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Physico-chemical and bacteriological quality assessment of some selected sachet water brands produced in Gwale local government Area, Kano Nigeria

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Abstract

The proliferation of sachet water products has been fuelled by the rising demand for clean, safe drinking water in areas where access to potable water sources remains a challenge. Unfortunately, some of the sachet water producers fail to adhere to the standards set by regulatory agencies, resulting in potential health risk for the unsuspecting consumers. Therefore, critical investigation of the various parameters of these water products is needed to determine whether they meet the safety standards established by regulatory agencies. Thirty (30) different brands of sachet water (15 NAFDAC registered and 15 non-NAFDAC registered) were randomly collected (n=3) from producers in Gwale Local Government Area, Kano Nigeria to assess their physico-chemical and bacteriological quality. The parameters were determined using standard methods. The mean results of the temperature, pH, turbidity, conductivity, chloride and total hardness of the NAFDAC registered samples were found to be in the range of 25.9-29.7 ^{o}C, 6.8-7.2, 0.1-1.2 NTU, 11.0-41.8µs/cm,15.0-25.1 mg/L and 2.0-17.6 mg/L respectively, while for the non-NAFDAC registered samples, the mean range were found to be 25.8-30.8 ^{o}C, 6.6-8.7, 0.5-2.2 NTU, 13.6-46.8 µs/cm, 17.0 23.0mg/L and 15.8-25.3 mg/L for the same parameters respectively. These results are in compliance with the standards set by the National Agency for Food Drug Administration and Control (NAFDAC), Nigerian Industrial Standard (NIS) and World Health Organization (WHO) except pH values of 8.7 found in some non-NAFDAC registered samples which were a bit higher than the recommended limits. Some non- NAFDAC registered samples were found to contain aerobic mesophilic bacteria, though below the limit set by the aforementioned regulatory agencies. Statistically, there is significant difference ($p>2.326$) between the NAFDAC registered and the non-NAFDAC registered samples in aerobic mesophilic bacterial count but there is no significant difference in terms of coliform count between the two groups ($p< 2.326$). This finding highlights the need for regular microbiological monitoring so as to ensure public health safety.

Keywords: Physico-chemical; Bacteriological; Assessment; Sachet water brands; Gwale L.G.A

1. Introduction

Water is one of the most important factors in the development of any society. It is the second most important factor for all living organisms after air. It serves as the fundamental life force that sustains all organisms on earth. Water is the vital element that enables the survival, growth and development of every living organism making it an indispensable component of our environment. Without water, the intricate web of life could not exist. Human beings in particular can survive longer periods without food but not without water. Water is needed by living organisms to enable them carry out various physiological functions and it also acts as medium for all biochemical reactions within plants and animals.

According to Mukundan *et al.* (2022) water is not only essential for sustaining human life, but also for maintaining ecosystem health, biodiversity, food production and societal development.Water therefore, plays an essential role in supporting the lives of all living organisms.

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Access to sufficient quantities of safe and affordable drinking water is a prerequisite for human life (Vorosmarty *et al*, 2017). A report from the third World Water Forum (2003) shows that accessibility and availability of fresh, clean water is the key to sustainable development and an essential element in health, food production and poverty reduction.

While water is indeed the essence of life, its contamination with pathogenic microorganisms transforms it into a silent killer, capable of causing a myriad of diseases and illnesses. The potential health risks associated with consuming contaminated water are vast and far-reaching, often resulting in debilitating illnesses that can cause irreparable harm, particularly in vulnerable individuals such as children and the elderly. According to WHO (2017) drinking water quality is a key factor in preventing water borne diseases such as cholera, typhoid and diarrhea, some of which can be fatal. Therefore, the protection and purification of water resources must be prioritized to ensure the safety and well-being of all living beings.

Water for human consumption is characterized by being potable. Potable water or drinking water is the water that is safe for human consumption and free from harmful contaminants such as microorganisms, chemicals and heavy metals and meets specific standards for health, aesthetics and safety. According to EPA (2018) drinking water should be safe to drink and aesthetically pleasing. Aesthetic attractive and organoleptically acceptable water is important for consumers' confidence and acceptance, as people are more likely to consume water that is visually appealing and free from any off-putting sensory characteristics.

