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# Adulteration of Honey on the Cape Coast Market in the Central Region of Ghana

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***Abstract*— Background and objectives:** *This research is driven by the need to combat the growing concern of honey adulteration, a practice that compromises the quality and authenticity of this natural product. Adulteration of honey is a pressing concern that compromises its quality, authenticity, and nutritional value. This study investigates the presence of adulterants in honey samples collected from the Cape Coast metropolis in the Central Region of Ghana. Methods: Seven honey samples were analyzed. They were selected from different outlets in the metropolis. Laser- induced fluorescence (LIF) technique was employed to identify potential adulterants by examining the fluorescence spectra of the samples. The fluorescence patterns were compared to a reference database to determine the authenticity of the honey. Results: The LIF analysis revealed distinct fluorescence patterns among the samples, indicating potential adulteration. The control sample exhibited a characteristic fluorescence profile consistent with pure honey, while certain samples exhibited altered fluorescence spectra. This deviation in fluorescence patterns strongly suggests the use of additives or adulterants in the honey samples. Conclusion: The findings indicate the presence of adulteration in the samples. The altered fluorescence spectra observed in some samples strongly suggest the use of adulterants, potentially compromising the quality and authenticity of the honey. To combat honey adulteration effectively, stringent regulatory measures, increased consumer awareness, and continuous monitoring are necessary.*

***Keywords*— adulteration, honey, Laser- Induced Fluorescence, spectra**

## I. INTRODUCTION

Honey's nutritional richness and potential health benefits have been negated by the proliferation of adulteration practices (Guleria et al., 2019)[1]. Adulteration involves the deliberate incorporation of extraneous substances into honey to compromise its quality.

The primary constituents of honey are carbohydrates, specifically sugars. Fructose and glucose are the dominant sugars present, accounting for approximately 85-95% of the total carbohydrate content (Molan, 1999)[2]. These sugars not only impart sweetness but also contribute to honey's unique hygroscopic nature, which helps prevent microbial growth and maintain its stability (Gupta & Kumar, 2017)[3]. The ratio of fructose to glucose is one of the indicators used to assess the botanical origin and quality of honey (Bogdanov et al., 2017)[4].

Enzymes play a crucial role in honey's composition and characteristics. Invertase, also known as sucrase, converts sucrose into fructose and glucose, enhancing honey's sweetness (White & Doner, 2018)[5]. Diastase, another enzyme, breaks down complex sugars like starch into simpler sugars, contributing to honey's nutritional value (Codex Alimentarius, 2020)[6]. These enzymatic activities are used as quality indicators and can be affected by factors such as temperature and processing methods.

Honey's natural acidity, reflected by its low pH, inhibits the growth of microorganisms, contributing to its remarkable shelf-life (Molan, 2017)[7]. Organic acids, including gluconic acid and acetic acid, are responsible for honey's acidic pH, which typically ranges from 3.2 to 4.5 (Molan, 2017)[7]. This characteristic pH level also contributes to the release of hydrogen peroxide, a potent antimicrobial compound (Jaganathan & Mandal, 2019)[8].

Honey is a treasure trove of minor constituents that contribute to its nutritional and therapeutic value. These include proteins, amino acids, vitamins, minerals, and antioxidants. The presence of amino acids such as proline and lysine, which are not found in significant amounts in other sweeteners, enhances honey's nutritional profile (Dramićanin, 2018)[9]. Furthermore, antioxidants like flavonoids and phenolic compounds confer honey's potential health benefits, including its anti-inflammatory and immune-boosting properties (Bertoncelj et al., 2017)[10].

The color of honey varies widely, ranging from pale yellow to dark amber, depending on its botanical origin (Da Silva et al., 2019)[11]. This variation arises from the different types of nectar and pollen collected by bees. Over time, honey may undergo crystallization, resulting in changes in texture and appearance. Crystallization is influenced by factors such as the ratio of glucose to fructose and storage conditions (Da Silva et al., 2019)[11].

The physical properties of honey, such as viscosity, density, and refractive index, are influenced by its composition. These properties are essential for various applications, including food processing and quality control (Kumar et al., 2021)[12]. The hygroscopic nature of honey, coupled with its low water content, contributes to its moisture absorbing capacity and makes it effective for preserving products like baked goods (Gupta & Kumar, 2017)[3].

