Assessment of Physicochemical Quality of Honey in the Wa Municipality Ghana

Cornelius K.A Pienaah, Mahama Dangana

Abstract—Honey production in Ghana has in recent times winning a paradigm shift from ordinary subsistence production to commercialization. This is as a result of increasing global, national and local demand for honey and other by-products of apiculture. Honey production is a doable and sustainable trade that creates income, recreation, employment, nutritional supplements for people and reduce rural poverty in Ghana. It is an important source of ecotourism, foreign exchange earnings and can be practiced by young, old, male or female. Input and equipment can be acquired locally. Honey production and consumption has become popular in Ghana and much else in Africa. However, the quality of honey sold in local markets, and consumed by majority of households in Ghana is unknown. This poses a public health risk to the consuming public. This paper analyses the physicochemical quality of honey sold in Wa market, Ghana. Specifically, indicators such as; the moisture content, pH, total solids, total soluble solids, and refractive index were tested for in 10 honey samples from wild and apiary sources. The test results from the Ghana Standards Authority (GSA) indicated that 99% of the samples tested met the Codex Alimentarius and International Honey Commissions standards. This implies that honey products on sale in the Wa municipality markets are generally safe for public consumption as it poses a little health risk to the consumers. However, the 1% still constitute some health risk.

Key words— Honey, Moisture, pH, Quality, Refractive Index, Total Solids, Total Soluble Solids

1 INTRODUCTION

In 2018, global production of honey was 1.9 million tons with 24% of this figure coming from China [1]. Turkey was the second biggest honey producer in the world with annual production of 81,115 tons [2]. According to [3], Turkey contributes 5.7 % of world's total honey production [4]. In 2013, Food and Agriculture Organization (FAO) estimated that Africa accounted for roughly 9% of global honey production (155,789 t), representing a 10% increase over 2000 and 13% by 2016. Ethiopia (50,000 t), Tanzania (30,000 t), Angola (23,300 t) and Central African Republic (16,200 t) are amongst the world's top 20 producing countries [5]. Ethiopia the largest bee producers in Africa and the fourth producer of beeswax in the world [6]. In Ghana, there is an increasing trend in honey production with some marketable by-products of honey production including bee wax, propolis, royal jelly, honeybee venom, and pollen and crop pollination [7]. The European Union (EU) in 2011, qualified Ghana to join other African countries who have also received the accreditation to export honey to the EU market. The international market for honey is growing and Ghana is expected to help fill the supply gap in Africa [8], [9].

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A study by [10] of honey sub sector in Ashanti, Brong Ahafo, Upper West, Upper East and Northern Regions and concluded that, households are employed in bee keeping. With all the regions showing an increasing trend of honey production between 2007 and 2008 as well as increasing projected trend figures in honey production for 2009 and 2010. This study identified total production of honey (gallons) in the year 2008 as; Brong Ahafo (10,584 gallons), Northern (4,262 gallons), Upper East (1,533 gallons), Upper West (1,746 gallons) and Ashanti (7,423 gallons) regions. This according to the study indicates a possible huge domestic market for honey in Ghana that needs to be exploited.

Honey is a product formed through the foraging activities of bees which are the main pollinators in agricultural crop fields [11]; [12]. Bees suck nectar, transform and combine it with specific substances of their own, and leave it in the honey comb to ripen [13]; [14]. The higher the sugar value of a plant, the more it is visited by bees for foraging [15]; [16]. However, agrochemicals affect bee health and when sprayed on farms has the potentials of accumulating and mixing with nectar of flowers and plants that the worker bees collect to form honey [17]. Honey is composed primarily by a mixture of sugars (85–95%), water (16–18%), proteins, free amino acids, organics acids, phenolic compounds, vitamins and minerals [18]; [19] ;[20] and classified into two main types: apiary honey and forest honey [21]. Honey is an important commodity in the international market; serving as foreign exchange earner for many countries. It serves as a source of cash incomes for many households [22].

Even though domestic market for beeswax and other by-products in Ghana is underdeveloped, beeswax alone has over 120 industrial uses. Honey production is a reliable key in reducing poverty and malnutrition [23]. It is widely used for both nutritional and medicinal purposes [24]. Honey is spoken of by all religious books, and accepted by all generations, traditions and civilizations, both ancient and modern as very nutritious food [25], [26].

