

## Determination of physical-chemical parameters in bee products: a preliminary investigation from Africa's most renewed bee village in Tanzania

### ABSTRACT

**Aim;** *the main objective of this study was to evaluate the determination of physical-chemical parameters in bee products: a preliminary investigation from Africa's most renewed bee village in Tanzania; specifically, the study presents preliminary findings of an inquiry that examined pesticide contamination in bee products from Kijiji cha Nyuki located in Tanzania. The study measured the levels of physical-chemical parameters in honey products harvested from the selected bee apiaries.*

**Material and methods;** *A mixed methods approach was adopted for this study and collected data both primary and secondary data were collected using physical observation and survey, interviews, and questionnaires, purposive and random sampling techniques were used in this study to select a total of 104 participants who was taken as a sample from universal populations. Qualitative and quantitative data were analyzed using IBM Statistical Package for Social Sciences (SPSS) Computer Programme version 25, where the statistics aspect was determined from the results obtained from both questionnaires and laboratory experiments. A preliminary investigation from Africa's most renewed bee village in Tanzania; Collected samples were analyzed at TBS & SGS laboratories.*

**Results;** *The results show all studied areas met honey quality assurance guidelines stipulated by the ministry of natural resources and tourism suggesting moisture content in honey should not exceed 21%. pH test showed honey sample from Egypt apiaries had higher pH of 4.3 and honey from Kijiji cha Nyuki had a low pH of 3.54 implying honey from the studied areas falls within the pH applicable range. Test of Hydroxymethyl furfural mg/kg discovered an average of 13.65 mg/kg in honey samples from 4 studied areas out of the 5, with 107.13 mg/kg of HMF in honey samples from Egypt. Suggesting that honey samples from the 4 study areas with exception of samples from Egypt met the TZS 851:2006 standards and national's guidelines of 40mg/kg Hydroxymethyl furfural. Finally, the Test of total reducing sugar as inverted sugar % m/m, from five samples as per Tanzania Bureau of Statistics (TBS) laboratory results found a maximum of 68.91 % m/m and 64.4 % m/m minimum. The amount of physical-mechanical contaminations that were identified in honey from 4 areas with the exemption of samples from Egypt apiaries poses no risk to consumers.*

**Contribution to policy implication;** *This study recommends interventions among farmers and beekeepers on the safe use of pesticides, good hygienic handling, and the storage practices. It has contributed to the understanding of how the regulations outlining the use of insecticides is being implemented, and the current economic condition of studied farms. This calls on policymakers to rethink ways of engaging the beekeepers, and to have an ongoing discussion with beekeepers and concerned stakeholders about a model that could be used to enhance pesticides regulation in Tanzania.*

**Key Words:** *Pesticides, honey, physical-chemical, TBS & Kijiji Cha Nyuki*

### 1. INTRODUCTIONS

Globally the consumption of bee products is on the rise, as consumers perceive honey as one of the health products that contain several benefits, this is despite several publications that have reported the presence of pesticides in honey and other bee products [22; 12; 2]. Several researchers continue to argue that honey products such as beeswax, honey, and bee pollen are not immune to pesticides

contamination due increased use of pesticides by emerging and existing farmers [5], which may cause the introduction of those toxic chemicals into the food thus put consumers health at risk since hives may be contaminated by direct or indirect exposure [31]. For example, [5] show that pesticide residues may originate from the treatment of bee hives with acaricides in the control of Varroa destructor. Similarly, the bees can get in touch with those pesticides during the foraging activities in an

average radius of 3-6 km around the farms[10;25;28]. Notwithstanding the negative aspect associated with chemicals, [14] argued that honey is a valuable food not only for its nutritious value, but also for its physical, chemical, and biological capabilities.

