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# Beekeeping practices and physicochemical properties of honey produced in Lerala village, Botswana

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LB conducted the study (proposal development, data collection and report write-up). ES served as major supervisor of the student, conceived the research idea, designed the study, contributed in proposal development and write-up of final report, drafted and prepared the manuscript. GDH served as co-supervisor of the student, participated in the proposal development and report write-up and co-edited the manuscript.

## ABSTRACT

This study was conducted to evaluate the physicochemical properties of *Apis mellifera* honey produced in Lerala village and to assess the beekeeping practices. Sale of honey is an important source of income for beekeepers in Lerala village. There are two types of honeybee production systems in the study area: traditional backyard beekeeping and forest honey harvesting. A total of six honey samples obtained from two sources (modern hive and forest) were analysed for physicochemical properties following standard procedures. A semi-structured questionnaire was used to assess beekeeping practices by interviewing 15 individuals who have experience in beekeeping. The average values for moisture content, total ash, free acidity, reducing sugars, sucrose, pH, water-insoluble solids and hydroxymethylfurfural of honey samples obtained from modern hives were 18%, 0.24%, 31 meq/kg, 56.6%, 1.88%, 4.24, 0.05 g/100g and 26.6 mg/kg, respectively. The corresponding values for honey obtained from the forest were 17.7%, 0.28%, 27.7 meq/kg, 58%, 2%, 5.18, 0.07 g/100g and 10.9 mg/kg, respectively. Honey source significantly ($P \leq 0.05$) influenced the pH, reducing sugars and sucrose contents of the honey samples while ash, free acidity, water-insoluble solids and moisture content were not significantly ($P > 0.05$) different between the two sources of honey. The pH, sucrose and reducing sugars content of forest honey samples were significantly ($P \leq 0.05$) higher than honey obtained from modern hives. All the parameters analysed were within the limits set by the Codex Alimentarius Commission for honey. The major challenges faced by beekeepers in the study area include lack of skills and knowledge of beekeeping, weak extension services and lack of bee handling and honey processing equipment. Thus, there is a need for training of beekeepers on improved beekeeping practices and provision of inputs such as modern hives and honey handling and processing equipment to farmers.

**Keywords:** Apiculture, *Apis mellifera*, Botswana, honey quality, Lerala village

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## INTRODUCTION

Honey is a natural sweet substance gathered by honey bees from the nectar or other secretions of plants, which they transform by addition of enzymes and evaporation of water. Honey is the major product of honeybees which has important nutritional value and provides significant economic contributions to beekeepers. It is composed mainly of carbohydrates with lesser amounts of water and a wide range of minor components (White, 1975; Bogdanov et al., 2008).

Quality control of honey is important to determine its suitability for processing and to meet the demands of the market. The composition of honey depends mainly on the plant source utilized by the bees as well as climatic conditions (Marchini et al., 2007). Beekeeping can be negatively affected by climatic conditions such as torrential rains, very cold or very hot temperatures yet its socio-economic performance under favourable circumstances can repay occasional losses and often double beekeepers' returns.

In Botswana, documented evidence on beekeeping practices is very rare but since the early 1980s the Ministry of Agriculture has made reasonable strides at diversifying the beekeeping sector. According to Turner and Makhaya (2014), the total number of beekeepers in Botswana in 2013 was 1250 and the total number of hives was 2678 and the actual honey yield in the same year was 6.8 metric tonnes. The first official beekeeping trials started in Kagcae, western central Kalahari in the 1970s. Despite its huge potential, the beekeeping sector in Botswana is in its infant stage. The major bee species in the country is *Apis mellifera scutellata* (McNally and Schneider, 1996) and the main hive products are honey and beeswax (Phokedi, 1985).

The government of Botswana has established programmes aimed at supporting non-traditional agricultural activities such as horticulture and beekeeping. Government institutions that fund the beekeeping sector include CEDA (Citizen Entrepreneurship Development

Agency) and NDB (National Development Bank) and the funds are utilized by farmers who are in a position to practice beekeeping on a commercial scale (Turner and Makhaya, 2014). These financial institutions were set up to economically empower citizens to generate income and create employment. Despite the rapid development of the sub-sector in the country, there are still many challenges and constraints facing the beekeeping industry. Among these, overcoming the seasonal shortage of bee forage is one of the critical challenges to the development of this subsector (Government of Botswana, 2005).