Since the EU in the year 2011 certified Ghana to join other African countries accredited to export honey to the EU market, this implies that the international market for honey is

expanding and Ghana is expected to meet the supply gap by increasing the volume of trade and quality of production. This opportunity (the opening of the EU market) comes with both prospects and challenges for the honey sector in the country. For instance, it creates an opportunity for generating more foreign exchange income through export and opportunity for employment due to increase demand for honey for export. But this also means that Ghanaian honey must meet international standards for it to be accepted in the EU market. Hence, the quality assessment of local honey is highly relevant. Quality honey is important not only for meeting international trade standards but also for reasons such as health and nutrition. The quality of honey is dependent on the source of collection, either from wild hunters or beekeepers and the method of extraction (traditional or modern methods) [27].

Despite this imperative, the quality of honey produce and sold in the Ghanaian markets is largely unknown. At the same time, there is a general lack of records and documentation on honey production, consumption and physicochemical quality in the country. Moreover, unlike in the developed countries, there is a permissible and accepted level of physicochemical quality of honey with label slips on honey containers before sale for consumption to the public. In the Ghanaian markets, such rigid standardization mechanisms are often missing. This poses great public health risk. In this respect, this paper assesses the physicochemical quality of honey produced and sold in the Wa municipality of Upper West Region of Ghana. Specifically, I tested for five variables: moisture content, pH level, total solids, total soluble solids, and refractive index in 10 honey samples from both wild and apiary sources. The samples were taken from the Wa markets from 10 different sellers at different times. The test results from the Ghana Standards Authority (GSA) indicated that 99% (9 samples) of the samples tested met the Codex Alimentarius and International Honey Commissions standards. However, the 1% (1 sample) was above the international quality standards.

2 MATERIALS AND METHODS

2.1 Study Area

Wa Municipality is one of the eleven District/Municipalities that make up the Upper West Region (UWR) of Ghana with its capital as Wa which also serves as the Regional capital of Upper West Region. The Wa Municipality shares administrative boundaries with Nadowli-Kaleo District to the north, Wa East District to the east and to the west and the south Wa West District. It lies within latitudes 1º40'N to 2º45'N and longitudes 9º32''W to 10º20'W. It has a land area of approximately 579.86 square kilometers, which is about 6.4% of the Region. The population of Wa Municipal, according to the 2010 Population and Housing Census, is 107,214 representing 15.3 percent of the region's total population. Wa Municipality lays in the Savannah high plains, which generally, is gently undulating with an average height between 160 m and 300m above sea level. Low lying areas are found in the following localities; Charia, Zingu, Kperisi to the north and Piisi, Dapouha, Boli, Sing, Biihe and Busa to the south. Valleys in the low lying areas collect and retain water over long period during the rainy season.

The vegetation is one of the guinea savannah grassland type, made up of short trees with little or no canopy and shrubs of varying heights and luxuriance, with grass ground cover in the wet season. Commonly occurring trees are Shea, Dawadawa, Kapok and Baobab. Cashew and Mango are exotic species that grow well in the area. Wa Municipality has two marked seasons, namely, the wet and dry seasons. The South Western Monsoon winds from the Atlantic Ocean bring rains between April and October, while the North-Eastern Trade winds from the Sahara Desert bring the long dry season between November and March. The mean annual rainfall varies between 840mm and 1400mm. Most of the rainfall occurs between June and September. One feature of the rainfall pattern is that it tends to occur in heavy downpours thus, that encourages run-off rather than soil moisture retention. It has been calculated that there are four humid months, in terms of soil moisture conditions and the period is only adequate for the cultivation of crops such as millet, guinea corn, yam, groundnuts and beans. The rainfall pattern is irregular and unreliable. Sometimes, it results as long period of no rain during the farming season which affects harvest [28].