Honey is used as value as a food and medicine (Sammataro & Avitabile, 2011)[13] for offerings, as sweetener, and in embalming processes (Crane, 1999)[14] and a divine symbol and a source of strength and therapeutic properties (Patel & Patel, 2011; Mazaraki, 2017)[15,16]. Moreover, it has antibacterial properties (Molan, 2017)[7], wound healing potential (Jull et al., 2015)[17].

Adulteration can introduce harmful contaminants into honey, including heavy metals, antibiotics, pesticides, and other chemical compounds. Consumption of adulterated honey may lead to acute and chronic health issues, ranging from allergic reactions to gastrointestinal disturbances and even more severe conditions. Contaminants can accumulate in the body over time, triggering allergic responses, organ damage, and adverse long-term health effects. Moreover, the absence or reduction of essential nutrients due to adulteration may undermine the nutritional benefits that pure honey offers (Bogdanov, 2007; Monakhova, 2014)[18,19].

The prevalence of adulterated honey not only threatens consumer health but also undermines the ethical and economic principles of fair trade and sustainability. Adulteration practices not only deceive consumers by providing substandard products but also erode the reputation of honest honey producers. This unfair competition compromises the livelihoods of legitimate beekeepers and undermines the integrity of the honey industry as a whole (Codex Alimentarius Commission, 2019; Dutta, 2018)[20,21].

The global trade of adulterated honey disrupts food safety regulations and standards. Adulterated honey can cross international borders and infiltrate markets, making it challenging for regulatory authorities to ensure that consumers receive safe and genuine products. The lack of comprehensive regulatory frameworks specifically targeting honey adulteration exacerbates these challenges, allowing unscrupulous practices to persist (Perna, 2021; Dutta, 2018 )[22,21].

One of the most significant risks posed by adulterated honey is the erosion of consumer trust in the food supply chain. As consumers become aware of adulteration practices, their confidence in the quality and authenticity of honey may wane. This loss of trust can extend beyond honey consumption, affecting overall consumer confidence in the safety and integrity of food products (Dutta, 2018)[21].

Adulterated honey undermines the efforts of legitimate beekeepers who adhere to ethical and sustainable practices. The economic viability of genuine beekeeping operations is threatened when the market is flooded with cheaper adulterated alternatives. This can lead to decreased demand for pure honey, pushing beekeepers out of business and disrupting the delicate balance of pollination and environmental conservation that bees facilitate (Perna, 2021; Dutta, 2018)[22,21].

In addition to individual health risks, the consumption of adulterated honey can have broader public health implications. The presence of contaminants in honey could contribute to the development of antibiotic resistance in humans, as well as the accumulation of harmful substances in the environment. The global nature of the honey trade also means that adulterated honey could potentially spread diseases across borders (Monakhova, 2014)[19].

Enforcing laws against honey adulteration can be complex due to the diverse range of adulterants and techniques used. Adulteration often involves sophisticated methods that can be challenging to detect without advanced analytical techniques. Developing effective legislation, regulations, and enforcement mechanisms to counteract adulteration requires collaboration between governments, regulatory agencies, and the industry (Dutta, 2018)[21].

Several substances are commonly used as adulterants in honey due to their similarities in appearance, taste, and texture. Some of the most frequent adulterants include: Sugar Syrups, High-Fructose Corn Syrup (HFCS), Cane Sugar, Molasses, Starch Syrups, Artificial Flavorings.

In Ghana, honey production has experienced a significant evolution from traditional honey hunting to modern beekeeping practices, contributing to economic growth, livelihood improvement, and agricultural sustainability. Beekeeping has become an important income generating activity, offering both economic and ecological benefits to the people of Ghana.

The history of honey production in Ghana is marked by a transition from traditional honey hunting to more advanced and sustainable beekeeping practices (Darkwa & Boateng, 2004)[23].

Beekeeping has emerged as a significant economic activity for rural communities in Ghana. Beekeepers can diversify their products, including honey, beeswax, propolis, pollen, venom, and bee brood, thereby increasing their income potential (Darkwa & Opoku, 2016; Abebrese et al., 2019)[24,25]. In 2008, honey production contributed about 23% to a beekeeper's annual income, and by 2009, the overall household income for families involved in the honey sector increased to approximately 37% (Darkwa & Opoku, 2016)[24].

