EVALUATION OF BOTTLED WATER IN THE GHANAIAN MARKET

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ABSTRACT

Similar to purchasing any commodity, the consumer has the sole responsibility for what products he/she may buy. Often the decision to buy a particular product hinges on several factors, namely the content composition displayed on the product label; an approval seal from an accredited regulatory body; date of manufacturing or expiry; packaging; or brand of the product. The decision of what to buy becomes challenging for an average Ghanaian consumer, who is also semi-literate and does not have a clear understanding of the implications of his/her decision. This study reports an analysis of the fourteen most popular brands of bottled water produced and distributed in Ghana. Using multi-criteria decision making (MCDM) to evaluate bottled water brand preference in the Ghanaian market. The goal is to ascertain which of the brands is best for the Ghanaian consumer, based on the content composition displayed on the bottle. The results suggest that displayed mineral constituent on bottled water can be used to select the best water on the Ghanaian Market.

Keywords: Bottled Water, Ghana, Entropy, TOPSIS.

INTRODUCTION

Access to safe drinking water supplies and improved water management is estimated to improve consumers' health and well-being as it prevents water-related diseases, including diarrhoeal diseases, schistosomiasis, filariasis, and trachoma, and helminths (WHO, 2004). Countries recognize the fundamental role that safe drinking water plays in economic and social development, hence focus more attention on the treatment, use, and preservation of water resources to avoid contamination (Suleiman & Khakee, 2017). As consumers become aware of the implications of safe drinking water, they resort to bottle water with the notion that it is safe. Al-Omran et al. (2012) defined drinking water as "water pure enough to be consumed with low immediate or long-term risks." In Ghana, drinking water can be accessed from tap water, sachet water, and bottled water. Bottled water is defined as "water that is intended for human consumption, and that is sealed in bottles or other containers with no added ingredients except that it may optionally contain safe and suitable antimicrobial agents" (Semerjian, 2011). A worldwide survey by Beverage Marketing Corporation (2017) revealed that bottled water consumption grew from 12.8 billion gallons in 2016 to 13.7 billion in 2017, signifying a 7% increment.

Bottled water sources may be from springs, groundwater, boreholes, municipal systems and others (Ehlers et al., 2004). Although bottle water is clean, it does not necessarily mean it is free from microorganism contaminations: these contaminations are mainly attributed to bottled water packaging, handling, transportation and storage (Kassenga & Mbuligwe, 2009). The average

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mineral constituents (e.g. calcium (Ca), magnesium (Mg), potential of hydrogen (pH), potassium (K), etc.) of bottled water are often displayed on the packaging labels to provide information of the water to the Ghanaian public. Each constituent plays a specific role in the human body with a deficiency causing severe harm. For example, calcium acts as primary structural constituents of the skeleton whilst a lack of it result in decrease in bone mineral content and a weaker bone structure (WHO, 2011). Bottled water patronization in Ghana is on the rise for a variety of reasons, including convenience, fashion, taste, and the assumption by consumers are that it is safer than tap water (El-Salam et al., 2008). These bottled water brands are regulated and certified by the Ghana Standard Authority (GSA).

Bottled water comes in different brands, prices and shapes exposing consumer to consumer choice decision which is a decision consumer have to makes when buying bottled water in Ghana. Consumers bottled water decisions are influence by friends' recommendations, social class, educational level, promotion, availability, and competitor effect, etc. (Lema & Wodaje, 2018). In terms of bottled water buying behavior both male and female shows indifferent behavior and the higher a consumer educational status, the higher the probability of purchasing bottled water in Ghana (Quansah et al., 2015). However, bottled water purchasing decision is based on GSA certification tag which assures consumers of water quality but not prioritization.

Ehlers et al. (2004) work surveyed ten different bottled water in South Africa to test its microbial quality. They concluded that 80% of the bottled water sampled fall within the acceptable limits set by the South Africa Bureau of Standard, with 20% deviating. That of Obiri-Danso et al. (2003) assessed the microbiological quality of eight bottle water in Kumasi, Ghana. Their result indicates that none of the bottled water contains any fecal contaminant; the iron content was within the World Health Organisation (WHO) and GSA recommendations, and no lead and magnesium were detected. Also, Oyelude and Ahenkorah (2012) study concluded that bottled water sold in Bolgatanga, Ghana possesses good bacteriological characteristics and is of good quality.