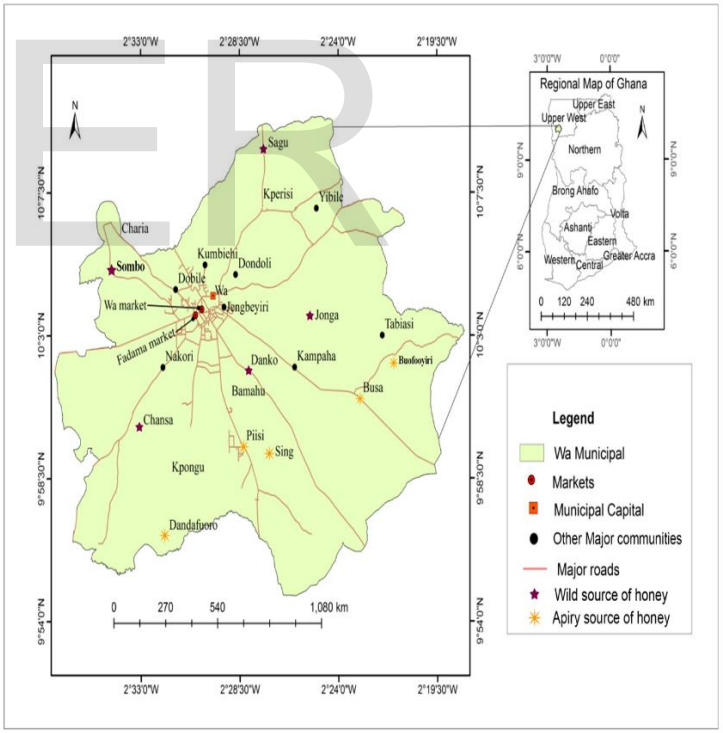

Fig 1: The Map of Wa Municipality

Source: GIS Revolution and I.T Consult

2.2 Samples and Sampling Procedure

Field investigation was carried out on honey vendors in the Wa market. A total of ten (10) vendors were identified at different locations of the market. The samples were purchased directly from different honey vendors in sterile bottles labeled as

sample (A, B, C, D, E, F, G, H, I, J). The samples were tested for the five physicochemical quality (pH, Moisture, Total Soluble Solids, Total Solids and Refractive Index). Each sample obtained was cross checked with the others based on the origin and season of harvest through a face to face interview with vendors and suppliers. The Wa market has two main areas namely the Fadama and Kejetia markets where all the ten different honey samples were bought. Five of the samples were from wild sources purchased at Fadama market in dry season of March while the remaining five samples were from apiary sources purchased at the Kejetia market in the rainy season of June. All the wild source honey were from Sagu, Sombo, Jonga, Danko and Chansa communities whilst the apiary source honey was from Busa, Piisi, Sing, Dandafuoro and Buosooyiri communities.

Basically the samples were transferred into sterilized and plastic bottles containers at room temperature (20°C) wrapped with aluminum foil before they were taken to the laboratory. All samples were kept at ambient temperature until the analysis. Before the samples were transferred into the sterilized plastic bottles, dead bees and other debris large and visible enough were removed by hand picking. All samples were analyzed in duplicates with the average recorded for analysis. See Table 1 below.

TABLE 1. HONEY SAMPLES OBTAINED AND TESTED FROM WA MARKET

SP	HV	M	Source	Month	Season	Honey type	QP (ml)
A	V1	FM	Sagu	March	Dry	Wild	500
B	V2	FM	Sombo	March	Dry	Wild	500
C	V3	FM	Jonga	March	Dry	Wild	500
D	V4	FM	Danko	March	Dry	Wild	500
E	V5	FM	Chansa	March	Dry	Wild	500
F	V6	KM	Busa	June	Rainy	Apiary	500
G	V6	KM	Piisi	June	Rainy	Apiary	500
H	V8	KM	Sing	June	Rainy	Apiary	500
I	V9	KM	Dandaf -uoro	June	Rainy	Apiary	500
J	V10	KM	Buosoo yiri	June	Rainy	Apiary	500 ml

Source: Field Data

Footnote: SP=Sample, HV= Honey Vendor, M=Market, FM=Fadama Market, KM=Kajetia Market, QP=Quantity purchased.