Ghana's honey production has not only satisfied domestic demand but has also found its place in international markets. The European Union's certification of Ghana as an authorized exporter of honey to the EU market in 2011 opened doors for expanded trade opportunities. This recognition signifies the quality of Ghanaian honey and its potential for export-driven growth (Achiano, 2016)[26]. However, maintaining and improving honey quality remains a challenge. The type of beehives used, harvesting methods, and processing techniques influence the quantity and quality of honey (Darkwa & Opoku, 2013)[27].

The prevalence of adulteration practices in the honey industry has raised significant concerns about the authenticity and quality of honey. This deceptive practice poses health risks, and unfair trade practices.

Researchers have turned to advanced analytical methods, such as laser-induced fluorescence (LIF), to combat this issue (Li & Yang., 2012)[28]. LIF capitalizes on the principles of spectroscopy and fluorescence to unveil the hidden molecular identity of a sample. Through laser excitation, specific compounds emit distinct fluorescent signals, allowing for precise identification and differentiation (Lee et al., 2015)[29].

The Cape Coast market is alleged to experience such adulteration cases .This study shall contribute to industry integrity, consumer protection, and to raise public awareness of the problem. Also, shed light on the prevalence in the Cape Coast metropolis.

With respect to limitations, the study is confined to the Cape Coast metropolis, potentially limiting the generalization of findings to other geographical areas.

## II. MATERIALS AND METHOD

2.1 Research Design

2.1.1 Research Approach

A quantitative research approach is adapted to emphasize the collection and analysis of numerical data to derive patterns, relationships, and statistical significance. Thus to provide a clear and objective understanding of the prevalence and characteristics of honey adulteration in the Cape Coast market.

*2.1.2 Research Type*

The research type chosen for this study is descriptive research. Descriptive research shall focus on providing a comprehensive depiction of the phenomenon of the extent of honey adulteration and its underlying factors within the Cape Coast market. This shall provide insights into the current state of honey quality in the market and identifying potential adulterants.

*2.2 Data Collection Methods*

This shall involve both primary and secondary data collection methods. Respectively provides valuable insights into the physical and chemical attributes of the honey samples and employing a comprehensive review of literature related to honey adulteration, detection methods, and its implications to providing a broader context and facilitating a comparison of findings from various studies.

*2.3* Study Area

The study area encompasses a selection of key outlets within the Cape Coast Metropolis in the Central Region of Ghana. These outlets are Science, Tantre, Kotokuraba, Ayensu, Pedu and Abura**.** Each contributing to the metropolis' economic activity. In addition, the Benso Bee Farm was chosen to offer a controlled source serving as a reference point. This controlled source acts as a benchmark against which honey samples can be evaluated for purity and potential adulteration since it conforms to known standards and practices. This approach facilitates the inclusion of diverse vendors, consumers, and regional variations that may influence the availability and quality of honey.

2.4 Sample Collection

2.4.1 Sampling Procedure

To ensure a representative and meaningful sample set, a systematic random sampling procedure was employed to capture a cross-section of honey available in the chosen outlets. The sampling was done in three months.

This approach aimed to minimize bias and ensure that various vendors, product types, and honey sources were represented.

2.4.2 Sample Preparation

Prior to analysis, the samples underwent a series of preparation steps to ensure consistent and accurate measurements:

Homogenization: Each sample was thoroughly mixed to ensure uniform distribution of any potential adulterants. This step aimed to eliminate bias arising from variations within the honey product.

Sample Labeling: Samples were labeled with unique identifiers to maintain traceability throughout the analysis process. These identifiers linked each sample to the corresponding vendor and market.

Storage: Prepared samples were stored in a controlled environment to prevent degradation and maintain the integrity of the collected honey.

2.4.3 Laboratory analysis

The Laser Induced Fluorescence transmission data was obtained by incident light on the sample with fiber on one end and collecting with another fiber from the other end at 180°. The procedure was repeated five times for each time transmission. Reference measurement was obtained by measuring the transmitted light as described when there was no sample.

Then, fluorescence spectra of samples measured with the Laser-Induced Fluorescence setup. For each measurement, drops of pure honey were placed on a glass slide. A bi-fabricated fiber probe with one of its ends connected to the laser source (blue LASER of power 100 mW and wavelength 445 nm), and the other end connected to the detector (ocean optics USB 200 spectrometer) that had a high pass filter in front that allowed the longer wavelengths ( 450 nm) that is fluorescence to enter. The spectrophotometer was connected to a computer that had the Spectra Suite for data acquisition and visualization. The software was set at an integration time of 300 ms, an averaging of 2, and a boxcar width of 10. Five replicates from each sample were taken to minimize measurement error.