In terms of physicochemical analysis, Danso-Boateng & Frimpong (2013) looked at the quality of bottled water brands produced and sold in Kumasi, Ghana. Their results suggest that all the bottled water analyzed temperature is higher than that of WHO and GSA; 40 % of the bottled water pH was below WHO and GSA standard, but all the physical and chemical parameters were within WHO and GSA standard. Kassenga & Mbuligwe (2009) comparative assessment of the physio-chemical quality of bottled and tap water in Tanzania revealed that bottled water has a slight advantage (color and turbidity) over tap water. They advise the Tanzania government to enact stringent measures to monitor the quality of water constituent displayed on bottled water. Al-Omran et al. (2013) paper focused on domestic bottled water in Riyadh City. Their result suggests that the majority of the bottled water content composition meets the standards of the regulatory bodies.

From the foregoing, all the papers reviewed concludes that bottled water is safe for consumption. This means the content composition displayed on bottled water is reliable and fall within WHO and GSA standards. The displayed mineral constituents exhibit multi-criterion decision-making (MCDM) features. Surprisingly, MCDM tools have been used extensively to analyze water properties. For example, Yekta et al. (2015) used hierarchical distance-based fuzzy approach to evaluate urban water supply systems, Karamouz et al. (2009) applied entropy theory to design on-line river water quality monitoring system, whilst Bozdağ (2015) combined AHP with GIS to assess irrigation water quality and others (Elevli & Ozturk, 2019; Golfam et al., 2019; Yousefi et al., 2018). The keynote here is none of these MCDM tools have been used to analyze the displayed mineral constituents on bottled water which account for consumers purchasing

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problems in Ghana and this paper aims to achieve that in the Ghanaian bottled water industry. Using two MCDM tools, entropy to calculate each mineral constituent weight and TOPSIS to rank the bottled water, the result suggests that MCDM tools can be used to select the best bottled water on the Ghanaian market. The rest of the manuscript is ordered as follows: Section 2 covers the evaluation criteria and methodology used to evaluate the data. Section 3 summarizes and discusses the outcome of the results, whilst section 4 concludes the paper.

METHODOLOGIES

Evaluation Criteria

The mineral content displayed on 14 commonly sold bottled water brands in the Ghanaian market was compiled for the analysis. The observed minerals are calcium (Ca), magnesium (Mg), nitrates (NO_3^-), sulfates (SO_4^{2-}), potassium (K), chloride (Cl), sodium (Na), iron, bicarbonates, and pH value. This six calcium, magnesium, nitrate, sulfate, potassium minerals, and pH values were common to all, and it was tabulated for the analysis. All the six displayed mineral constituents were compared to that of WHO (2011) refer to Appendix 1.

Multi-Criteria Decision Making (MCDM)

The decisions making an analytical method called multiple-criteria decision-making method (MCDM), which was developed in the 1970s, be used to evaluate the data on the various bottled water brands. The multiplicity of the mineral content values or criteria for judging the alternatives is inescapable, and the specific application of MDCM help solve the dilemma. An MCDM problem can be concisely expressed in matrix format as:

$$Y = \begin{pmatrix} * \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{pmatrix} \begin{pmatrix} C_1 & C_2 & C_3 & C_4 & \dots & C_n \\ X_{11} & X_{12} & X_{13} & X_{14} & \dots & X_{1n} \\ X_{21} & X_{22} & X_{23} & X_{24} & \dots & X_{2n} \\ X_{31} & X_{32} & X_{33} & X_{34} & \dots & X_{3n} \\ \vdots & \vdots & \vdots & \vdots & \dots & \vdots \\ X_{m1} & X_{m2} & X_{m3} & X_{m4} & \dots & X_{mn} \end{pmatrix} \quad (*)$$

$$W = \begin{bmatrix} W_1 & W_2 & W_3 & W_4 & \dots & W_n \end{bmatrix}$$

Where, $A_1, A_2, A_3, \dots . A_m$ are possible alternatives among which decision-makers have to choose, $C_1,\ C_2, C_3, C_4, \dots .\ C_n$ are criteria with which alternatives performance are measured, X_{ij} is the performance value of A_i concerning criterion C_j and W_j is the weight of criterion C_j. In the following sub-sections, two MCDM related methods, entropy method, and techniques for order preference by similarity to ideal solution (TOPSIS) used for the study are discussed.