[22] show that beekeeping activity in Tanzania can yield up to 138,000 metric tons of honey every year. The primary beekeeping and honey production areas are the Western areas which include Singida, Tabora, and Dodoma. The growing honey production is a result of the excellent climate. To date, the consumption of honey is rising due to its advantageous biological and physical-chemical attributes, involving antioxidant and antibacterial activities. According to [22] more than half of the honey yielded in the nation is consumed locally for diet and medicine. [2] noted that more than 70% of Tanzanian's population living in rural areas depend on agriculture for their livelihood. This calls for studies that can assist in revealing challenges associated with continued ecosystem functions when landscape changes, particularly as these changes relate to water-soil resources within a developing agricultural sector

[2] the study recommended further empirical studies that can examine the level of physical-chemical in honey products and their effect on consumers. The amount of chemical contamination in honey should be assessed to minimize the chances of honey products being contaminated[25;28]. Consumers have the right to safeguard their health, right information on the types and kinds of pesticides that have been used by farmers surrounding bees should be made available[2]. Bee products are produced in an environment that is contaminated by various pollutants. Therefore, monitoring bee products and their effects on human beings and the environment is vital. For instance, [10] show three main purposes of monitoring bee products exist: international competition, consumer health protection, and better-quality products.

According to [24] the maximum purity of honey is determined by its biochemical formation and by the careful draining of pollen grains from nectar by an intermediate valve in a honey sac. Furthermore, [24] investigation found several heavy metals accumulated in the body of bees due to the intensive consumption of pollen and bee bread. Honey product is perceived as ecologically clean when they correspond to established organoleptic,

hygienic, technological, and toxicological standards [21]. To determine the degree of pollution by toxicants, researchers rely on analyzing the content in the soil, water, and air which involved extensive labor, time, and financially demanding [17]. As result, there is a dearth of empirical information on the level of contamination of specific agricultural land in most poor countries [12], yet environmental pollution with heavy metals has mutagenic and carcinogenic effects causing poisoning and disruption of various physiological functions of the body [8; 17; 14]. For example, the increase in pollution resulting from the industrialization of nations has also increased waste yet most nations hardly have competent waste management systems[24]. Hence, many plants have been exposed to the high content of pollutants in the soil, and in the process exposing consumers to contaminated food and honey products, in the end causing chronic diseases [7]. In addition, environmental pollution resulting from road transport has further caused a notable threat to the purity of products of bee colonies [1;32]. According to [18] honey collected near large industrial enterprises and highways contains much more lead than that collected far. For instance, a sample size of honey collected from a long distance from the highway showed a very low content of iron, zinc, magnesium, copper, nickel, lead, cadmium, and cobalt[1]. In the same way [23] postulated that low concentrations of substances in the soil are dangerous for humans when moving along food chains, from plants to bees and then through honey products to consumers. Plants accumulate heavy metals through the air, and sometimes contamination is very low or sometimes higher. For example, vegetable absorbs much lead from the air, up to 95% [24;15].

Notwithstanding the notable negative effect, the quality of bee products can be attained through the adoption of technological requirements during their production, storage, and transportation [27;15]. Researchers have agreed that the application of pesticides without complying with regulation have been instrumental in causing negative effects on individual and colony level [29;30].

[30] states that the risks posed by chlorpyrifos on human health, especially on child neural development, caused the United States Environmental Protection Agency (US EPA) to ban its use as a household pesticide. [30] results showed that pesticide risk assessment procedures should investigate field-realistic

exposure to pesticide combinations. Despite other sources of pollution, it is becoming increasingly clear that the widespread use of pesticides on crops is a major factor [11;13]. As such, tight regulation is required to preserve honey bee health and rigorous analytical methods to confirm product quality [15]. Honey is composed of over 300 compounds, mostly carbohydrates (>75 %) and water (~18 %), with minor components comprising proteins, amino acids, vitamins, antioxidants, minerals, essential oils, sterols, pigments, phospholipids, and organic acids [4; 31]. The chemical composition and quality of honey depend on the type of melliferous plants the nectar was collected from, the beekeeping practices, and storage conditions. Hence examining the presence of pesticides in honey is critical regarding the reproduction of safe and quality honey products [16].

Therefore, the purpose of this study was to present preliminary findings of an inquiry that examined pesticide contamination in bee products from Kijiji cha Nyuki located in Tanzania. Specifically, to measure the levels of physical-chemical parameters in honey products harvested from the selected bee apiaries.

