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Evaluation of the Chemical and Bacteriological Quality of Bagged Water in Ivory Coast (Seven Localities)

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A B S T R A C T

The aim of this study is to assess the physico-chemical and microbiological quality of water packaged in an industrial way and those packaged in a traditional way in order to understand the risks of exposure of the consumer population. To achieve this objective, a survey was carried out among 600 people. 270 samples of bagged water were collected in seven localities in Côte d'Ivoire. Then, physico-chemical and microbiological analyses of the samples were carried out to determine the quality of the water. It emerges from this work that the majority of the pH of the water packaged in bags in these localities are acidic. The temperatures of the packaged waters vary between 13.6 and 22.6°C. The levels of residual chlorine recorded in the conditioned waters of the cities studied do not comply with the limit value recommended by the WHO, which is around 0.2 mg/L. Concerning the microbiological quality of the bagged water, the analyses revealed the presence of mesophilic aerobic germs, Total Coliforms and Escherichia Coli. Waters packaged in an artisanal and industrial way are not of good quality from a bacteriological point of view.

Introduction

The importance of water is preponderant, like other indispensable elements in human life, both for its consumption and for its physiological needs (UN, 2019). Indeed, humans can refuse to eat food, but they cannot go more than three days without drinking water (Akiyo, 2017). Water is an element in promoting the health of living beings and the socio-economic development of human communities. Consumption of poor quality water would then constitute an assault on the life of the consumer. It is for this reason that the quality of drinking water appears to be an issue of concern throughout the world (WHO, 2011; El Haissoufi *et al.,* 2011)

In recent years, in Côte d'Ivoire, the marketing of bagged water has become an activity that offers several significant socio-economic opportunities to the population (Ble *et al.,* 2015). These waters are conditioned in an artisanal way in households or in an industrial way in semi-industrial companies.

Like manufactured products, water packaged in sachets seems to have the consent of many consumers (Ble *et al.,* 2009). This is because they are convenient, refreshing and in expensive for low-income residents. Increasingly, however, the quality of bagged water is being questioned on both sides for a number of reasons.

Is the conditioned water drinkable?

Does the quality of industrially packaged water in bags differ from that of artisanal bottled water?

Does the quality of industrially packaged water in bags differ from that of artisanal bottled water?

It is to answer these concerns that this study aims to assess the physico-chemical and microbiological quality of water packaged in an industrial way and those packaged in an artisanal way in order to apprehend the risks of exposure of the consumer population.

Materials and Methods

Presentation of the Study Area

The quality of the bagged water discussed in this study was observed in some localities in Côte d'Ivoire. These localities were selected in the main regions: Abidjan (South), Abengourou (South-East), Bouaké (Centre), Korhogo (North), Daloa (Centre-West), de Man (West) and San-Pedro (South-West). In these areas, there is a diversity of packaged waters that are sold (Figure 1).

Investigations

A investigation took place from December 22, 2017 to August 28, 2018 in seven localities in Côte d'Ivoire to find out the types of water sachets consumed, the conditions of water bagging and the water used for packaging. To this end, a semi-directive questionnaire was developed based on a qualitative analysis of the population.

Sampling

The sampling campaign was conducted from January 17 to May 28, 2018. A total of 270 sachets of artisanally and industrially packaged water were collected. 210 sachets were collected in Korhogo, Bouaké, Daloa, Man, Abengourou and San-Pedro with 30 sachets per city. 60 sachets were collected in Abidjan. They were collected with vendors in bus stations, stores and near public roads. They were then placed in coolers containing ice to maintain temperatures at 4°C until the laboratory.

Physical and chemical analyses

The pH, temperature and conductivity were determined using a HACH44600 portable multimeter according to the techniques of Rodier et al (2009). Turbidity was measured with a HACH 2100P turbidimeter according to Rodier *et al.,* (2009).

Residual chlorine was measured with a LOVIBOND MD200 colorimeter (SODIMEL, France) with diethyl paraphenyl diamine (DPD) pellet (reagent).

Nitrate was determined according to HACH methods with the UV / visible Spectrophotometer DR 6000 HACH (SODIMEL, France).

Microbiological analyses

Mesophilic aerobic germ count was performed on Plate Count Agar (PCA,) (Difco) and incubated at 37°C for 24 hours. Total coliforms and *Escherichia coli* were enumerated on crystal violet and neutral red

(VBRL,) and TBX biliated lactose media according to ISO 9308-1:2014.

Salmonella was tested on Hektoen gelose according to the ISO 6579 (2002) method, following: pre-enrichment, enrichment, isolation and identification.

Statistical analysis

The histograms were obtained based on mean values and standard deviations using the Excel 2013 analysis utility. The mean values of the artisanal and industrial bagged water were compared using an analysis of variance (ANOVA) with a factor at the significance threshold set at $p = 0.05$. XLSTAT software was used to process the data.