The most widely consumed and accessible drinking water is water sold in plastic bottles and sachets. The increased demand for these drinking water products is partly due to the inadequate or non-availability of reliable municipal tap water and perception that sachet/bottled water offers a healthier, tastier and more convenient option than the municipal tap or well water. The production of sachet water in Nigeria started in the late 90s and today the advancement of scientific technology has made sachet water production one of the fastest growing industries in the country (Airaodion *et al.*, 2019). The introduction of sachet water popularly known as "pure water" was aimed at providing safe, hygienic and affordable drinking water to the public and to curb the magnitude of water related infections in the country (Ezeugwunne, *et.al,* 2009).

In order to be considered safe for human consumption, water must adhere to certain standards set forth by regulatory bodies such as the World Health Organisation (WHO), the National Agency for Food and Drug Administrative and Control (NAFDAC) and Nigerian Industrial Standard (NIS). These standards cover a range of parameters including physical/chemical, microbiological parameters and other aspects of water quality. However, there are several sachet waters in circulation which are produced and sold to the unsuspecting consumers in the public that may not necessarily comply with the acceptable standard for quality drinking water. A report from Airaodion *et al*. (2019) stated that despite the strong effort by NAFDAC in the regulation and quality assessments of sachet water and other foods and drugs in Nigeria, most manufacturers have not complied with the agency's regulations.

Compliance with these standards ensures drinking water free from harmful contaminants, making it suitable for human consumption and capable of supporting healthy living. Therefore, there is a need for constant investigation of these products to ensure that they meet the required standards and are safe for human consumption.

2. Materials and methods

2.1. Description of the Study Area

Kano state covers an area extending between latitude 120°40' and 100°30' and longitude 70°40' and 90°40'. According to the National Population Commission (NPC, 2016) the population of Kano state was estimated to be around 15.05 million. The state is characterized by two distinct seasons: the wet/rainy season, which lasts from May to September. This season is characterized by high rainfall, high humidity and cooler temperature. The dry/harmattan season lasts from October to April and is characterized by hot and dry weather, with occasional dust storms and low humidity USAID (2021).

Gwale local government area on the other hand, lies between latitude 11.97743^0 and longitude 8.406540 and is located to the South-West of Kumbotso local government area, West of Ungoggo local government area and East of Municipal local government area of the State.

2.2. Sample Collection

A total of ninety (90) samples of thirty (30) different brands of sachet water (15 NAFDAC registered and 15 non-NAFDAC register) were randomly collected at various sachet water factories in Gwale Local Government Area, Kano state. The samples were collected immediately after production of the sachet water and were labeled appropriately. It was taken to the laboratory in insulated containers with ice packs. Analysis was carried out within 4 hours after sampling, where immediate microbiological evaluation was delayed; the samples were refrigerated at 4 ^{0}C and analyzed within 24 hours of collection as described by Abdullahi and Indabawa (2004).

2.3. Determination of Physico-Chemical Parameters

2.3.1. Temperature

The temperature of the water samples were measured as described by (APHA, 2005). The temperatures were measured in the storage room immediately after production of the sachet water with a pH meter model 8681. This instrument was supplied with a fully integrated pH/temperature electrode with pH accuracy of ±0.2. The electrode of the pH meter was rinsed in distilled water and blot dried. It was then immersed into the water sample for 30 seconds until the reading was maintained, and the temperature reading recorded from the meter scale.

2.3.2. Hydrogen Ion Concentration (pH)

The pH of the water samples were measured in the storage room with a pH meter model 8681. The electrode of the pH meter was rinsed in distilled water and blot dried. It was then immersed into the water sample for 30 seconds until the reading was maintained, and the pH reading recorded from the meter scale (APHA, 2005).