2.3 pH analysis of Honey samples from Wa market

The pH was determined by direct measurement, using a pH meter standardized. The apparatus/equipment used for this analysis includes: pH meter, Thermometer, Volumetric flask, 100mL capacity and Beakers. The analysis procedure involves the following steps:

- Step 1**:** Standardize pH meter by immersing the electrode in standard buffer of pH 7 was carried out. If the pH meter reads pH 7 no asymmetry potential adjustment is required. If the reading is not exactly pH 7 the necessary asymmetry potential adjustment is made to get the instrument to read pH 7; the temperature reading was noted for further analysis.
- Step 2: The electrode was removed from the buffer solution and rinsed with a jet of distilled water from the wash bottle.
- Step 3: The electrode was gently wiped with a soft clean dry tissue paper and immersed in a buffer of pH 4 solution. If the reading is not pH 4 adjust the slope % to get the instrument read pH 4.
- Step 4: Recheck the pH meter against the buffer solution of pH 7 and pH 4 any time an adjustment is made.
- Step: 5 finally, the electrode was rinsed, dry it and immerse it in degassed sample and read its pH, noting the temperature of the malt. Between successive measurements rinse the electrode with distilled water and recheck the pH meter against the standard buffer after series of sample pH measurements. All results were recorded to the nearest 0.05 pH. All measurements were done in duplicates with the average value as final measure of the pH of honey [29]

2.4 Moisture content analysis of Honey samples from Wa Market

A number of factors influence the final value of moisture parameter in honey produced by honeybee colonies, such as low air humidity, medium abundance of nectar flow, good colony strength and ventilation of the beehive. The determination of moisture was done using Digital refractometer. All measurements were performed at 20°C, after waiting for 6 minutes of equilibration. The corresponding % moisture (g/100 g honey) was obtained from the refractive index of the honey sample by consulting a standard table by [30] for the purpose. The moisture content of honey samples were estimated by determining the refractive index of the sample with the use of refractometer. The samples were directly smeared on the surface of the prism evenly; after two minutes the reading of refractive index was recorded. Each sample was measured twice and averages of two readings recorded and corresponding value for moisture content recorded.

2.5 Refractive Index of Honey Samples from Wa Market

The refractive index of honey is said to be a rapid, accurate and simple measure of its moisture content. The refractive index measurement was done with an abbe refractometer. The refractometer's sample compartment were made at room

temperature. The electrical conductivity measurements was done at 25 º C using PH/Conductivity meter model 20º C (Denyer instrument). The instrument was calibrated using 0.01m Kcl (potassium chloride solution). The refractive index of the honey has codex standard of 1.4000 – 1.9000 at Ghana Standard Authority (GSA).

2.6 Total Soluble Solids (TSS) analysis of Honey Samples from Wa Market

The refractive index of a test solution is measured at 20oC ± 0.5 °C using a refractometer by GS ISO 2173: 2003. The refractive index is correlated with the amount of soluble solids (expressed as sucrose concentration) using tables, or by direct reading on the refractometer of mass fraction of soluble solids. The Equipment and reagents used include; Refractometer and Distilled Water. The procedure for analysis involves reparation of test solution; a clear liquid product is thoroughly mixed in the laboratory sample and uses it directly for the determination. Semi-thick products (purees, etc.); thoroughly mix the laboratory sample. Press a part of the sample through gauze folded in four, rejecting the first drops of the liquid and reserving the remainder of the liquid for the determination.

Measurement: distilled water should give a reading of zero. If not and where possible, the refractometer must be adjusted to read zero. The prism plate is wiped dry with a soft tissue free from fluffs. Several drops of distilled water are placed on the prism surface. An equal number of drops from the fruit juice are placed on the refractometer prism plate. The reading on the prism scale is noted to one decimal place. After each test the prism plate must be cleaned with distilled water and wiped dry. Record results in analyst's notebook (GSA-QR-T08). The test report contain at least the following data: All information necessary for the identification of the sample includes; a reference to the method used, the results and the units in which the results have been expressed, date and type of sampling (if known), date of receipt of the laboratory sample, date of test, any particular points observed in the course of the test, any operations not specified in the method or regarded as optional which might have affected the results. The results obtained from the total soluble solids on the ten honey samples include; all samples were analyzed in duplicates and the percentage mean recorded at Ghana Standard Authority (GSA).