Results and Discussion

Survey results

Figure 2 shows the proportions of water conditioned in an artisanal and industrial way. 70.31% of the population surveyed consume industrially packaged water. In contrast, 29.68% of the population surveyed in these localities consume water packaged in an artisanal manner. Industrially packaged water is consumed more than artisanal water. According to the population, industrially packaged water is more available and more hygienic than artisanal water. According to Kouadio *et al.,* (2013) semi-industrial water is more accessible and less contaminated than artisanal water.

pH of bagged water

The average pH values of artisanally packaged waters vary between 5.8± 0.57 and 7.2 ± 0.54. For industrially packaged water, the pH values range from 5.8 ± 0.48 to 6.8 ± 0.69. The results of the analyses reveal that there is no significant difference between the

pH of waters conditioned in an artisanal and industrial way. This shows that the waters packaged in an artisanal and industrial way could come from the same source.

The pH values of these waters are between 5.8 and 7.2 and most of them are below 7. This shows the acidity of these waters. This acidity could be related either to the types of rocks crossed by these waters or to the types of treatment adopted. The work ofAhoussi *et al.,* (2018) and MBra*et al.,* (2015) carried out on groundwater in some regions of Côte d'Ivoire, revealed the acidity of these waters.

Turbidity of bagged water

The average turbidity concentrations of bagged water range from 1.3 ± 0.17 to 2.8 ± 0.24 NTU. The figure shows that there is a significant difference between the turbidity values of artisanal and industrial packaged water in the cities of Korhogo, Bouaké, Daloa and Abidjan. The average turbidity values of bagged water are less than 1 NTU which is recommended by the WHO for drinking water. This difference could be justified by the type of treatment adopted during water conditioning. According Blé *et al.,* (2015), some people use filters during conditioning while.Otcher do not use filters. This is because filters can retain suspended solid.

Température of the water in the bag

The average temperature values of the conditioned water vary between 13.6 ± 0.89 and 22.5± 1.45°C. They reveal that there is a significant difference between the temperatures of water conditioned in the artisanal and industrial way in the cities of Korhogo, Daloa, San -Pedro. The majority of the temperatures of these waters comply with the value recommended by the WHO, which is 22° C for drinking water.

Table.1 Bacterial loads of water packaged in sachets in an artisanal way

| Sample city	Germes aérobies mésophiles	Coliformes totaux (UFC/100mL)	*Escherichia Coli (UFC/100 mL)*	*Salmonella (100 mL)*
Korhogo	542 ± 19	510 ± 26	0	Absence
Bouaké	712 ± 18	414± 12	90 ±28	Absence
Daloa	528±15	621±14	485 ± 10	Absence
Man	485±14	451± 12	-	Absence
Abengourou	451 ± 17	451± 18	-	Absence
San Pedro	556 ± 24	458 ± 12	490 ± 25	absence
Abidjan	545 ± 18	451± 12	-	absence
Level of contamination n (%)	19,99	17,61	4,76	0

Table.2 Bacterial load of industrially packaged water

Sample city	Germes aérobies mésophiles	Coliformes totaux (UFC/100mL)	*Escherichia coli (UFC/100 mL)*	*Salmonella (100 mL)*
Korhogo	369 ± 13	420 ± 18	684 ± 22	Absence
Bouaké	418 ± 15	185± 24	-	Absence
Daloa	398±18	-	-	Absence
Man	189 ± 16	212± 15	-	Absence
Abengourou	289± 21		-	Absence
San Pedro	389 ± 14	471± 17	502 ± 17	Absence
Abidjan	186 ± 19	147± 14,5	-	Absence
Level of contamination (%)	14,28	9,04	3,32	