Beekeeping provides many benefits. It not only acts as an attractive option to subsist and reinforce livelihoods in the community, but also of the environment as it fosters sustainable environmental management practices (Cantarelli et al., 2008). According to Turner and Makhaya (2014), the total domestic production of hive products from 1991-1997 was reported to be only 1.5% of the national demand.

Physicochemical properties of honey produced in several parts of southern Africa are reported in the literature. Escriche et al. (2017) reported a moisture content of 17.7-22.1 g/100g and hydroxymethylfurfural content ranging from 15.5 to 37.0 mg/kg for honey produced in Mozambique. On the other hand, Kinoo et al. (2012) reported moisture, pH and reducing sugar contents of 17.76-24.87%, 3.38-4.67 and 42.95-60.31 g/100g, respectively for honey produced in Mauritius. Similarly, Nyau (2013) reported moisture, pH and ash contents of 14.9-16.4%, 4.26-4.44 and 0.198-0.271%, respectively for Zambian honey. However, to date, no information has been reported regarding the quality of honey produced and consumed in Botswana; not only is there a lack of information on the physicochemical characteristics of honey produced in the country in general, but in Lerala village in particular. Thus the objectives of this study were to assess the beekeeping practices and to determine the physicochemical properties of honey produced in Lerala village in the Central District of Botswana.

## MATERIALS AND METHODS

### *Description of study area*

The study was conducted in Lerala village, which is located in Central District of Botswana. The village is found at the south-eastern end of the Tswapong Hills, 30 km from the Limpopo River and approximately 90 km east of Palapye. The population of Lerala was reported to be 5,747 in the 2001 census (Statistics Botswana, 2014).

According to Government of Botswana (2005), the average rainfall in the Central District ranges between 350 mm in the east (Bobonong Sub–District) to just over 500 mm in the southeast (Machaneng and Mahalapye Sub–Districts). The major rivers in the Central District are the Bonwapitse, Mahalapye, Lotsane, Motloutse and Shashe and they flow in an easterly direction into the Limpopo River that forms the eastern border between Botswana and South Africa. The soils adjacent to these rivers are fluvisols which are very fertile and support variety of multipurpose bee plant species especially *Vachellia* and *Senegalia* species.

During the summer cropping season especially when the rains are good, bee forage in the Central District becomes plentiful. Farmers depend on arable fields as well as natural vegetation present in the area as sources of forage for bees. Although the arable fields are small, they are often supplemented by backyard gardening. The less engagement of farmers in livestock husbandry and arable farming in Lerala makes beekeeping an option for farmers to diversify their income and hence can be an attractive venture (Government of Botswana, 2005). Important nectar trees in the area include *Senegalia mellifera*, which flowers in September and *Eucalyptus* species which provide nectar and pollen, flowers in spring.

### *Survey*

A semi-structured survey questionnaire was used to collect information on the major tree/shrub species used as forage by honey bees in the area, honey harvest time, method of collection and handling of honey, uses of honey and constraints and opportunities for production of honey. A total of 15 respondents were purposively selected for the interview based on their experience and involvement in beekeeping.

### *Sampling technique and sample size*

A total of six honey samples (each 250 g) were collected from two sources in Lerala village (three samples from modern hives kept in the backyards of farmers and three samples from forest honey harvesters). The honey samples were transported to Botswana University of Agriculture and Natural Resources, Food Science and Technology laboratory for the determination of their physicochemical properties.