2.7 Total Solids (TS) analysis of Honey samples from Wa Market

The principle involves a known mass of sample is evaporated to complete dryness on a steam water bath and further dried at 105±1°C to a constant weight in a thermostatically controlled oven. The apparatus/equipment use include; an analytical balance, capable of weighing to an accuracy of 0.1mg, Desiccator, provided with drying agent and hydro-metric indicator, Oven thermostatically controlled at 100°C - 110°C, Aluminum can, Steam water bath and Beaker – 250ml capacity. The procedure for Analyses involves, Dry two clean Aluminum cans in an oven at a temperature of 105°C between 15 – 20mins in an oven cool them in a desiccators. Weigh 10g of sample into the cans and place them on the water bath which is heated to about 100°C. Remove cans after the sample is evaporated to dryness. Place them in the oven for 30 min. Remove from oven, cool in a desiccators and weigh. Analysis is done in duplicate per each sample and the mean value taken.

The percentage Total Solids is Calculated as;

$$\% \text{ Total Solids} = \frac{M1 \times 100}{M2}$$

Where; M1 = weight of solids (weight difference between can and sample after evaporation and weight of empty can) M2 = weight of sample taken for analysis.

The analysis was done on ten honey samples at Ghana Standard Authority (GSA)

3 RESULTS

3.1 pH of honey

The pH (moles per liter) is an indicator of honey quality confirming the stability of honey to fermentation. Pure honey normally contains relatively small amount of acid which is important for the honey taste. Thus, honey is mildly acidic and pH value lesser than 7. Fig 2 presents the test results of ten (10) honey samples pH from the Wa market.

The pH values for all samples ranged from 3.73 to 4.28 (moles per liter) of honey sold in Wa market. These results confirm the acidic nature of honey [30]. The honey that had the highest pH was that of honey sample A (4.28) and B (4.28) from the market. These samples are from wild source collected at Sagu and Sombo communities in the dry season respectively. The IHC [31] set pH of 3.2 to 4.5 (moles per liter) as the required standard for honey considered safe for consumption. This shows that all the honey samples tested are within the required levels and safe for consumption. The test results equally conformed to the International Honey Commission (IHC) set standard for pH. Besides that, Sample "I" recorded an average pH of 3.73 as the lowest. The acidity of the honey samples in the study is due to a large number of organic acids. The main acid is gluconic acid which is in equilibrium with its lactones or its esters and inorganic ions such as phosphates and chlorides. There are also formic, tartaric, maleic, citric, succinic, butyric, lactic, and oxalic acids as well as various aromatic acids [32].