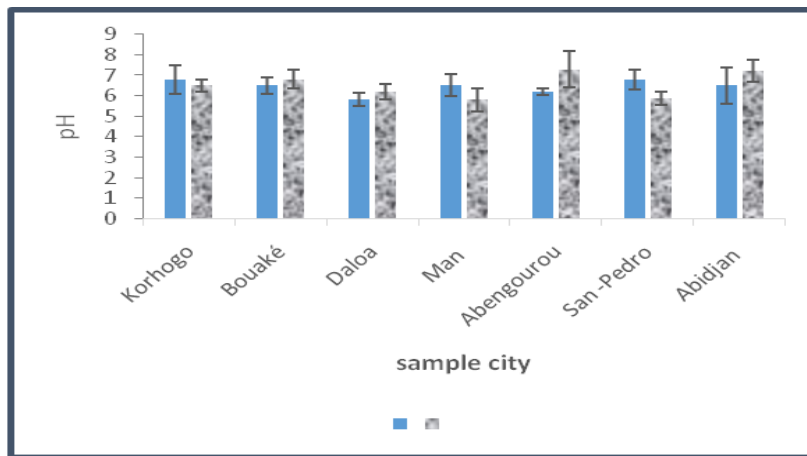**Fig.1** Study areas of 7 localities of the Ivory Coast
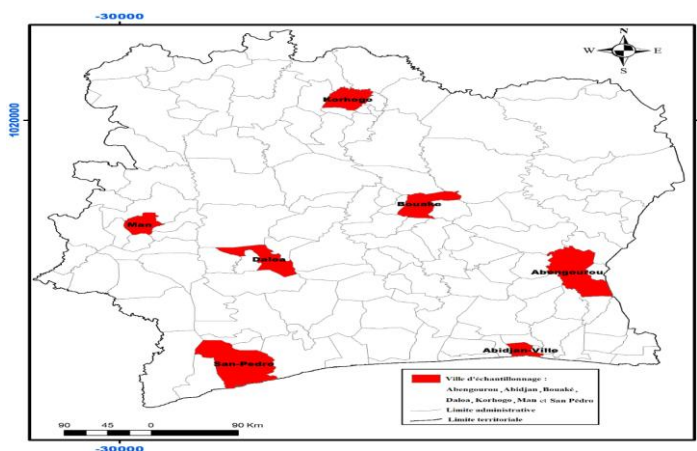
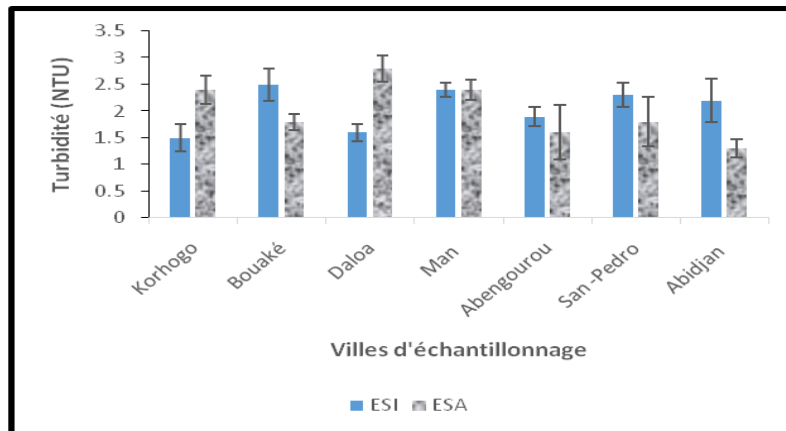**Fig.2** Proportion of consumption of packaged water
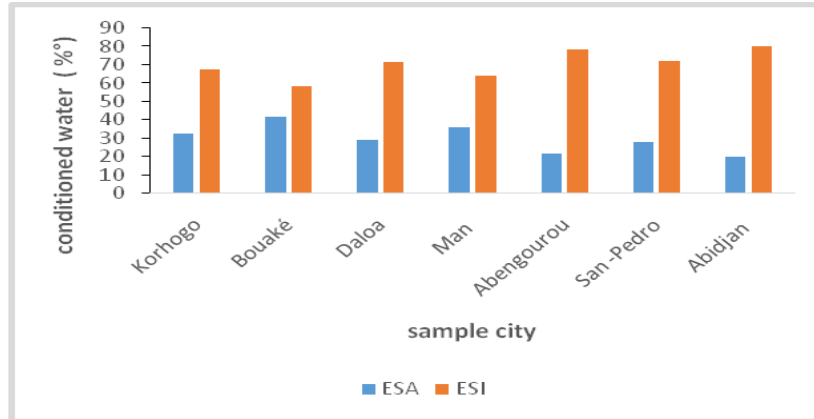
ESI : Industrially packacger water
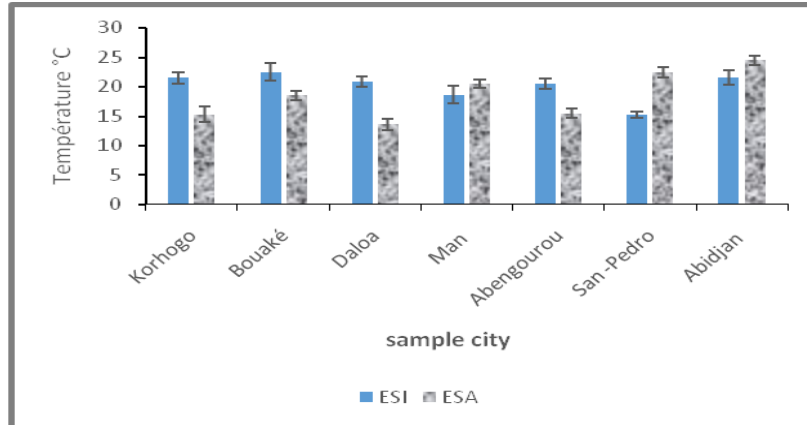ESA : Artisanally packager water

