace water or other healthier beverages in the diet).

Impact on Weight and Metabolism: Weight gain (many acidic beverages, particularly those that are high in sugar and calories, contribute to weight gain and obesity when consumed in excess), insulin resistance regular consumption of sugary acidic drinks can lead to insulin resistance, a precursor to type 2 diabetes. This is particularly concerning individuals who consume these beverages frequently.

Impact on Oral Health: Increased risk of oral infections i.e., the combination of acid and sugar in these drinks can promote the growth of harmful bacteria in the mouth, increasing the risk of oral infections, gum disease, and bad breath), discoloration of teeth. acidic beverages, especially those that are colored, can stain teeth over time, leading to discoloration and aesthetic concerns.

https://doi.org/ 10.5281/zenodo.13429763 ISSN 2488-8648

Impact on Nutritional Balance: The high acid content in these beverages can interfere with the absorption of certain nutrients, such as calcium and magnesium, potentially leading to deficiencies if these drinks are consumed frequently, empty calories - acidic beverages often provide little to no nutritional value, contributing empty calories that can displace more nutrient-dense foods and drinks in the diet.

Possible Mitigation of Risks Associated with Consumption of the Malt Drinks

Strong and positive Pearson correlation coefficient was obtained between pH values of each malt brand and dilution factors, indicating that pH values increased with dilution factor (Fig.2). By implication, direct relationship exists between malt pH values and dilution factors with correlation coefficient (r) varying from + 0.719 to + 0.955. The correlation coefficient was significant at $p \leq 0.05$ for 3 brands (MTX, MLT and GRM) and other two brands (AMS and GNM) significant at $p = 0.08$ and 0.13 respectively. Unit increase on pH values relative to the mean values of each drink before dilution with water and impact on acidity of the drink are presented in Table 3. Dilution with water raised pH values in the range of 6.8 to 7.2 from a mean value of 4.5 for GRM, 6.7 to 7.01 from a mean value of 4.6 for GNM, 6.54 to 7.79 from a mean value of 4.7 for MLT, 6.25 to 6.61 from a mean value of 5.0 for MTX and 7.9 to 8.0 from a mean value of 5.0 for AMS.