2.3.3. Turbidity

This was determined in the laboratory using a turbidity meter model LP 2000. The instrument was supplied with a small glass tube that has a lid inserted inside a hole on the meter. The tube was removed from the hole and filled with distilled water, the lid was replaced tightly on the tube. The tube was then inserted into the hole on the meter. The reading button was pressed, and the reading was taken after it was maintained on the meter scale. The tube was removed from the hole and the distilled water was poured out. The water sample was poured into the tube, the lid was replaced and the tube was inserted into the hole on the meter. The reading button was pressed and the reading was subtracted from the initial reading of the distilled water (Hanna Instruments, 2004).

2.3.4. Total Hardness

Total hardness was determined by ethylenediamine tetra acetic acid (EDTA) titrimetric method as described by APHA (2005). In this method, fifty milliliters of each water sample in a 250ml flask was mixed with 1ml of NH_4 CI-NH_4OH buffer and 2 ml of Solochrome black "T" indicator and titrated with 0.02N EDTA to a blue end point. Total hardness was calculated with the expression:

$$Total\ hardness(mg/L) = \frac{A\ x\ 100}{50} \dots\dots\dots\dots\dots (1)$$

Where A = Titre value

2.3.5. Chloride

This was determined by titration method as described by AOAC (2000) where 100ml of the water sample was measured and poured into a conical flask. Two drops of potassium chromate indicator were added and then shaken. It was then titrated against 0.025M silver Nitrate ($AgNO_3$). The end-point of the titration was given by a red color of the silver chloride precipitate. Titration was repeated on a further two 100 ml water samples and the average of the mean volume of silver nitrate used was calculated and recorded.

$$Chloride\ Cl-\ in\ mg/L = \frac{A\ x\ M\ x\ 35.45\ x\ 1000}{Sample\ Volume} \dots\dots\dots\dots\dots (2)$$

Where
A = Titrate value
M = Molarity of titrant ($AgNO_3$)

2.3.6. Electrical Conductivity (EC)

This was measured in the laboratory by following the protocol of APHA (2005). In this method, a conductivity meter Hach model (0150) was used. This meter measured the current passing through a solution between two electrodes in the probe. The electrodes were standardized in distilled water and placed into the water samples for 20 seconds and the reading was recorded in microsiemens per centimeter (µs/cm).

2.4. Determination of Bacteriological Parameters

2.4.1. Enumeration of Aerobic Mesophilic Bacterial Count

This was carried out according to the protocol of Refai, (1979). In this method, one end of each sample of the sachet water was cleansed with 70% ethanol. A sterile pair of scissors was used to cut open the water sample at the sterilized end. One milliliter (1 ml) of the sample was aseptically dispensed into a test tube containing 9.0 ml of sterile distilled water and labeled 1:10. From this tube, 1.0 ml was dispensed after agitation into another tube containing 9.0 ml of sterile distilled water and labeled 1:100. This was also agitated and from it 1.0 ml was dispensed into another tube containing 9.0 ml of sterile distilled water and labeled 1:1000 and the procedure was repeated up to $1:10^5$. Using sterile pipette 1.0 ml of inoculum was transferred from the dilution tubes into duplicate Petri dishes. This was followed by pouring of a warm molten nutrient agar (Oxoid). The plates were then gently rocked on a flat surface and allowed to solidify, and finally incubated at 37 ^{0}C for 24 hours. Following 24 hours incubation, plates containing 30 - 300 colonies were selected and counted, and the number multiplied by the inverse of dilution factor to get the number of colony forming units per ml (cfu/ml).

2.4.2. Enumeration of Total Coliform

The multiple tube fermentation technique was used for the enumeration of total coliform bacteria, as recommended by Refai, (1979). Each sample was inoculated into 3 sets of tubes as follows; 10 ml of each sample inoculated into five tubes containing 10 ml of sterile double strength lactose broth with inverted Durham tubes. Then, one ml of each sample inoculated into five tubes each containing 5 ml of sterile single strength lactose broth with inverted Durham tubes. Then 0.1 ml inoculated into five tubes each containing 5 ml of sterile single strength lactose broth with inverted Durham tubes. The tubes were incubated at 37 ^{0}C for 24 hours. Following incubation, tubes showing gas production were counted and compared to the MPN table adapted from APHA, (1992) for the determination of most probable number (MPN) of coliforms.