2.4.4 Data Analysis

Descriptive statistics unveiled honey sample trends, while Principal Component Analysis (PCA) transformed variables into uncorrelated components, exposing patterns and relationships.

The principal components that captured the maximum variance in the data were extracted and ranked based on their eigenvalues. The loadings and scores of the principal components were analyzed to interpret the underlying factors contributing to the variation in the dataset. Scatter plots, biplots, or other graphical representations were generated to visualize the distribution and clustering of the honey samples based on the principal components.

## III. RESULTS

*Table 1: Absorbance, Brix (%), And Moisture Content (%) Of Honey Samples*

| Sample | Absorbance (au) | Brix (%) | Moisture Content (%) |
|---|---|---|---|
| Control (Benso bee farm) | High | 78.5 | 16.2 |
| H1 (Science market) | Medium | 75.8 | 18.4 |
| H2 (Tantre) | High | 80.2 | 15.8 |
| H3 (Kotokuraba) | Low | 73.6 | 19.1 |
| H4 (Ayensu) | Medium | 77.9 | 16.8 |
| H5 (Pedu) | High | 79.1 | 16.5 |
| H6 (Abura) | Medium | 76.3 | 17.9 |
| CODEX | - | 80 | 20 |

**Source: Bartels/Aggrey/Gadzekpo Laboratory analysis 2023**

- Brix represents the percentage of total soluble solids in honey, which is an indicator of its sweetness.
- Moisture content refers to the percentage of water present in honey, which affects its quality and stability.

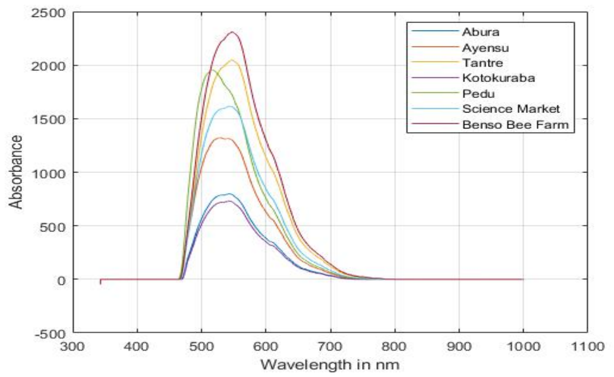


*Fig.1: Overall spectra of the samples*

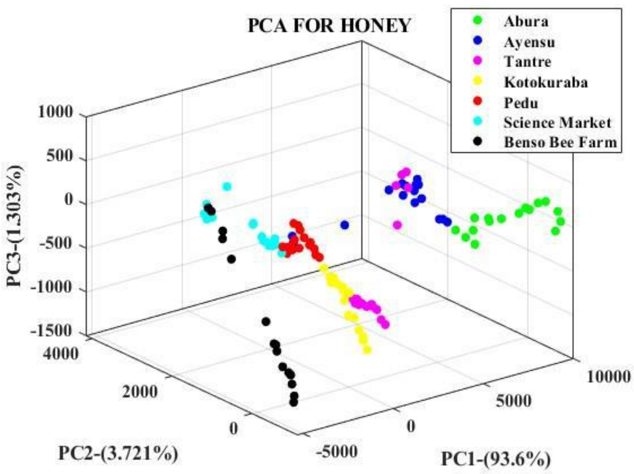


*Fig.2: PCA graph*

## IV. DISCUSSION

As shown in **Table 1,** the control sample exhibited a Brix value of 78.5%, indicating a high level of sweetness, and a moisture content of 16.2%, within the acceptable range for quality honey (CODEX, 2019)[20]. Among the market samples, variations in Brix and moisture content were observed. H2 had the highest Brix value of 80.2%, indicating increased sweetness, while H3 had the highest moisture content of 19.1%.

These variations in Brix and moisture content highlight the potential differences in quality and composition among the honey samples obtained from different outlets.

4.1 Control (Benso Bee Farm):

From Table 1, Fig 1 . The brix content of the control sample (79.5%) is slightly lower than the standard honey from the CODEX standard of 80.0%, indicating a slightly reduced sugar concentration. The moisture content of 19.1% for the control sample is comparable to the CODEX standard. The brix content of most samples is within the range of the standard honey, except the Tantri sample. In relation to the other samples, the control shows slight differences in both brix and moisture content. These differences might reflect variations in beekeeping practices, environmental conditions, or regional characteristics [Monakhova, 2014)[19].