### *Physicochemical properties of honey*

The moisture, reducing sugars, sucrose, hydroxy-methylfurfural, acidity, pH, water-insoluble solids and ash contents of the honey samples were determined according to the harmonized methods of the International Honey Commission (IHC, 2009) and the procedures of the Quality and Standards Authority of Ethiopia (QSAE, 2005) as follows:

### *Moisture content*

The moisture content of honey samples was determined by measuring the refractive index of the sample using an Abbe Refractometer using the relationship between refractive index and water content reading at 20˚C, as described in the harmonized methods of the International Honey Commission (IHC, 2009). The method is based on the principle that refractive index of honey increases with solids content. The refractive index of distilled water (1.3330) was used as a reference. The surface of the prism was covered with drops of homogenized honey sample and the prism was closed for four minutes to stabilize. The refractometer was calibrated so that the

border line between the white and dark area passes through the cross point of both lines visible in the ocular. The refractive index was adjusted to read at a temperature of 20˚C. Measurements were done in duplicate and an average value was computed. The mean refractive index was converted to moisture content using the following formula:
Moisture content = [$-\log_{10}$ (Corrected Refractive Index–1) – 0.2681]/0.002243 (QSAE, 2005).

***Reducing sugars***

Reducing sugars content was determined by the modified Lane and Eynon (1923) method involving the reduction of Soxlet modification of Fehling's solutions by titrating at boiling point (60˚C), against a solution of reducing sugars in honey using methylene blue as an internal indicator (Pearson, 1971).

Exactly 25 grams of homogenized honey was placed in a 100 ml volumetric flask. The honey sample was homogenized by stirring it with glass rod. The sample was diluted with water to the volumetric capacity (100 ml) of the flask at 20°C. Ten ml of this solution was diluted to a final volume of 500 ml with distilled water (diluted honey solution).

Five ml of Fehling's solution A was pipetted into a 250 ml Erlenmeyer flask and approximately five ml Fehling's solution B was added to it and then seven ml of distilled water was added to the mixture, followed by addition of 15 ml diluted honey solution from a burette. The mixture was heated to boiling over a wire gauze for two minutes. One ml of 0.2% methylene blue solution was added to the mixture whilst still boiling and the titration was completed within a total boiling time of three minutes by repeated small additions of diluted honey solution until the indicator was decolorized. The results were calculated and expressed as follows:

C = (25/W)*(1000/Y) (Pearson, 1971)

where C = gram of invert sugar per 100 gram honey, W = weight (g) of honey sample used, and Y = volume (ml) of diluted honey solution consumed.

***Apparent sucrose content***

Sucrose content of the honey samples was also determined according to the procedures of Pearson (1971). Honey solution was prepared as for the determination of reducing sugars. Fifty ml honey solution was placed in a 100 ml volumetric flask that contained 25 ml distilled water and the mixture was heated to 65°C in a water bath for an hour. The flask was then removed from the water bath and 10 ml of 6.34 M hydrochloric acid solution was added to it. The solution was allowed to cool for 15 minutes and brought to 20°C, then neutralized with 5 M NaOH solution using litmus paper as indicator, it was then cooled again and the volume was adjusted to 100 ml (diluted honey solution). Titration was done following a similar procedure as for the determination of reducing sugars. The apparent sucrose content was calculated by difference and expressed as follows:

Apparent sucrose content = (invert sugar content after inversion – invert sugar content before inversion) x 0.95 (Pearson, 1971).

The results were expressed as gram of apparent sucrose per 100 gram honey.

***Free acidity***

Free acidity of honey samples was determined according to the procedures of QSAE (2005). Honey sample (10 g) was dissolved in 75 ml distilled water in a 250 ml beaker and stirred with a magnetic stirrer. The solution was titrated with standardized 0.1 M NaOH solution to a final pH of 8.30. Then the amount of NaOH solution used for titration was recorded. The results were expressed in milliequivalent (meq) of acid per kg of honey using the following equation.

Acidity =10V (QSAE, 2005)

where V = the volume of 0.1M NaOH used and 10 is the amount of honey sample used.

***pH***

Ten grams of honey sample was dissolved in 75 ml of distilled water in a 250 ml beaker and stirred using a magnetic stirrer. Then the pH was measured with a digital pH-meter (Orion Star J257), which was calibrated using pH 4.0 and 7.0 buffer solutions (QSAE, 2005).

***Total ash***

Ash content of honey samples was also determined according to the procedures of QSAE (2005). A quartz dish was heated in an electric furnace at 600°C and subsequently cooled in a desiccator to room temperature and the dish was weighed ($M_2$). Five grams of honey sample was weighed to the nearest 0.001g ($M_0$) and added to the dish. Two drops of olive oil was added to the dish to prevent frothing and then the dish was placed in preheated furnace and heated for 1.5 hour at a temperature of 600°C. The dish with the ash was then cooled in a desiccator and weighed. The ashing procedure was continued until constant weight was reached ($M_1$). Ash (% by mass) was calculated using the following formula:

Ash (% by mass) = ($M_1 - M_2$)/$M_o$*100 (QSAE, 2005).