2.4.3. Confirmation of Coliform Bacteria

For the confirmation of coliform bacteria, the protocol of Refai, (1979) was also adopted, in this method a loopful of broth from gas positive tubes was streaked onto eosin methylene blue (EMB Antc UK) agar plate and incubated at 37 ^{0}C for 24 hours. The plates were observed after 24 hours for the presence of bluish black colonies with green metallic sheen which confirms the presence of coliform bacteria. Colonies that formed green metallic sheen on EMB were bio-chemically characterized to be E.*coli* using indole, methyl red, vogers proskauer and citrate tests.

2.4.4. Isolation and Characterization of E.coli

Imvic Reactions: (1 = Indole, M= methyl red, vi= vogers = proskauer and C= citrate). This is a test where *E.coli* can be differentiated from other coliform groups such as *Enterobacter aerogenes*.

Indole Test

This was carried out according to the protocol of Bankole and Shuaibu (2008). In this method, 5 ml of peptone water was inoculated with a loopful of the test sample and incubated for 24 hours. After 24 hours, 3 drops of Kovacs indole reagent was added and shaken gently. A positive reaction is indicated by the development of a red color in the reagent layer above the broth within 1 minute. In a negative reaction, the indole reagent retains its yellow color.

Methyl Red Vogers Proskauer Test

This was carried out as recommended by (Bankole and Shuaibu, 2008). In this method, 5 ml of MR-VP broth culture of 2 days incubation was inoculated and incubated for 48 - 72 hours at 35 ^{0}C.

2.5. Statistical Analysis

The physico-chemical parameters, Aerobic mesophilic bacterial count and total coliform count of both the NAFDAC and the non-NAFDAC registered sachet water samples were evaluated with the statistical program for the social sciences

(SPSS) version 15.0 for windows 2003. The mean, standard deviation (S.D) and t- test were used to summarize the physico-chemical and bacteriological qualities of the sachet waters under study.

3. Results

Table 1 Mean Values of Physico-Chemical Parameters of the NAFDAC Registered Sachet Water Samples Collected in Gwale, L.G.A

Parameters/ Sample Codes	Temperature (^{0}C)	pH	Turbidity (NTU)	Conductivity (µs/cm)	Chloride (mg/L)	Total Hardness (mg/L)
A1	26.5	7.1	0.1	11.5	18.8	2.0
A2	26.1	6.9	0.3	11.6	15.1	4.5
A3	26.1	7.2	1.1	21.1	21.6	17.4
A4	25.9	7.2	1.0	20.6	25.0	16.5
A5	26.3	7.1	0.5	12.1	22.8	13.6
A6	27.5	7.0	0.3	11.0	15.0	4.5
A7	26.3	6.8	0.8	18.0	23.1	13.0
A8	26.5	6.8	1.0	11.8	21.0	8.0
A9	26.0	6.9	0.5	13.0	22.3	14.5
A10	26.0	6.9	0.7	11.3	20.1	14.0
A11	29.7	7.2	1.2	41.8	25.1	17.6
A12	27.2	6.9	0.6	15.8	20.4	16.6
A13	27.0	6.8	0.9	11.1	22.2	17.3
A14	29.1	6.8	1.0	15.2	20.5	16.0
A15	27.5	7.0	0.1	11.0	21.5	16.8

Key: A1-A15 NAFDAC registered Sachet Water

Table 2 Mean Values of Physico-Chemical Parameters of the non-NAFDAC Register Sachet Water Samples Collected in Gwale, L.G.A

Parameters/ Sample Codes	Temperature (^{0}C)	pH	Turbidity (NTU)	Conductivity (µs/cm)	Chloride (mg/L)	Total Hardness (mg/L)
B1	27.3	6.9	0.7	18.5	19.8	16.5
B2	27.3	7.2	1.8	37.0	23.0	24.0
B3	27.2	6.6	0.6	34.0	21.6	20.5
B4	27.0	7.1	0.5	16.8	20.0	25.0
B5	26.5	6.8	0.7	15.1	17.0	16.0
B6	27.0	8.7	2.2	46.8	23.0	16.5
B7	26.1	8.1	2.0	42.5	20.3	15.8
B8	25.9	6.7	0.5	13.6	17.0	15.9