## **2. LITERATURE REVIEW**

### **2.1 Empirical Literature Review**

Nabatiel et al. (2021) study measured moisture using the refractometry method. The refractive indices of honey samples were measured at ambient temperature using a refractometer and all measurements were done at 20°C by adding a correction factor to obtain the corresponding percentage of moisture from the refractive index by referring to a standard table of AOAC. [3] postulates that the physicochemical properties of honey should not exist average moisture content of honey samples is 20% and 21% mellifera, honey. Even though the mineral content of honey is a positive nutritional feature, [12] is of the view that it may contribute to environmental pollution, hence regular monitoring of toxic heavy metals is vital to ensure nutritional quality and safeguard consumers against contaminants [22]. On a slight note, [14] show that honey possesses different colors varying between dark amber, light amber, and white. The color difference is due to the difference in the percentages of dissolved substances in the origin of the plant, such as the pigment compounds that are transported through nectar and are rich in chlorophyll and carotene. Internationally the pH values of honey samples' specifications ranged between

3.44 to 4.83 [20]. To conclude a study by [14] revealed diverse activity in terms of mineral contents, pH, density, sugar contents, and antioxidant and antibacterial activity. This could be related to the difference in properties of the nectar source, the climate, the environmental conditions, and geographical distribution. [33] measured HMF concentration is widely recognized as a parameter influencing honey freshness because it is typically absent (or present in only trace amounts in fresh honey), whereas its concentration tends to rise during processing and/or aging. In honey, HMF results from the acid-catalyzed dehydration process of hexose sugar (fructose). HMF indicates honey freshness, overheating, and poor storage. Fluctuations in the HMF content of honey samples can be due to several factors including; pH, plant sources, storage conditions, and climate change in the area where the honey was extracted. The maximum limit for HMF in honey is set at 40 mg/kg (with a higher limit of 80 mg/kg for tropical honey) to ensure that the product has not been overheated during processing and is safe for consumption [29]. The HMF level indicates that honey must be handled under appropriate temperature and storage conditions, thus, the higher the HMF, the lower the quality of honey [19]. [39] assessed the presence of copper in honey and other bee products, copper is one of the essential elements for maintaining metabolic activity; however, it causes toxic effects at high concentrations. Honey and other bee products contain copper at different concentrations that vary by region and region due to differences in environmental conditions, seasons, and years [39] Honey products can be contaminated by copper, for example, copper has been detected in honey products in Turkey up to 198.361 µg/g wet weight.

### **2.2 Theoretical Literature Review Theory of Planned Behaviour (TPB)**

The theory of planned behavior was introduced in the 1980s to predict individual decision-making toward the presence of certain scenarios [37]. The theory argued that human action and behavior depend on individual intentions and control ability that is influenced by sociocultural factors and the external environment.

In this study, the theory of planned behavior has been utilized to explain the relationship between the individual use of pesticides in agricultural activities and with intention to increase food production without considering the impact on the environment, it has been

noted that 20% of sickness in Australian has been contributed by the food handling behavior [35]. The behavior beliefs of farmers on the uses of pesticides to boost the fertility of land have caused environmental contamination which results in bees contamination since most of the resources required by honey bees are found on plants and crops, first through direct contamination that occurs due to handling and substances that used by beekeepers; and second is indirect contamination that occurs due to transportation of unwanted and toxic substances during the collection of pollen, nectar, water, and propolis and transferred to beehives; first through direct contamination that occurs due to handling and substances that used by beekeepers; and second is indirect contamination that occurs due to transportation of unwanted and toxic substances during the collection of pollen, nectar, water, and propolis and transferred to beehives [36]. Therefore, the attitude and perceived behavior of individuals have a direct contribution to the intention of using pesticides that results in the contamination of bee products. The theory of planned behavior has been criticized based on the argument that the theory ignored the lack of resources and opportunities for the household to decide using pesticides can be influenced by more factors such as environmental factors and economic factors than the decision-making of individual, also the theory fails to describe the timeframe of human intention and control action ability of an individual. But with that limitation, the planned behavior theory (PBT) is more accurately been utilized in determining physical-chemical parameters in bee products from honey-producing areas.

### **2.3 Honey activities landscape in Tanzania**

Tanzania is among the Sub-Saharan countries with the largest forest ecosystem which is covered with Miombo woodlands in more than two-thirds of the total forested land [22;2]. According to the Tanzania National Forestry Resources Monitoring and Assessment (NAFORMA) report [40] the woodlands cover about 44,726,246 hectares out of 48.1 million hectares. The beekeeping sector in Tanzania generates about US\$ 19 million per annum, employing about 2 million people, helps in biodiversity, and increases agricultural production through pollination [6]. At the household level, the sector contributes up to about 33% of the household income source in the Miombo woodlands of Tanzania. Naturally, besides

honey, there are beeswax, propolis, royal jelly, and honeycomb as the by-products of beekeeping [6].