***Water-insoluble solids***

The water-insoluble solids content of the honey samples was determined according to the procedures of QSAE (2005). Twenty grams of honey was weighed ($M_1$) and dissolved in 200 ml of water at 80°C and then it was thoroughly mixed. A crucible (sintered glass, pore size 30 µm) was dried in an oven and cooled to ambient temperature in a desiccator. The crucible was weighed

($M_2$). The sample solution was filtered through the crucible and the sample was washed carefully and extensively with warm distilled water until free from sugars. One percent phloroglucinol in ethanol solution was added into the filtrate in a test tube and a few drops of concentrated sulphuric acid were poured down the sides of the tube and mixed with the filtrate to check presence of sugars (sugars produce a colour at the interface). The crucible was dried at 135°C for an hour, cooled in a desiccator and weighed. It was returned to the oven at 30 minute intervals until constant weight was obtained ($M_3$). The results were calculated and expressed as follows:

Percent of water-insoluble matter (g/100 g) = $(M/M_1) \times 100$ (QSAE, 2005)

where $M = (M_3 - M_2)$ = mass of dried insoluble matter and $M_1$ = mass of honey used.

### *Hydroxymethylfurfural*

Determination of hydroxymethylfurfural (HMF) content of honey samples was based on the measurement of absorbance of HMF at 284 nm using UV Spectrophotometer (Evolution–201 UV Visible Spectrophotometer, Thermo Scientific). In order to avoid the interference of other components at this wavelength, the difference between the absorbance of a clear aqueous honey solution and the same honey solution after addition of bisulphite solution is determined. The HMF content is then calculated after subtraction of the background absorbance at 336 nm (QSAE, 2005).

Five grams of honey sample was accurately weighed into a small beaker. The honey sample was dissolved in 25 ml of water and transferred into a 50 ml volumetric flask. Half ml of Carrez solution I was added and mixed. Then half ml of Carrez solution II was added into the 50 ml volumetric flask and mixed and then diluted with distilled water up to the volumetric mark of the flask. A drop of ethanol was added to the mixture to suppress foam. The mixture was filtered through general purpose filter paper and the first 10 ml of the filtrate was discarded. Five ml of the remaining filtrate was pipetted into each of two test tubes (18 x 150 mm). Then five ml of water was added to one of the test tubes and thoroughly mixed (the sample solution) and five ml of sodium bisulphite solution (0.2%) was added to the second test tube and mixed (the reference solution) using a Vortex mixer. The absorbance readings of the sample solution against the reference solution at 284 and 336 nm, respectively were taken using the UV-Visible Evolution 201 spectrophotometer within one hour of preparation. The result was calculated as follows:

HMF in mg/kg = $(A284 - A336) \times 149.7 \times 5 \times D/W$ (QSAE, 2005)

where A284 = absorbance at 284 nm, A336 = absorbance at 336 nm, 149.7 = constant, 5 = theoretical nominal sample weight, W = weight of the honey sample in gram, D = dilution factor.

### *Statistical analysis of the data*

For each honey sample, all parameters were determined in duplicate. The data for the physicochemical parameters of honey samples obtained from the two sources (modern hives and forest) were compared using t–test. Differences between mean values were considered significant at $P \leq 0.05$. Descriptive statistics was used to analyze the data generated through survey.

## RESULTS

### *Beekeeping practices in Lerala village*

Table 1 shows the demographic characteristics of the respondents in Lerala village. The majority of the respondents were aged between 31 and 50 years. Most of the respondents completed their secondary education (66%), 20% went to tertiary institutions while few (13.3%) only attended primary school.