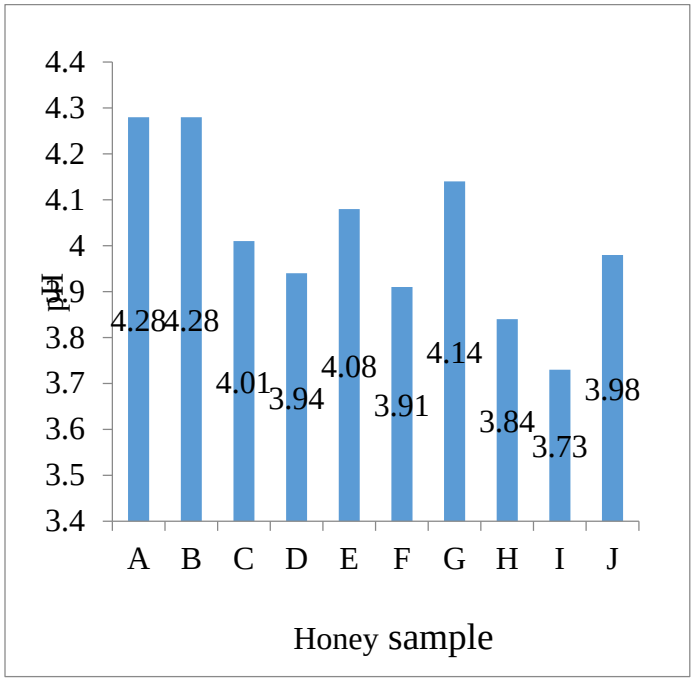

Fig 2: pH of honey from Wa market

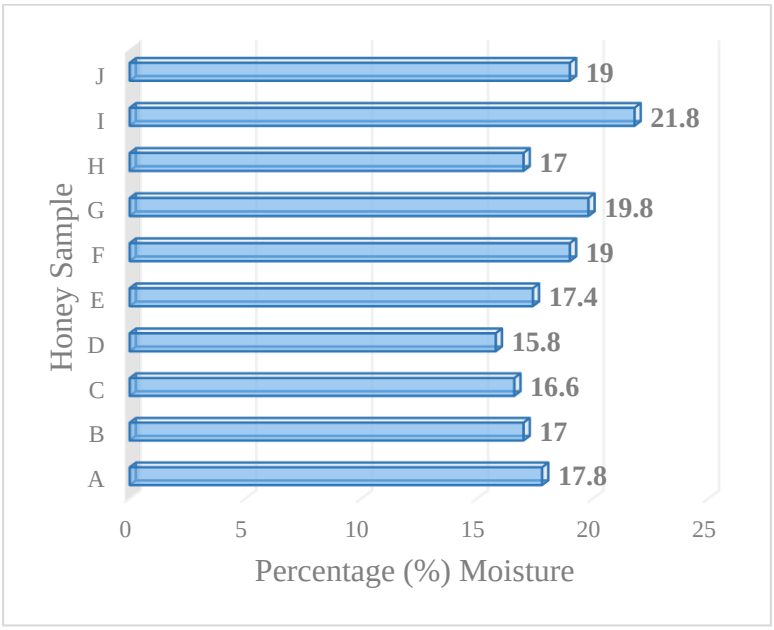

Fig 3: Moisture of honey on Wa market

3.2 Moisture content of honey

The test results of the moisture content from the ten (10) different honey samples ranged from 15.8 to 21.8% illustrated in (Fig 3). According to [33] and Codex Alimentarius Commission, 2001 set an upper limit of moisture at 21% and 20% respectively. The results indicate that, nine (9) samples, representing (99%) were all within the acceptable moisture content in honey established by Codex Alimentarius Commission and EU Council. This indicates that, the low water levels obtained reflect a mature harvest of the different honey samples [35]. The low moisture content observed may have been due to the increase in sugar content, storage, good packaging and hygienic practices of the nine (9) samples during processing. From the analysis, only one sample (1%) exceeded these set limits. Thus (Sample "I") recorded 21.8% as the highest moisture content in honey. The increase in the moisture content of honey is an indicator of adulteration.

Adulteration of honey can result in reduction of nutrition and medicinal value [36] and may ferment during storage. This sample was harvested in the rainy season with could result in cross contamination from water during harvest. The sample could have not been matured before harvest. This could led to the increase in moisture content.

3.3 Total Soluble Solids (TSS) of honey

The test results obtained from the ten (10) honey samples shows that TSS ranged from minimum value of 77.6% to maximum of 83.9% for with the mean TSS as 79 ± 2 % in fig 4. The results agree with those reported by [37] as Total Soluble Solids value ranged between 70%-85% sugars. Generally, the nine (9) samples revealed high total soluble solids (sugar content). For all the nine (9) honey samples, total soluble solids were generally more than or equal to 80% and can be considered of high grade and highly stable upon storage. The high sugar content of the honey analyzed suggests that the honey samples were ripped and matured in the honey combs before harvested.

On the other hand, honey Sample ''I'' recorded 77.6% which is less than 80% set standard by International Honey Commission. The honey is likely to ferment during storage and may not have been matured before harvest. This could have resulted in the high moisture content of this sample of honey. This could have resulted in the high moisture content of this sample of honey.