[22] show that beekeeping activity in Tanzania can yield up to 138,000 metric tons of honey every year. Honey products are predominantly cultivated in Singida and Tabora. [22] further indicated that more than half of the honey harvested nationwide is consumed locally for diet and medicine. Additionally, the consumption is motivated by its biological and physical-chemical attributes consisting of antioxidant and antibacterial. According to [2] about 70% of Tanzanian's population living in rural areas depend on agriculture for their livelihood. This view is further cemented by [28] stating that the main source of livelihood remains agriculture, including growing cereals, sorghum, beans, and cowpeas. In terms of quality, [22] postulates that honey harvested from Singida and Tabora had more capability of impeding microbial growth than that from the central area. Accordingly, [22] concludes that honey from the central and western regions had a relatively higher capability to inhibit microbial growth. For example, honey from Inyonga, Manyoni, Dodoma town, Issuna, Singida town, Shinyanga town, and Nzega showed relatively higher total phenol, antioxidant, and vitamin C substance [22]. In regards to acidic pH, [15] study found honey was acidic with a pH ranging from 4.05 to 4.8, which falls within the regulation pronounced by the United Republic of Tanzania - Ministry of Natural Resources and Tourism [38] reported a pH range of 3.42 to 6.10 for Tanzanian honey. According to [15] low pH and high sugar content of honey create an acidic environment and osmolarity that results in antimicrobial properties of Tanzanian honey. According to [5] the content of honey can vary from 15 – 23%, and water content can affect the quality and some characteristics of honey such as viscosity, specific gravity, maturity, taste and crystallization, and specific gravity. Therefore, the quality of honey and its composition depends on the vegetation types available in an area [15].

### **2.4 Types of pesticides and its usage in Africa**

[13] indicates that Kenya farmers rely heavily on mechanization and the use of pesticides to meet the market demands. [13] the study showed pollen contained 90% of the pesticides, and 50% was detected in honey. A similar trend has been noted in previous studies with some researchers concluding that

pollen is the most contaminated hive product [1;14]. In general, insecticides are the most prevalent, presenting (>50%), followed by fungicides (27%) and herbicides (20%), the study further identified organophosphates (31%) and carbamates (33%) appeared to be the most commonly used throughout Kenya [13]. Furthermore, [19] indicated that 60% of the dairy farm owners from Northern Ethiopia sell products to the public from animals treated with a variety of pesticides without considering their effect on human health. Likewise, [26] revealed that increased pesticide use, handling, and management of pesticides are associated with environmental and health risks in Ethiopia. In terms of their categories, [23] show pesticides can be classified into 7 classes: carbamates, organophosphates, herbicides, acaricides, neonicotinoids, pyrethroids, and fungicides.

### 3. RESEARCH METHODOLOGY

The study followed a scientific and systematic assessment of the scenario that use a quantitative research paradigm known as positivist; where descriptive research design was used to measure the pesticide contamination in bee products in the laboratory scientifically;

The areas of the study were selected based on the growing bees farming activities as major Agroecological zones in Tanzania in terms of honey production. Kijiji cha Nyuki is one of the major leading bee farming in Africa and a leader in the use of advanced technology and bee farming practices. The selected apiaries spread apart (<10m from each other).

Samples were collected from the apiaries between August and September 2021 and represented locally produced honey from the Kijiji cha Nyuki. Samples were stored in scientifically approved cooler boxes and transported to TBS and SGS laboratory for real-time examination, and it was stored at 20°C. In this study area, the sample size included a sample of Bee products that comprised four (4) honey sample, Bee pollen One Kg, propolis 500gm, and Bee wax One Kg. The sample collection process was guided by experts and experienced agronomists from the selected area. After collection, the pollen pellets were homogenized using a glass jar, and 100 g were subsampled and frozen at -20 °C. As shown by [10] researchers have opted to make use of small samples and reduce solvent volumes in analytical procedure due to the environmental and economic concerns. Hence this investigation opted for the QuEChERS. The QuEChERS method is being used by several researchers as it assists in reducing several steps in analytical procedure thereby minimizing potential sources of error. Physical observation and survey were used to identify the vulnerable areas of bee keeping, farming activities nearby selected area to provide clear picture of the area and possibility of bee keeping infrastructure to be impacted by agricultural pesticide. Building on noted concerns, this study main objective was to examine the level of chemical contamination in honey samples collected from various apiaries located in Kijiji cha Nyuki Figure 1. Samples were cleaned and extracted based on the methods given by TBS.