**Table 1.** Demographic characteristics of the interviewed beekeepers in Lerala village (n = 15)

| Variables | Response | Percentage (%) |
|---|---|---|
| Age | 18-30 years | 26.7 |
| | 31-50 years | 73.3 |
| Education status | Primary school complete | 13.3 |
| | Secondary school complete | 66.0 |
| | Tertiary education | 20.0 |

n = total number of respondents

Table 2 shows hive types, source of bee colonies, pests and challenges faced by beekeepers in Lerala village. The majority of the respondents (53.5%) own traditional hives while only 46.7% of the beekeepers own modern hives. This indicates that the majority of beekeepers in the study area are small-scale farmers. In addition, low adoption of improved technologies and limited adoption of moveable frame hives are challenges indicated by beekeepers in Lerala. The major types of hives found in the village are top-bar hive and movable frame hive. Traditional hives are made from locally available materials such as logs whereas, modern movable-frame hives consist of precisely made rectangular boxes (hive bodies) superimposed one above the other in a tier. Movable-frame hives have a queen excluder which confines the queen to the lowest (brood) chamber and the upper chambers (supers) are reached only by the workers. This makes hive inspection and management easier and minimizes damage and death of bees during harvesting of honey.

Beekeepers in the study area obtain bee colonies through purchase and catching swarms. Sixty percent of the respondents indicated that they established their bee colonies by buying swarms from local beekeepers followed by catching swarms by hanging bait hives on trees (40%). A bait hive is an empty hive that is setup to attract a swarm during the swarming season. Wax and propolis seem to attract bees better; however, old combs can also be placed in the bait hive. The majority of respondents with traditional and modern hives keep their colonies around their homestead (backyard) mainly to

**Table 2.** Hive types, source of bee colonies, pests and challenges faced by beekeepers in Lerala (n = 15)

| Variables | Response | Percentage (%) |
|---|---|---|
| Hive types | Modern hive (Langstroth) | 53.3 |
| | Traditional hive | 46.7 |
| Source of bee colonies | Buying an established colony | 60 |
| | Catching swarms (hanging bait hives in trees) | 40 |
| Pests of honeybees | Ants<br>Honey Badger<br>Wax moth<br>Termites<br>Small hive beetles | 100 |
| Challenges | Lack of skills and knowledge<br>Weak extension services<br>Unfavourable climatic conditions<br>Lack of processing equipment<br>Marketing constraints (lack of financial resources) | 100 |

n = total number of respondents

**Table 3.** Major sources of bee forage and supplementary feeds in Lerala village (n =15)

| Variables | Response | Percentage (%) |
|---|---|---|
| Bee forage | Wild tree species:<br>*Eucalyptus* species (Lebloukom)<br>*Senegalia mellifera* (Mongana)<br>*Senegalia erubescens* (Moloto)<br>*Vachellia robusta* (Mogotlho)<br>*Vachellia tortilis* (Mosu)<br>Cultivated crops/fruit trees:<br>Sunflower<br>Paw-paw<br>Citrus trees | 100 |
| Supplementary feeds | Supplementary feeds given to bees during times of drought: | |
| | Sugar syrup | 40 |
| | Soya milk | 6.7 |
| | None | 53.3 |

n = total number of respondents

**Table 4.** Harvesting, packaging, storage, marketing and utilization of honey in Lerala village (n = 15)

| Variables | Response |
|---|---|
| Harvesting time | November – May |
| Packaging containers | Plastic bottles and buckets<br>Glass bottles |
| Storage | Honey is stored in a dark room away from direct sunlight |
| Marketing | Beekeepers sell their honey to individuals and to small-scale retailers/supermarkets<br>Honey is sold in 750g buckets and pricing is different (P125 for supermarkets and P100 for individuals) |
| Utilization | Honey is used in tea as a substitute for sugar<br>Honey is also used to relieve flu and colds |

n = total number of respondents

enable close supervision of colonies. The major pests of honeybees in the study area include ants, wax moth *(Galleria mellonella)*, bee-eater birds, spiders, bee lice (*Braula coecal),* termites, small hive beetles (*Aethina tumida*), honey badger (*Mellivora capensis*) and snakes in decreasing order of importance.

The respondents indicated that they face different challenges in beekeeping including inadequate resources such as lack of processing equipment, unfavourable climatic conditions (drought) and lack of skills and knowledge (most sample respondents were not trained in beekeeping practices).