Entropy Method for Weight Determination

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The concept of entropy is applied to determine the criteria weight. Entropy is a term in information theory, also known as the average amount of information (Shi-Fei & Zhong-Zhi, 2005). The criteria weights are calculated by the entropy method. According to the degree of index dispersion, the weight of all evaluating indicators is calculated by information entropy. The entropy method of weight calculation is highly reliable, free of decision-makers' biasness and can be easily adopted in information measurement (Zhi-hong et al., 2005, cited in Akyene, 2012). If a decision matrix *Y* shown above with *m* alternatives and *n* indicators, entropy steps of weight calculation are as follows:

a. In matrix Y, featuring weight P_{ij} is of the *ith* alternative to the *jth* factor:

$$P_{ij} = X_{ij} \Big/ \sum_{i=1}^{m} X_{ij} \qquad (1 \leq i \leq m\,, 1 \leq j \leq n) \qquad (1)$$

b. The output entropy e_j of the *jth* factor becomes

$$e_{ij} = -k \sum_{i=1}^{m} P_{ij} \ln P_{ij} \qquad \left(k = \frac{1}{\ln m} : 1 \leq j \leq n\right) \qquad (2)$$

c. The variation coefficient of the *j*th factor: g_j can be defined by the following equation:

$$d_j = 1 - e_{ij} \qquad (1 \leq j \leq n) \qquad (3)$$

d. Calculate the weight of entropy W_j:

$$W_j = d_j \Big/ \sum_{j=1}^{m} d_j \qquad (1 \leq j \leq n) \qquad (4)$$

The Technique for Order Preference by Similarity to Ideal Solution Method (TOPSIS)

There are several MCDM tools like analytical hierarchy process (AHP), simple additive weighing (SAW), technique for order preference by similarity to the ideal solution (TOPSIS), preference ranking organization method for enrichment of evaluations (PROMETHEE), Borda-Kendall Method (BK), among others used for decision-making (Wang & Luo, 2009; Vetschera & De Almeida, 2012; Franek & Kresta, 2014; Mardani et al., 2015; Widianta et al., 2018; Jozaghi et al., 2018;). Wang & Luo (2009) concluded that most of the decision tools suffers rank reversal phenomena. Jozaghi et al. (2018) in their studies selecting the dam site using MCDM emphasized that AHP and TOPSIS are among the most widely adopted techniques. Widianta et al. (2018) compared AHP, SAW, TOPSIS, and PROMETHEE MCDM techniques. In terms of ranking, they resolved that TOPSIS and PROMETHEE rank same followed by SAW and AHP, whilst for accuracy TOPSIS tops all the other with 95% followed by PROMETHEE (93.34%), SAW (81.67%) and AHP (50%). These proofs validate why TOPSIS was selected for this study.

TOPSIS was initially developed by Hwang & Yoon (1981) to rank alternative over multi criteria. Over the years, several researchers have used this method in evaluating several MCDM problems (Peiyue et al., 2011; Akyene, 2012; Qu et al., 2016; Onu et al., 2017). TOPSIS finds the best alternatives by minimizing the distance to the ideal solution and maximizing the distance to

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the negative-ideal solution (Jahanshahloo et al., 2006). All the alternative solutions can be ranked according to their closeness to the ideal solution. Below are the generalized six (6) steps of TOPSIS calculation process:

Step 1, calculate the normalized decision matrix Y. The normalized value β_{ij} is obtained from:

$$\beta_{ij} = X_{ij} \Big/ \sqrt{\sum_{i=1}^{m} \left(X_{ij}\right)^2} \qquad (1 \leq i \leq m\,; 1 \leq j \leq n) \qquad (5)$$

Step 2, calculate the weighted normalized decision matrix:

$$V_{ij} = \left(\beta_{ij} \times W_j\right) \qquad (1 \leq i \leq m;\ 1 \leq n) \qquad (6)$$