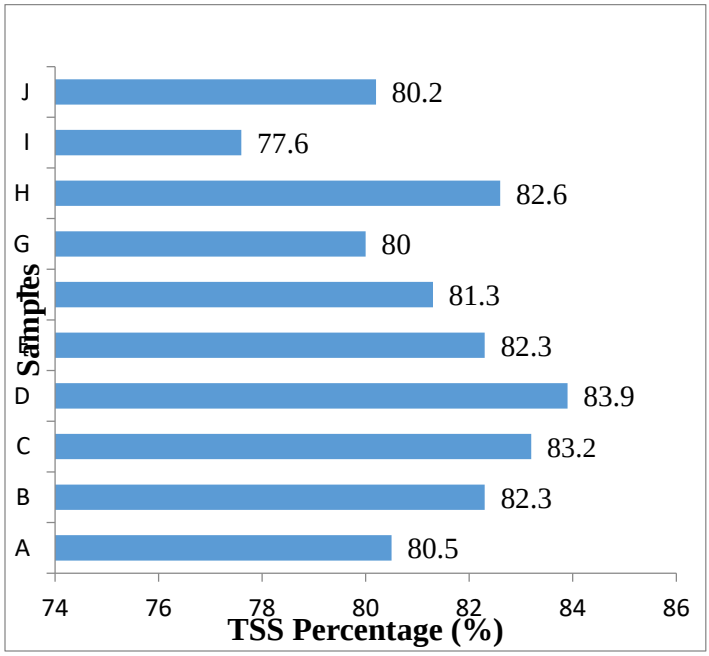

Fig 4. Total Soluble Solids of honey in Wa market

3.4 Total Solids (TS) of honey

The test results obtained from the ten (10) honey samples illustrated indicate a maximum and minimum TS values of 78.3 g/100 g and 86.99 g/100 g respectively (See figure 5). The average total solids value of the honey samples analyzed in the study was 81 ± 2 g/100 g. Ninety nine (99%) of the honey samples (A, B, C, D, E, F, G, H and J) had total solids values that agreed with those (78.4 – 82.8 %) reported by [38]. while sample "I" (78.30 g/100 g) did not conform. The higher the total solid content, the lower the moisture content and vice versa.

Generally, all the nine (9) honey samples analyzed had high total solids depicting low moisture content, and high shelf life stability accept sample ''I'' that has an increase in moisture content and slightly low Total Soluble Solids. The high total solid content might also be an indication of high mineral content and other soluble solids (sugars).

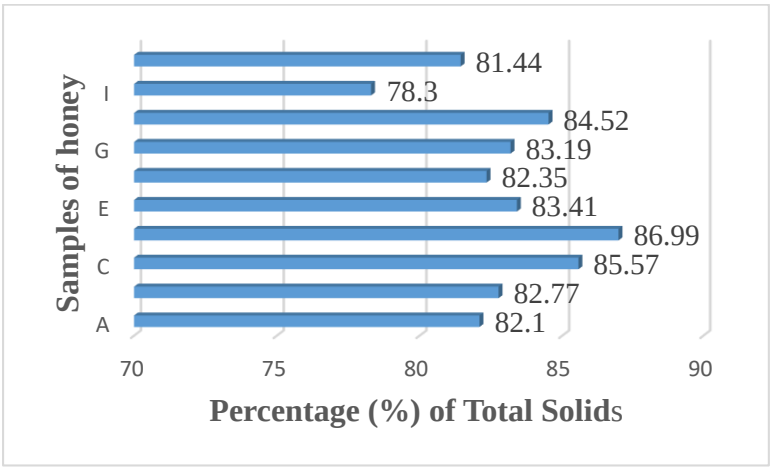

Fig 5. Total Solids of honey in Wa market.

3.5 Refractive Index of honey

The refractive index of the samples ranged from 1.489 to 1.499 with an average of 1.489 ± 0.005. The measured values (A,B,C,D,E,F,G,H,I,J) 1.494, 1.496, 1.497, 1.499, 1.495, 1.491, 1.489, 1.496, 1.484 and 1.491 respectively agree with those reported by [37] and fell within those standardized for American honey with slight difference with Sample ''I''. The refractive index of honey is said to be a rapid, accurate and simple measure of its moisture content [39]. The less variation in the refractive index values of the honey analyzed confirms less variation in their moisture content. This helped prevent microbial contamination and activities stated. The honey samples in this study therefore might have a stable shelf life without crystallization and fermentation accept Sample ''I''.