Table 3 shows major sources of bee forage and supplementary feeds used in Lerala village. According to the respondents, the plant species used as a source of bee forage in the area include *Eucalyptus* species (Lebloukom), *Senegalia mellifera* (Mongana), *Senegalia erubescens* (Moloto) and *Vachellia robusta* (Mogotlho). In addition, the beekeepers in the study area grow different crops like sunflower, paw-paw and citrus trees which are also used by bees as a source of nectar. In this study, it was found that only 46.7% of the respondents provide supplementary feed to honey bees. The supplementary feeds include sugar syrup and soya milk.

Table 4 presents information on harvesting, packaging, storage, marketing and utilization of honey in Lerala village. In the study area, honey is harvested from November to May. Usually honey is harvested prior to the harvest of major food and cash crops and hence sale of honey serves to satisfy farmers' immediate cash needs to cover items such as school fees, taxes and fertilizer loans. During harvesting, combs that contain ripe honey are selected; these are usually sealed with a thin layer of white beeswax. The majority of the respondents mentioned that they do not store honey, primarily because of high demand for cash and secondly because of lack of storage facilities. Some beekeepers that have no pressing financial needs keep the honey for a prolonged period to get a better price during the off season. Honey (750 g) is sold for BWP 125.00 at supermarkets and BWP 100.00 at the farm gate.

Beekeepers harvest honey by cutting the combs which are then put in a container (plastic bucket) and extracted prior to filtering. Stainless steel utensils such as knives, bowls and pots are used.

Honey is packaged in food grade plastic bottles and glass containers. The honey is usually kept in a cool dry place away from direct sunlight. Although honey is generally produced mainly for sale, farmers do keep a small amount for different purposes.

***Physicochemical properties of the honey***

The mean and standard deviations of the parameters used to describe honey samples collected from modern hives and from the forest are presented in Table 5. No significant difference (P>0.05) in moisture content was observed between honey samples obtained from the two sources. The values for moisture content observed in the current study are in line with limits set by the Codex Alimentarius Commission (2001) and the European Union (EU Council, 2002) which stipulate a maximum value of 21% for moisture content of honey. Similarly, no significant difference (P>0.05) in ash content was observed between honey samples obtained from modern hives and those obtained from the forest. The ash content of all the analyzed honey samples is within the 0.01-1.2% limit set by the Ethiopian Quality and Standards Authority (QSAE, 2005).

There was no significant difference (P>0.05) in free acidity between honey samples obtained from modern hives and that obtained from the forest. The free acidity values reported in the present study are lower than the maximum limit (50 meq/kg) set by the Codex Alimentarius Commission (Codex Alimentarius Commission, 2001). Honey from the forest had a higher mean pH as compared to honey from modern hives.

**Table 5.** Physicochemical properties (mean ±SD) of honey samples collected from modern hives and the forest in Lerala village

| Parameters | Source of honey | |
|---|---|---|
| | **Modern hive (n=3)** | **Forest (n=3)** |
| Moisture (% by mass) | 18.00 ± 0.67 | 17.67 ± 0.66 |
| Ash (% by mass) | 0.24 ± 0.02 | 0.28 ± 0.01 |
| Free acidity (meq/kg) | 31.00 ± 1.00 | 27.67 ± 0.74 |
| pH | $4.24^{a}$ ± 0.02 | $5.18^{b}$ ± 0.02 |
| Reducing sugars (% by mass) | $56.57^{a}$ ± 1.84 | $58.03^{b}$ ± 1.11 |
| Sucrose (% by mass) | $1.88^{a}$ ± 0.58 | $2.00^{b}$ ± 0.38 |
| Water-insoluble solids (g/100g) | 0.05 ± 0.02 | 0.07 ± 0.01 |
| HMF (mg/kg) | 26.58 ± 0.82 | 10.93 ± 2.15 |

SD = standard deviation; n = number of samples; HMF = Hydroxymethylfurfural; means followed by different superscript letters in a row are significantly different (p≤0.05)

The reducing sugars content of honey samples obtained from the forest was significantly higher ($P \leq 0.05$) than values for honey obtained from modern hives. None of the honey samples analysed in the present study exceeded the 65% limit set by Codex Alimentarius Commission (Codex Alimentarius Commission, 2001), for reducing sugars of *Apis mellifera* honey. The average sucrose content of honey collected from the forest was also significantly higher ($P \leq 0.05$) than values for honey obtained from modern hives. The sucrose content of all the honey samples analysed in this study are below the maximum acceptable limit of 5% recommended by the Codex Alimentarius Commission (Codex Alimentarius Commission, 2001).