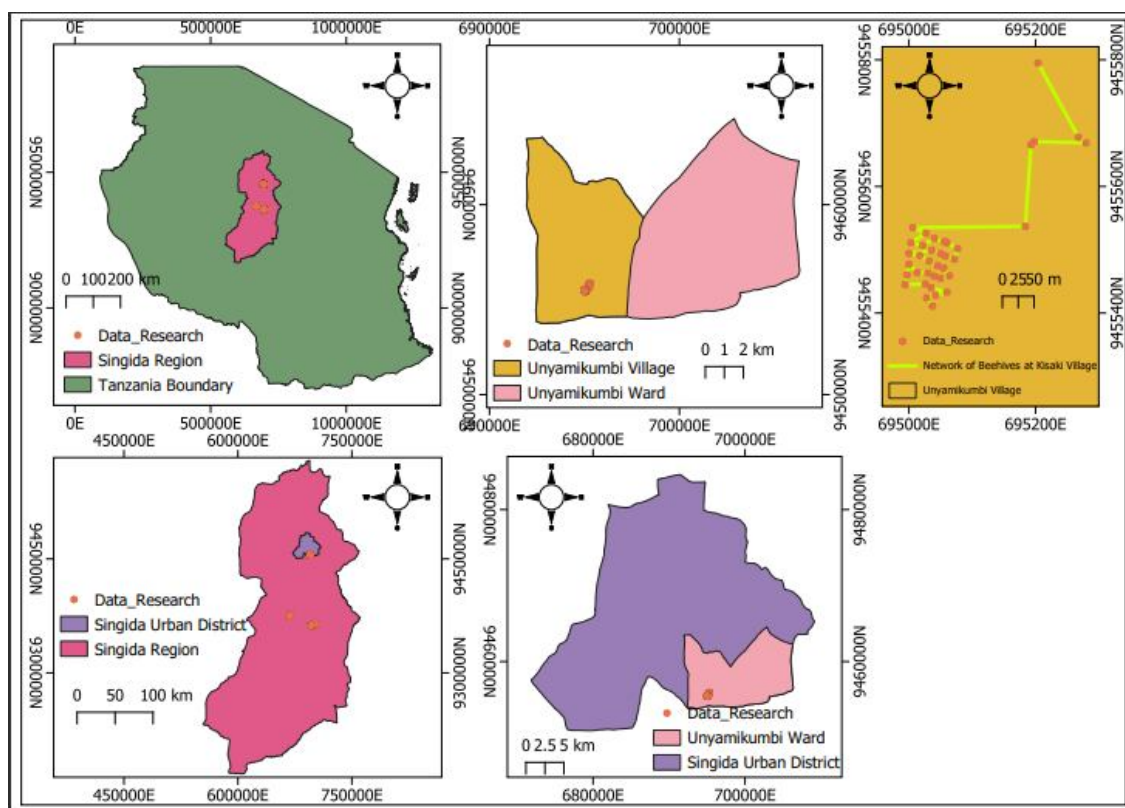


Figure 1; Map presenting honey activities landscape in Tanzania

### 3.1 Sample preparation and Analysis of Honey Products

The analysis comprised the different physical and chemical parameters as well as the metal

and pesticide pollutants, Table 1 indicates a summary of Physio-chemical parameters analyzed in honey products and their respective test methods

Table 1; Physio-chemical parameters and test methods

S/N	Parameters	Units	Test Methods
1.	Metals: Copper, Zinc, Arsenic, and Lead	mg/kg	MP-AES
2.	pH	Unitless	TZS 851: 2006 (pH meter)
3.	Moisture Content	% m/m	FCL/SOP – TM/10-02
4.	Total Reducing sugar	% m/m	TZS 851: 2006
5.	Hydroxymethyl furfural (HMF)	mg/kg	FCL/SOP – TM/14-01
6	Pesticides: Cyhalothrin (lambda)	mg/kg	AOAC 2007.01. (GC-MS/MS)
7	Chlorpyrifos	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
8	Esfenvalerate	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
9	Deltamethrin	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
10	Cypermethrin	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
11	Trifluralin	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
12	Pendimethalin	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
13	Cyfluthrin	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
15	Imidacloprid	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
16	Cymoxanil	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
17	Boscalid	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
18	Pyraclostrobin	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)