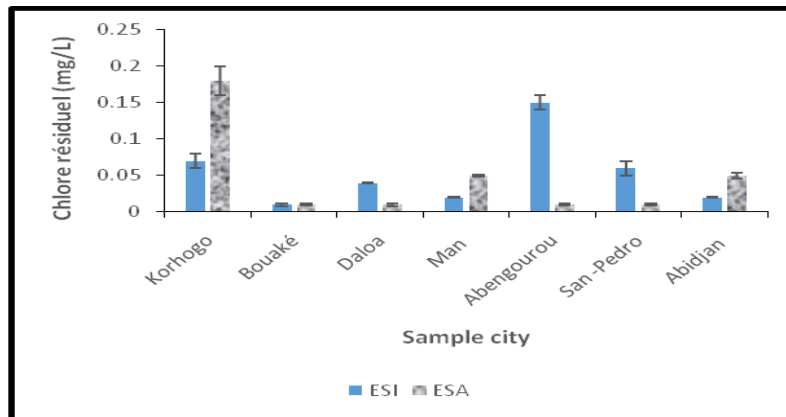**Fig.3** pH of waters conditioned in an artisanal and industrial

Fig.4 Turbidity of water conditioned in an artisanal and industrial way

Fig.5 Temperature of artisanal and industrial packaged water

Fig.6 Residual chlorine from water conditioned in an artisanal and industrial manner

Residual chlorine from bagged water

Residual chlorine values vary between 0.1 and 0.18 mg/L. The residual chlorine values recorded in the conditioned water of the cities studied are below the limit value recommended by the WHO, which is around 0.2 mg/L for drinking water. The non-compliance of the residual chlorine values observed in bagged water would be related to the phenomenon of evaporation during the bagging of water. These low chlorine levels could also be due to the exposure of this water to solar radiation. Low levels of residual chlorine were observed by Kouakou *et al.,* (2010), in Andokoi's stored water in Abidjan. They point out that high indoor temperatures promote the evaporation of chlorine.

According to Kahoul and Touhami (2014), chlorine is a gas that evaporates during water storage. Indeed, chlorine prevents the proliferation of most pathogenic microorganisms (Belghiti *et al.,* 2013).

Bacterial load of artisanally packaged water

Tables 1 and 2 show the bacterial loads of mesophilic aerobic germs, total coliforms of Escherichia Coli and Salmonella Sp. in artisanal and industrial conditioned waters. There is a total absence of Salmonella sp. in both types of conditioned water. It should be pointed out that the levels of contamination of artisanally packaged waters with mesophilic aerobic germs, total coliforms and

Escherichia Coli are 19.99%, 17.6% and 4.7%, respectively. For industrially packaged waters, the contamination levels of these water samples by mesophilic aerobic germs, total coliforms and Escherichia Coli are 14.28, 9.04 and 3.32, respectively. The proliferation of these bacteria in industrially packaged waters could be due to the low residual chlorine values obtained in bagged waters. Indeed, chlorine prevents the proliferation of most microorganisms in water (Belghiti *et al.,* 2013).An analysis of the different types of water reveals that water samples conditioned in an artisanal way are more contaminated than those conditioned in an industrial way. The high contamination of samples of artisanally packaged water could be due to the hygienic conditions during packaging and transport. Indeed, these artisanally packaged waters were packaged by hand. Handling of the water during packaging and transport could lead to the proliferation of bacteria in the water. Hounsounou *et al.,* (2017) state in their work that the various manipulations of water are potential factors in its contamination. Also, according to Ayad, (2017), shows that water can be of good quality at the source, but the hygienic conditions adopted during storage and transport can contribute to the degradation of its quality.

In conclusion this study carried out in the cities of Korhogo, Bouaké, Daloa, Man, Abengourou, San-Pedro allowed to appreciate the quality of water conditioned in a craft and industrial way.

It emerges from this work that the majority of the pH of the water packaged in bags in these localities are acidic. There is a significant difference between the values of turbidity of water packaged in an artisanal and industrial manner in the cities of Korhogo, Bouaké, Daloa and Abidjan. Temperatures of conditioned water vary between 13.6 and 22.6°C. The levels of residual chlorine recorded in the conditioned water of the cities studied do not comply with the limit value recommended by the WHO, which is of the order of 0.2 mg/L. Concerning the microbiological quality of the bagged water, the analyses revealed the presence of mesophilic aerobic germs, Total Coliforms and Escherichia Coli. The analyses revealed that the samples of water conditioned in an artisanal way are more contaminated than those conditioned in an industrial way. Therefore, the water packaged in the artisanal and industrial way is not of good quality from a bacteriological point of view.

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