4.2 The spectra

The spectra as shown in Fig.1 provides valuable information about the chemical composition and characteristics of the honey samples. The control sample obtained from the Benso farm served as a reference point for the comparison of other samples to establish a baseline for the expected properties of pure, unadulterated honey. Any deviations observed is attributed to potential adulteration or differences in composition.

Again, from **Table 1**, Fig 1, the control sample from the Benso bee farm exhibited a high absorbance, indicating its purity and lack of adulteration. Likewise, H2 and H5 indicating a potential similarity in composition. On the other hand, H1, H4, and H6 displayed a relatively medium absorbance, which suggests a potential level of adulteration or compositional differences (ref), with their Brix and moisture content further supporting the possibility of alterations in composition.

In H3, a significant deviation from the control is observed, suggesting potential adulteration or compositional differences. The Brix value of 73.6% and moisture content of 19.1% also deviate from the expected ranges for unadulterated honey.

4.3 PCA Analysis

From figure 2, the variance explained by each principal component was as follows: PC1, 93.6%; PC2 3.721%; and PC3, 1.303%. These percentages indicate the proportion of total variability in the original data captured by each respective principal component. Key observations are as follows:

4.3 .1. Control Cluster: The black dots representing the control, formed a distinct cluster. This indicates that the control share similar characteristics in terms of their brix and moisture content. The proximity of these dots suggests that they are tightly grouped together in the reduced-dimensional space.

4.3 .2. Inter-Cluster Relationships: Notably, some parts of the black dots formed clusters with parts of the pale blue dots, indicating a certain degree of similarity between the control and H1 (Science Market) .This suggests that there might be shared characteristics between these two groups, albeit to a lesser extent compared to the within-group clustering.

4.3 .3. Cluster Separation: The red and blue dots for Pedu(H5) and Ayensu(H6), respectively forming clusters with the pale blue dots might indicate some level of similarity in brix and moisture content among these groups. However, it is important to note that the rest of the dots were mostly distinct and separate from each other, indicating clear differences in their composition.

## V. CONCLUSION

1. The analysis of Brix and moisture content indicated variations among the honey samples, suggesting the presence of potential adulteration.

2. The investigation utilizing the LIF (Laser-Induced Fluorescence) technique provided valuable insights into adulteration in honey from the Cape Coast market.

3. The analysis involved seven samples, including a control sample obtained from the Benso farm, and each sample was analyzed five times to obtain the mean absorbance spectra using Principal Component Analysis (PCA).

4. The absorbance spectra demonstrated variations among the honey samples, indicating potential adulteration. The control sample from the Benso farm exhibited the highest absorbance, representing the expected properties of pure, unadulterated honey. In contrast, the remaining six samples displayed different absorbance values, suggesting potential adulteration or compositional differences.

5. Among the adulterated samples, Tantre exhibited the highest absorbance, closely resembling the absorbance value of the control sample. This suggests that Tantre honey may have undergone similar adulteration or shared similar compositional characteristics with the control. Following Tantre, Pedu, Science Market, Ayensu, and Abura displayed progressively lower absorbance values, indicating varying degrees of adulteration. Kotokuraba showed the lowest absorbance value among the adulterated samples, signifying a potentially higher level of adulteration or compositional differences compared to the others.

6. These findings highlight the presence of adulteration in the honey samples from the Cape Coast market, as indicated by their deviating absorbance values compared to the control.

7. The variations in absorbance suggest differences in the composition and quality of the adulterated samples compared to the control, emphasizing the need for quality control measures in the honey industry.

## RECOMMENDATIONS

- To address honey adulteration effectively, it is essential to strengthen regulatory measures, enhance consumer education, promote transparency and traceability, and foster collaboration among beekeepers, regulatory authorities, researchers, and industry associations.
- Additionally, further research and development are required to refine testing and detection methods and establish comprehensive honey quality monitoring programs.
- These findings emphasize the need for strict quality control measures, increased consumer awareness, and continuous monitoring to ensure the availability of pure and authentic honey products.
- By implementing these recommendations and continuing research efforts, we can combat honey adulteration, protect consumer health, support the local honey industry, and ensure the availability of high-quality and authentic honey in the Cape Coast region.

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