19	Picoxstrobin	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
20	Etofenprox	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)
21	Clothianid	mg/kg	AOAC 2007.01. (LC-MSMS/GC-MSMS)

#### 4. DISCUSSION AND RESULTS

##### 4.1 Moisture Content in Honey

This study was conducted to investigate the presence of pesticide residues in honey produced in the Kijiji cha Nyuki Singida. The analyzed sample consisted of organophosphorus, organonitrogen, organochlorine, and certain pyrethroids compounds. The TBS laboratory examination identified 19.5 % m/m of moisture in honey samples collected from three different places (Kijiji cha nyuki, AghondiManyoni, and Getruultingi). The examination further identified 19.7 % m/m in honey samples from Egypt and 19.9% m/m in honey samples from

Sajalanda – Itigi. All five tested areas reported an average sample size of 19.62% m/m as per the TBS laboratory test. In general, raw honey will normally have a moisture content of approximately 18%, which is still within the international recommendation of 21% of moisture content. Therefore, the results of this study show all studied areas met honey quality assurance guidelines (TZS 851:2006) for Tanzanian honey products promulgated by the ministry of natural resources and tourism that suggest the moisture content in honey should not exceed 21%, also standard guides that honey produced by a stinging honey bee for table honey the moisture contents should not be more than 20% whereby to industrial honey the moisture content should not be more than 22 % (Figure 1).

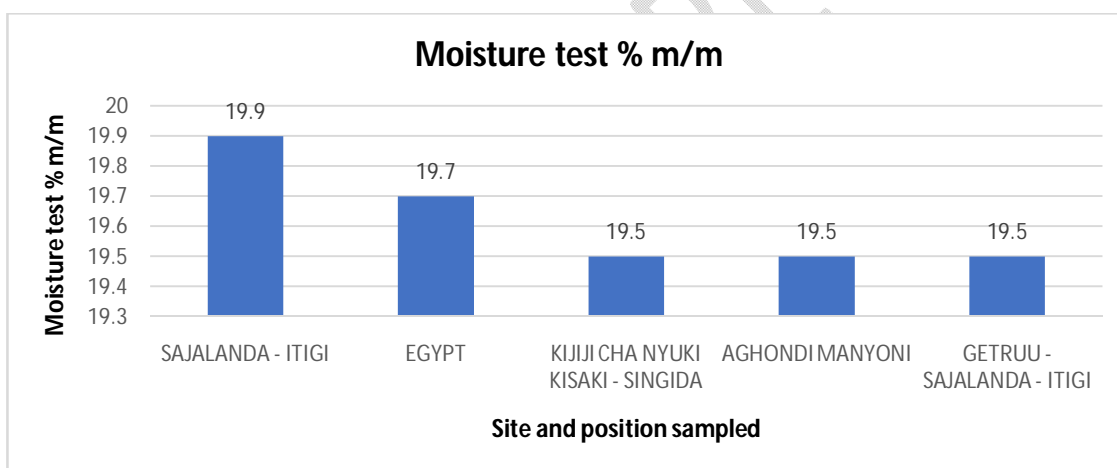


Figure 1; Moisture Content from five studies areas

##### 4.2 pH test of honey from five samples

Figure 2 discusses the pH test of five honey samples collected from five different sources (Kijiji cha nyuki, AghondiManyoni, Getruultigi, and Sajalanda – Itigi and Egypt) revealing an average of 3.96 pH. On contrary, a honey sample from Egypt apiaries had higher pH of 4.3, and honey from Kijiji cha

Nyuki had a low pH of 3.54. The normal acidity of honey ranges from a pH of 3.5 and 5.5 depending on its botanical source, the pH of nectar, soil or plant association, and the concentration of different acids and minerals such as calcium, sodium, potassium, and other ash constituents. Therefore, current results fall within the pH applicable range.