Where. W_j is the weight of the *jth* criterion and $\sum_{i=1}^{n} W_j = 1$.
Step 3, calculate the ideal solution V^+ and the negative ideal solution V^-:

$$V^+ = \{v_1^+,\ v_2^+,\ v_3^+,\ \cdots,\ v_n^+\} = \left\{\left(Max\, v_{ij} \middle| j \in J\right), \left(Min\, v_{ij} \middle| j \in J\right)\right\}$$

$$V^- = \{v_1^-,\ v_2^-,\ v_3^-,\ \cdots,\ v_n^-\} = \left\{\left(Min\, v_{ij} \middle| j \in J\right), \left(Max\, v_{ij} \middle| j \in J\right)\right\} \qquad (7)$$

Step 4, calculate the separation measures, using the m-dimensional Euclidean distance:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - V^+\right)^2} \qquad (1 \leq i \leq m; 1 \leq j \leq n)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - V^-\right)^2} \qquad (1 \leq i \leq m; 1 \leq j \leq n) \qquad (8)$$

Step 5, calculate the relative closeness to the ideal solution:

$$Y_i = \frac{S_i^-}{S_i^+ + S_i^-} \qquad (1 \leq i \leq m) \qquad (9)$$

Step 6, the larger TOPSIS value, the better the alternative.

RESULTS AND DISCUSSION

For evaluating the mineral content of the respective bottled water brands, the tabulated data, as shown in Appendix 1, becomes the decision matrix illustrated under equation *. The proposed MCDM methods are then applied for weight determination and subsequent ranking for meaningful and further interpretations. The weight determination for the respective mineral

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content values was achieved by using the entropy model. Equation 1 produced the data normalization, as shown in Appendix 2, while equations 2, 3, and 4 were applied to obtain the results shown in Appendix 3. As a check, the weight of entropy sums up to 1, indicating a perfect degree of index dispersion. The results of the TOPSIS algorithm's calculations are shown in Appendix 4. It is observed that it is feasible to use entropy analysis and TOPSIS to rank the respective bottled water brands according to the set of mineral constituent parameters displayed on the respective bottled water brand.

The ranking of the respective bottled water brands is shown in appendix 4. Bottled water brand (BWB) 1 emerged as the best bottled water on the market, followed by BWB 3, BWB 4, and BWB 2 positioned at second, third, and fourth, respectively. The bottom three were BWB 12, BWB 13, and BWB 11 positioned at twelfth, thirteenth, and fourteenth. The results suggest that displayed mineral constituent on bottled water can be used to select the best water on the Ghanaian Market. The main advantage of MCDM tools is that they are less time consuming and cost-efficient when using it for analysis as compared to that of laboratory analysis.

CONCLUSION

Bottled water has changed the face of the Ghanaian water market, with the majority of people purchasing it for different reasons, although it's not free from microorganism's contamination. Most often, bottled water packaging displays the mineral constituent of the water that can be only be verified in the laboratory. Nevertheless, this displayed mineral constituent exhibit an MCDM feature, and this study focused on using MCDM tools to evaluate bottled preference on the Ghanaian market. Relevant literature reviewed confirmed that the mineral constituents displayed on bottled water are consistent with WHO and GSA standards. Based on this confirmation, fourteen (14) bottled water were selected, and common mineral constituent showcased on the package of each bottled water tabulated. Entropy was used to calculate the weight of each mineral constituent and TOPSIS to rank the bottled water. The result suggests that MCDM can be used to rank bottled water on the Ghanaian market. This implies that the displayed mineral constituent data exhibited on the bottled water is of prime importance to customers when it comes to selecting bottled water brands. Besides, the results suggest that Ghanaians social life in the arena of health will be improved since they will be drinking the best water on the market. On the economic side, the increase in demand and supply of bottled water needs to be addressed. That is, on the demand side, bottled water demand may rise while on the supply side producers must increase their supply to match demand. If this phenomenon is not addressed producers of the best-bottled water will lose some of their staunch customers to the next best-ranked bottled water. This implies although MCDM tools can rank the best-bottled water on the Ghanaian market, so far as the bottled water content matches GSA/WHO standard each producer can sell to their capacity. The main limitation of this paper is the inability to confirm the ranked water with corresponding laboratory analysis.