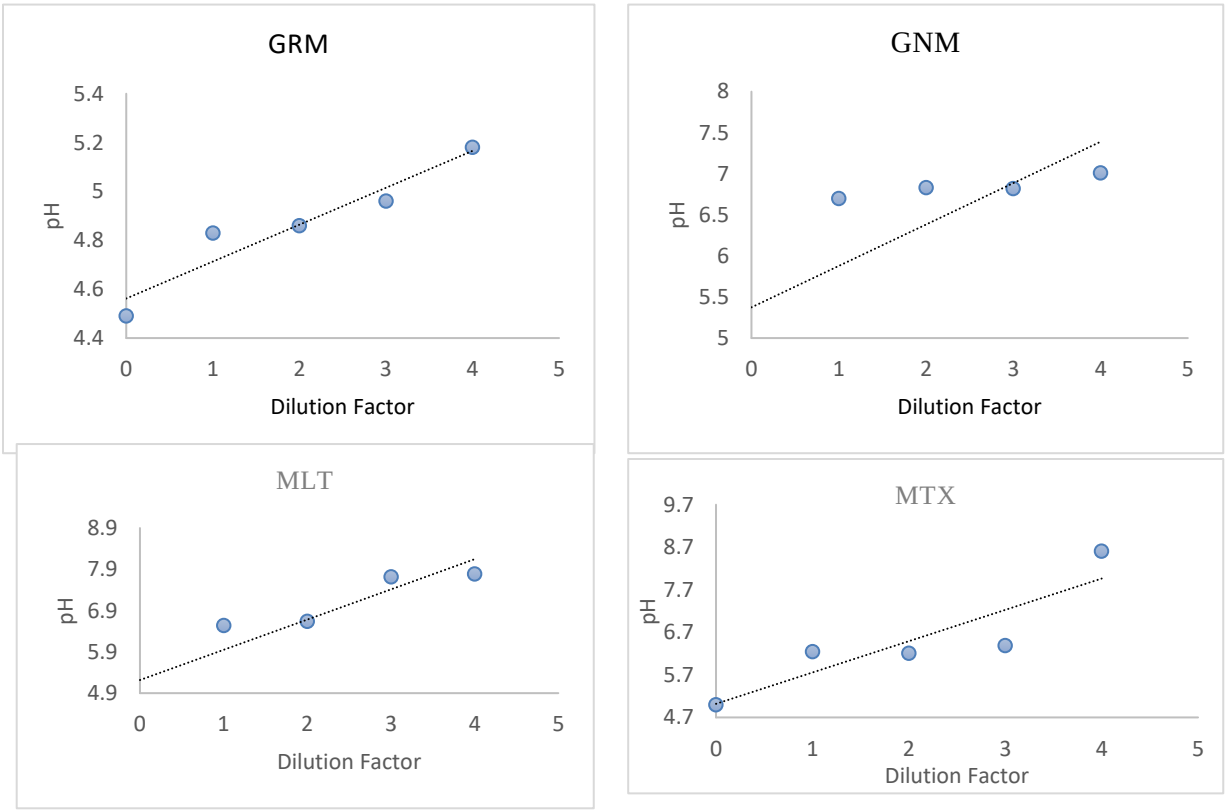

Fig. 2: Correlations between pH values et al dilution factors

https://doi.org/ 10.5281/zenodo.13429763 **ISSN 2488-8648**

Table 3: Effect of Common Consumer habit on Malt Drink Acidity

S/N	Code for Malt Brands	Mean pH value before dilution with water	pH range after dilution with water	Correlation Coefficient (r)	Range of pH Unit increase	Reduction in Malt drink acidity by dilution with water
1	GRM	4.5	6.8 to 7.2	0.96, p = 0.01	2.3 to 2.7	23-to-27-fold reduction
2	GNM	4.6	6.7 to 7.0	0.77, P = 0.13	2.1 to 2.4	21-to-24-fold reduction
3	MLT	4.7	6.5 to 7.8	0.93, P = 0.01	1.8 to 3.1	18-to-31-fold reduction
4	MTX	5.0	6.3 to 6.6	0.89, P = 0.02	1.3 to 1.6	13-to-16-fold reduction
5	AMS	5.0	7.9 to 8.0	0.72, P = 0.08	2.9 to 3.0	29-to-30-fold reduction

The increase of pH value with dilution factor suggests that diluting the malt drink with water impacted the acidity of the malt drink. The pH value for the neat malt drink before dilution showed that the drinks were acidic (4.5 to 5.0) but water dilutions gave the range of 6.3 to 8.0. Being a logarithmic scale, a unit change in pH implies an increase or decrease of an integer value by tenfold (Arnold, 2012). For instance, a change in pH from 3.0 to 4.0 indicates a 10-fold reduction in acidity. Similarly, a change from 3.0 to 2.0 indicates a 10-fold increase in acidity of the medium. Data obtained from this study, therefore, showed that diluting malt drinks with water (Common Consumer Habit) has the potential to reduce the acidity of the drinks in the range of 13 to 31 folds. This upholds the common consumer habits (CCH) as a possible mitigation strategy to reducing consumer risk to acidosis and associated health effects.

Conclusions and Recommendation

Study revealed that the commonly consumed brands of malt drinks sold in Bayelsa State were acidic. However, the common consumer habit (CCH) of diluting the drink with water has the potential of reducing the acidity. It is recommended that consumers should ingest these acidic drinks responsibly, maintain good oral hygiene practices such as brushing teeth after consumption of such drinks. Furthermore, drinking plenty of water and maintaining a balanced diet can help offset some of the negative effects of these acidic drinks. It is also recommended that a survey on consumer appreciation of the common habit of diluting malt drinks with water be conducted. Specific aspects of consumer behavior or perception to explore include taste preferences (what taste profile do consumers seek by diluting the drink e.g., less sweet, more refreshing?), health concerns (are consumers diluting due to concerns about sugar, calories, or other health factors?), economic motivation (do consumers dilute to make the product last longer or for financial reasons?), product experience (how does dilution affect the overall satisfaction with malt drinks?), perception of quality (do consumers feel that diluting the product diminishes or enhances its quality?). These are recommended to provide insights that could inform product design, marketing strategies and public health recommendations.

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