B9	26.9	6.9	1.0	26.8	21.4	25.3
B10	26.5	6.8	1.2	40.8	20.0	22.1
B11	26.0	8.3	1.6	46.5	23.0	25.3
B12	25.9	7.7	1.5	46.0	23.0	25.0
B13	30.8	7.5	1.1	23.1	17.0	16.5
B14	25.8	7.1	1.4	27.8	18.3	16.2
B15	27.5	7.9	1.2	23.8	17.1	16.0

Key: B1-B15 non-NAFDAC registered Sachet Water

Table 3 Aerobic Mesophilic Bacterial Count of the NAFDAC and the non-NAFDAC Registered Sachet Water Samples in Gwale L.G.A. Kano, Nigeria

Test	Status of Water Labeled	N	Mean	STD	Df	Tcal.	Tcr	Level of Significance
Aerobic Mesophilic Bacterial Count (cfu/ml)	NAFDAC Registered Water	15	2.327	0.490	58	4.578	2.326	SD
	non-NAFDAC Registered Water	15	1.560	0.777		4.578	2.326	

Key: STD – Standard deviation; SD – There is significant difference; Tcal – Calculated value; Tcri – Critical value

Table 4 Coliform Counts of the NAFDAC Registered and the non-NAFDAC Registered Sachet Water Sampled in Gwale L.G.A. Kano, Nigeria

Test	Status of Water Labeled	N	Mean	STD	Df	Tcal.	Tcr	Level of Significance
Coliform Count	NAFDAC Registered Water	15	3.033	1.066	58	2.051	2.326	NS
	non-NAFDAC Registered Water	15	2.467	1.074		2.051	2.326	

Key: STD – Standard deviation; NS – No Significance difference; Tcal – Calculated value; Tcri – Critical value

4. Discussion

Table 1 and 2 shows the mean physico-chemical parameters of the NAFDAC registered water samples and the non-NAFDAC register water samples respectively. Water temperature is a measure of the thermal energy (or heat) present in a sample of water. The water temperature for both the NAFDAC and the non-NAFDAC registered sachet water recorded in this study were slightly higher than the findings of Magaji (2020) who reported a temperature range of 25.2-27.2 ^{o}C in his study. This may be due to differences in the environmental temperature. The mean temperature range of 28.37-27.03 ^{o}C was reported by Solomon *et al.* (2018). A report from Illela *et al*. (2021) reported a temperature range of 27.06-28.33 ^{o}C in their study. Higher water temperature can promote the growth of bacteria including aerobic mesophilic bacteria and *E.coli.*

pH stands for potential of hydrogen and is a measure of the acidity or alkalinity of water. The water mean pH values recorded in this study have lower values in the NAFDAC registered samples compared to non-NAFDAC register samples. The high water pH found in some samples of the non-NAFDAC registered samples may be attributed to the presence of alkaline minerals such as calcium carbonate or magnesium carbonate which are naturally present in the source of the water and are not completely removed during the treatment process. A report obtained from Illela *et al*. (2021) observed pH range of 6.60-7.44, Opafola *et al*. (2020) reported a pH range of 6.57-6.79±0.02 and Solomon *et al*. (2018) reported pH mean values of 6.1-4.1. Water with too high or too low pH can have an unpleasant taste and smell. The NAFDAC and NIS recommends a pH range of 6.5-8.5 for drinking water.

Turbidity refers to the cloudiness or haziness of water caused by suspended particles such as clay, silt, algae and other organic matter. The mean range values of turbidity in this report are found to be lower in the NAFDAC registered samples than the non-NAFDAC register samples. However, all the values fall within the recommended limits of <5 NTU set by NAFDAC, NIS and WHO for drinking water. A report from Magaji (2020) observed turbidity of drinking water to be in the range of 0.0-4.41 NTU. A study by Opafola *et al*. (2020) reported a turbidity range of 0.00-0.59±0.02 NTU. High turbidity causes the water to be cloudier, which can be aesthetically unappealing. Water with high turbidity can provide a protective environment for bacteria to grow and thrive which may lead to an increase in aerobic mesophilic bacteria and *E.coli.*