4 DISCUSSION

The overall pH value of the test ranged between (3.73 to 4.28) which is lower than commonly known standard pH value of 3.42–6.10 for honey from A. mellifera [40], (3.52 – 5.13) reported by [41] and (3.87 – 5.12) by [42]. Notwithstanding, the pH values obtained from the study are comparatively in line with past study reports of honey pH value (3.2 and 4.5) by [12], (3.75 and 4.21) in Nigerian [43], (3.5 to 4.7) reported in Algeria [44], India, Brazil, Spain, and Turkey [45] and (3.7 to 4.2) [46]. The Low pH of the honey samples from the test inhibit the presence and growth of micro-organisms and makes honey compatible with many food products in terms of pH and acidity. This parameter is of great importance during the extraction and storage of honey as it influences the texture, stability and shelf life of honey [47]. Also, [47], reported that pH of honey has not been legislated but the possibility of recording very high pH is as a result of adulteration.

Moisture and refractive index is among the most essential

feature of honey quality. The refractive index is a measure that proportionally decreases with increasing water content, and therefore is used to determine the moisture content in honey. The moisture of honey depends on the environmental conditions and the manipulation from beekeepers at the harvest period, and it can vary from year to year [48]. Moisture content of honey may vary from 15 to 20% [49]. If the moisture content exceeds twenty-two per cent (22 %), honey is likely to ferment [50]. The higher the water content of the honey, the higher the possibility of fermentation. Water content of honey is closely related to its fermentation. The volume of water present in honey determines its stability against fermentation and granulation [51]. According to [50], moisture content of honey is a very important physical quality characteristic, as it affects other properties like density, specific gravity, refractive index, viscosity and optical properties, and also plays an important role in the preservation of honey. From the test results of all ten (10) honey samples in the study only 1% (sample ''I'') recorded 21.8% as the highest moisture content in honey. This means that consumers of Sample ''I'' which is suspected to be adulterated are at risk of increase consumer's blood sugar, which can cause diabetes, abdominal weight gain, and obesity, raise the level of blood lipids and can cause high blood pressure [52]. Moisture content (≤20%, w/w) is a significant standard for honey, because high moisture content increases the value of water activity and promotes yeast growth leading to fermentation during storage. Absolutely, the osmotolerant yeasts such as Saccharomyces spp. can grow in a low water activity value at 0.61 using a large amount of glucose and fructose in honey to produce alcohol and carbon dioxide [53].

According to the grading system of [54], honey with total soluble solids greater or equal to 81.4% is considered of higher grade (A and B), while that falling between 80% and 81.3% is considered to be of lower grade C. In light of this, the TSS (sugar content) of the honey sample tested ranged from 77.6% to 83.9%. This made 99% of all the honey tested in the study conformed to [54] grade A and B categories. The values of total solids obtained were also in line with the report of [38] as 78.4–82.8%. The TSS of the results were slightly different from those reported by [55] as 72.2–76.5%. Sugars i.e. glucose and fructose mainly comprise the total solids present in honey accounting for about 85% [55]. The TSS is closely connected to the amount of sugars existing in honey, making it an essential marker of conceivable adulteration. The soluble solids content of honey is a reliable index of adulteration [56] and a major factor for the categorization of the glycemic index, a major concern for diabetic persons. Thus, the honey examined in this study can be considered stable with regard to fermentation upon storage and thus of high grade except honey sample ''I''

5 CONCLUSION

This paper assessed the physicochemical quality of honey in the Wa municipality of Upper West region, Ghana. I assessed five main parameters including; pH, Moisture content, Total Solids, Total Soluble Solids and Refractive Index in ten (10) samples randomly taken from local vendors in two markets. The test results, as provided by the Ghana Standards Authority (GSA) indicated that 99% of the samples tested agreed with [57] and IHC standards. This indicates that the quality of honey in the Wa municipality (and to a larger extent Ghana) fall within international quality standards for honey pH, Moisture, TSS, TS and Refractive Index. This also means that honey in the Wa municipality is generally safe for human consumption based on the parameters analyzed. These findings also means that Ghana's local honey production can take advantage of the opening of EU market for increased export, income and employment. However, since the physiochemical quality of honey can change over time (due to floral origin of nectar, farmers' practices, processing techniques, packaging and storage practices), I recommend regular assessments of the quality of honey from time to time.

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6 ACKWOWLEDGMENT

We acknowledge Jambadu Lazarus, a PhD candidate at TU Darmstadt (Germany) and Utrecht University (the Netherlands) for his contribution to this paper. We also acknowledge the staff of Ghana Standard Authority for conducting the test on honey samples.

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