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APPENDIX

Appendix 1

Bottle Water Brand	Calcium (mg/l)	Magnesium (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Potassium (mg/l)	pH
BWB 1	4.00	4.90	0.06	2.70	3.20	7.75
BWB 2	2.30	1.90	0.20	10.50	3.00	7.50
BWB 3	4.00	4.90	0.06	2.70	1.80	7.75
BWB 4	3.20	2.40	0.09	10.90	2.20	6.96
BWB 5	1.60	0.90	0.01	2.30	0.30	7.25
BWB 6	0.80	0.60	0.00	0.00	0.40	7.00
BWB 7	3.00	1.60	0.00	0.00	3.00	7.05
BWB 8	3.70	1.00	1.86	1.12	2.00	6.90
BWB 9	1.00	0.30	0.00	0.00	0.70	7.25
BWB 10	1.00	0.50	0.02	2.39	0.50	6.79
BWB 11	3.20	1.50	8.50	4.00	1.90	7.50
BWB 12	0.80	0.00	0.00	4.00	0.30	6.90
BWB 13	2.80	1.90	5.00	0.02	3.10	7.50
BWB 14	0.84	0.60	0.56	6.90	1.20	7.25

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World Health Organization						
	<100	<200	<50	<250	<10	6.5≤pH≤8.5

Appendix 2

Bottle Water Brands	Calcium (mg/l)	Magnesium (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Potassium (mg/l)	pH
BWB 1	-0.25892	-0.32942	-0.02057	-0.16293	-0.27093	-0.19659
BWB 2	-0.18836	-0.20600	-0.05384	-0.33358	-0.26220	-0.19267
BWB 3	-0.25892	-0.32942	-0.02057	-0.16293	-0.19628	-0.19659
BWB 4	-0.22929	-0.23583	-0.02862	-0.33771	-0.22119	-0.18393
BWB 5	-0.14904	-0.12682	-0.00452	-0.14655	-0.05549	-0.18868
BWB 6	-0.09172	-0.09512	0.00000	0.00000	-0.06911	-0.18459
BWB 7	-0.22096	-0.18543	0.00000	0.00000	-0.26220	-0.18542
BWB 8	-0.24845	-0.13633	-0.24720	-0.08832	-0.20916	-0.18294
BWB 9	-0.10773	-0.05660	0.00000	0.00000	-0.10435	-0.18868
BWB 10	-0.10773	-0.08323	-0.00820	-0.15035	-0.08166	-0.18110
BWB 11	-0.22929	-0.17805	-0.34019	-0.20830	-0.20283	-0.19267
BWB 12	-0.09172	0.00000	0.00000	-0.20830	-0.05549	-0.18294
BWB 13	-0.21222	-0.20600	-0.36229	-0.00327	-0.26663	-0.19267
BWB 14	-0.09504	-0.09512	-0.11551	-0.28016	-0.15147	-0.18868

Appendix 3

	Calcium (mg/l)	Magnesium (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Potassium (mg/l)	pH	
E_j	1.38935	1.26320	0.67058	1.16220	1.34448	1.47238	
d_j	-0.38935	-0.26320	0.32942	-0.16220	-0.34448	-0.47238	-1.30219
W_j	0.29900	0.20212	-0.25298	0.12456	0.26454	0.36276	1.00000

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Appendix 4				
Bottle Water Brands	**S^-**	**S^+**	**Y_i**	**Ranking**
BWB 1	0.28290	0.05578	0.83530	1st
BWB 2	0.24935	0.09040	0.73393	4th
BWB 3	0.26897	0.07455	0.78297	2nd
BWB 4	0.25227	0.07541	0.76988	3rd
BWB 5	0.21680	0.17003	0.56046	8th
BWB 6	0.21443	0.18982	0.53043	11th
BWB 7	0.24686	0.11424	0.68363	5th
BWB 8	0.20026	0.13294	0.60103	6th
BWB 9	0.21465	0.18550	0.53642	10th
BWB 10	0.21454	0.18059	0.54296	9th
BWB 11	0.10389	0.23989	0.30221	14th
BWB 12	0.21561	0.19174	0.52930	12th
BWB 13	0.15346	0.16744	0.47822	13th
BWB 14	0.20828	0.16244	0.56183	7th

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