The conductivity of water is a measure of its ability to conduct electrical current. The mean conductivity values recorded in this study slightly differ in the NAFDAC and the non-NAFDAC samples. These values are lower than the values reported by Solomon *et al*., (2018) whom reported mean range of electrical conductivity of 118.77-79.93 µs/ cm and in another report from Chiwetalu, *et al*. (2022) was 100-264 µs/cm, Opafola *et al*. (2020) reported electrical conductivity range of 0-145.00± 5.00 µs/cm and Illela *et al*. (2021) reported electrical conductivity in the range of 60.80-150.30 µs/cm. High conductivity values indicate that there are more dissolved ions present in the water, which suggest that the water is in contact with a source of ions, such as minerals-rich rock soil.

Chloride is a dissolved ion that is commonly present in drinking water. Similar mean values of chloride are obtained for the NAFDAC registered samples and the non-NAFDAC register samples. These values are within the recommended limit set by WHO (2003) of 250 mg/L. This result is higher than the result of Airaidion *et al,* (2019) who reported chloride in the range of 1.45-9.12 mg/L and Abasiekong *et al*. (2016) reported chloride range of 0.00-29.22 mg/L.

Total hardness refers to the concentration of calcium and magnesium ions in water. The mean range of total hardness in this study is lower in the NAFDAC registered samples as compared to the non-NAFDAC register samples. The range of total hardness reported by Airaidion *et al* (2019) was found between the ranges of 4.00-62.00 mg/L. Water with high total hardness can have a hard taste which can be unappealing. NAFDAC requires total hardness to be less than 100 mg/L.

Table 3 shows the level of significance of aerobic mesophilic bacteria count of both the NAFDAC and the non-NAFDAC registered sachet water samples. Statistically, there is a significant difference in aerobic mesophilic bacteria count between the NAFDAC and the non-NAFDAC registered samples (p> 2.326). From the report of Opafola *et al*. (2020) it was found that a total bacteria count of 200-1700 cfu/ml was observed in drinking water.

Table 4 Indicates the level of significance of coliform count of the NAFDAC registered samples and the non-NAFDAC registered samples. Statistically, there is no significant difference in terms of coliform count between the two groups (p< 2.326). High levels of coliform bacteria can indicate the presence of harmful pathogens, which can cause water-borne diseases. A report from Opafola *et al*. (2020) indicated zero total coliform in their findings. Total coliform of 0-130 CFU/100 ml was reported by Solomon *et al*. (2018). In the findings of Abasiekong *et al.* (2016) the range of coliform bacteria recorded was 1-26 cfu/ml. There was no *E.coli* detected in all the water samples. This result deviates with the findings of Abasiekong *et al.* (2016) who detected *E.coli* in the range 1-28 cfu/100 ml in more than 40% of the studied water samples.

5. Conclusion

From the findings of this research, it can be concluded that all the physico-chemical parameters of the sachet water samples under study met the standards set by NAFDAC (2007) NIS (2008) and WHO (2003) except some samples that have pH of 8.7 which is above the recommended limit set by the aforementioned regulatory bodies. The aerobic mesophilic bacterial count was significantly different between the NAFDAC registered and the non-NAFDAC register samples, which suggest that NAFDAC registration plays a role in improving the quality of sachet water. The total coliform count has no significant difference between the two groups and *E.coli* was not detected in all the water samples under study.

Recommendations

From the findings of this research, the following recommendations can be made;

- NAFDAC should intensify their efforts on the assessment of water quality of all sachet water industries in the study area.

- NAFDAC should constantly conduct routine tests on these products and publish regularly the list of producers who have registered their products, and then alert consumers about those with the good quality/safe products.
- Producers who did not register with NAFDAC should be enforced to do so.
- Consumers should make use of only the NAFDAC registered sachet water.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest. The authors affirm that all research procedures performed in this study were in accordance with ethical standards of the subjects, the community and the environment.

Statement of ethical Approval

The authors affirm that all research procedures performed in this study were in accordance with ethical standards of the subjects, the community and the environment.

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