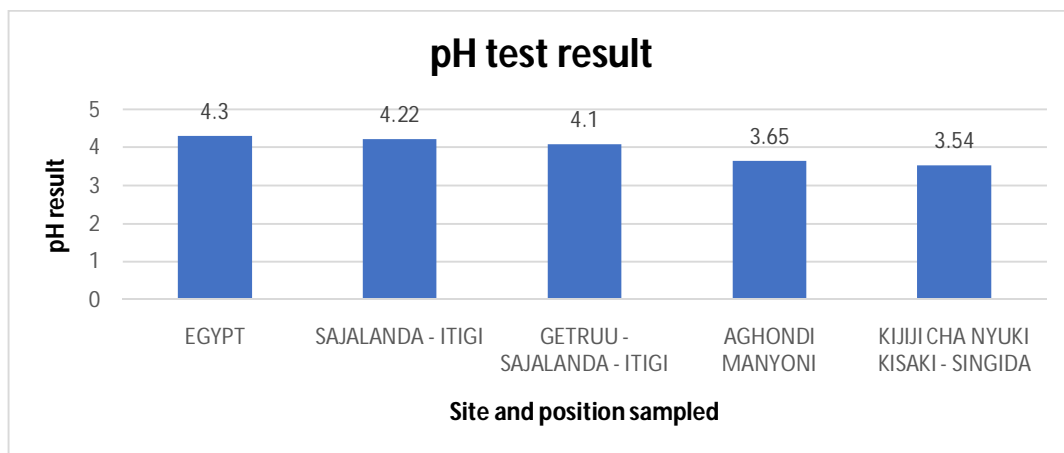


Figure 2; pH test of five honey samples collected from five different sources

#### 4.3 Test of hydroxymethylfurfural (HMF) mg/kg

The examination in Figure 3 reveals an average of 13.65 mg/kg of HMF in honey samples from Kijiji cha Nyuki, AghondiManyoni, Getruultiigi, and Sajalanda – Itigi. However, the study also found 107.13 mg/kg of HMF in honey samples from Egypt as seen in chart 3 below. The Codex Alimentarius Standard commission established by Food and Agriculture Organization (FAO) has set the maximum limit for HMF in honey at 40 mg/kg (with a higher limit of 80 mg/kg for

honey originating from tropical regions) to ensure that the product has not undergone extensive heating during processing and is safe for consumption[9]. This means honey samples from Kijiji cha nyuki, AghondiManyoni, and Getruu – Sajalanda – Itigi and Sajalanda – Itigimet the TZS 851:2006 (Honey- Specification) standards and guidelines for quality assurance of bee products produced in Tanzania which states that the HMF should not exceed 40mg/kg. On the contrary honey samples from Egypt failed to pass this standard.

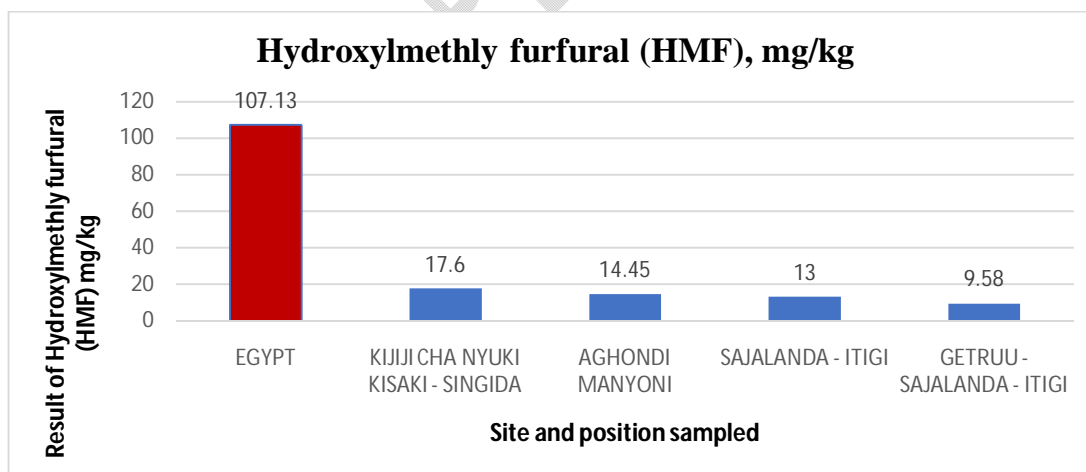


Figure 3; Hydroxymethyl furfural (HMF), mg/kg

#### 4.4 Test of total reducing sugar as inverted sugar % m/m

The examination of five samples as per the TBS test found 68.91 % m/m as the maximum amount of total reducing sugar as per the

sample collected from AghondiManyoni and 64.4 % m/m as the minimum amount of total reducing sugar based on the sample collected from Kijiji cha Nyuki as shown in Figure 4. The average amount of total reducing sugar as inverted sugar identified from all five samples

of honey is 66.46 % m/m. All five samples correspond to TZS 851:2006 Honey-Specification standards since the total

presence is above the minimum requirement of 60%.

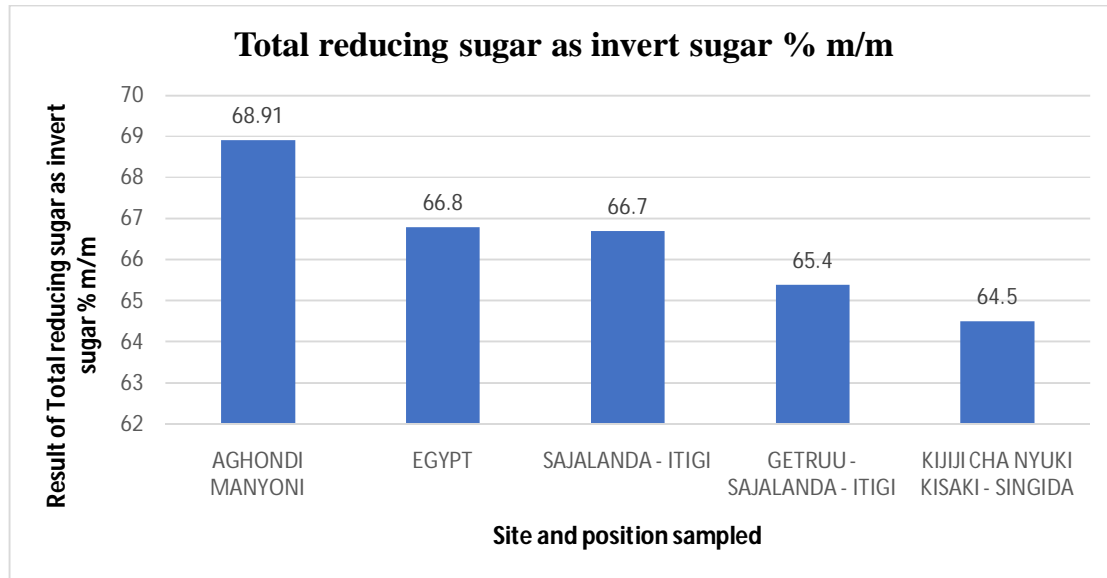


Figure 4; Test of total reducing sugar as inverted sugar % m/m

## 5. CONCLUSION

In terms of the amounts of moisture content in honey, the results of this study show all studied areas met honey quality assurance guideline TZS 851:2006 stipulated by the ministry of natural resources and tourism suggesting moisture content in honey should not exceed 21%. In regards to the pH test, 3 samples out of 5 revealed an average of 3.96 pH. On contrary, a honey sample from Egypt apiaries had higher pH of 4.3, and honey from Kijiji cha Nyuki had a low pH of 3.54 inferring that honey from the studied area falls within the pH applicable range.

Further, a Test of HMF mg/kg discovered an average of 13.65 mg/kg of HMF in honey samples from 4 studied areas out of the 5, with 107.13 mg/kg of HMF in honey samples from Egypt. This implies honey samples from the 4

study areas with exception of honey samples from Egypt met the TZS 851:2006 standards and national's honey production guidelines of 40mg/kgHMF.

Finally, the Test of total reducing sugar as inverted sugar % m/m, from five samples as per TBS laboratory results found a maximum of 68.91 % m/m and 64.4 % m/m minimum. To conclude, the study found existing physical mechanical contaminations in honey samples resulting from the increased use of pesticides by farmers' owners. Nevertheless, the amount of physical-mechanical contaminations that were identified in honey from 4 areas with the exemption of samples from Egypt apiaries poses no risk to consumers this suggests that honey products from the Kijiji cha Nyuki and surrounding areas can be used for various needs, medical needs included.

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