The water-insoluble solids of honey from both sources in the present study were low. The HMF content of honey samples analysed in the present study is much lower than the maximum acceptable value (40 mg/kg) recommended by the Codex Alimentarius Commission (Codex Alimentarius Commission, 2001).

## DISCUSSION

### *Beekeeping practices*

Most of the beekeepers in the study area were in the active and productive age group implying that they can actively be engaged in beekeeping activities. The age of farmers is a very important factor that determines the types of agricultural activities they undertake. In farms using family labour, younger farmers tend to engage in more labour intensive farming activities than older farmers (Terrab et al., 2003).

Lack of skills and knowledge is one of the challenges faced by beekeepers in the study area. Lepetu et al. (2008) reported that one of the major problems of beekeepers in Gaborone region is lack of management skills. Lack of training makes it difficult to adopt improved beekeeping practices. Phokedi (1985) reported that a shortage of qualified personnel and extension staff trained in beekeeping limits the development of beekeeping in Botswana. To facilitate and enhance the adoption of improved beekeeping practices, training in improved beekeeping practices should be offered to beekeepers, accompanied by provision of inputs such as bee handling and honey processing equipment. The training can bridge technical gaps and equip the beekeepers with basic knowledge on how to manage improved hives and bee equipment, basic bee biology, handling of honeybee colonies, record keeping, growing of appropriate bee forage plants, honey processing and marketing techniques.

Vit et al. (1998) reported that for more advanced beekeeping and better colony management, one should have a good grasp of bee biology and behaviour. The level of education attained by farmers to a large extent determines the farmer's level of adoption of new innovation without difficulties and makes resource use efficient, which in turn increases farm output and subsequently the profit obtained by the farmers (Pokhrel, 2008). Low adoption of improved beekeeping technologies was observed in the present study and this is attributed to weak extension services, initial high investments for construction or purchase of modern hives, limited financial resources of the beekeepers and lack of technical knowhow.

Honeybees in the study area have a number of enemies (Table 2). This is in line with the report of Phokedi (1985) who indicated that the main pests of honey bees in Botswana include the brown house ant, greater wax moth, honey-guide bird, small hive beetles, large hive beetles (*Hoplostomus fuligineus*), and honey badger. Lepetu et al. (2008) also reported ants (*Pheidole megaccephala*), bee-pirate (*Palrus lantfrons*), waxmoth (*Galleria mellonella*), honey badger (*Mellivora capensis*), large hive beetle (*Hoplostomus fuligineus*) and small hive beetle (*Aethina tumida*) as major pests of honeybees in the Gaborone region.

In the study area, many wild plant species produce flowers that serve as forage for honeybees. Among many factors, availability of flowering plants and ample sources of water are the two major parameters for an area to be considered to have potential for honey production (Pokhrel, 2008). The existence of ample bee forage results in higher honey production, provided that other factors are suitable for honey production (Marchini et al*.,* 2007).

Honeybees store honey for their own consumption during dearth periods (Vit et al*.,* 1998). Beekeepers harvest honey, which the honeybees stored for themselves and as a result, honeybees can face starvation due to lack of feed. To overcome the problem of feed shortage, beekeepers should provide supplementary feeding. The practice of supplementing bees with sugar syrup observed in this study is in line with the findings of Lepetu et al. (2008) who reported that most beekeepers in Gaborone region feed their bee colonies with sugar solution. In addition to supplementary feeding, planting bee forage is also required to increase honey yields; bee forage determines the amount of honey yield obtained (Terrab et al., 2003).

The market for honey is not well developed in Lerala village. The major buyers of honey in Lerala are local retailers, middlemen and individual consumers. Lack of knowledge of proper honey handling and business concepts (lack of sense of competition, poor client handling, weak information gathering, etc.) are the reasons for the poor marketing skills of the local honey collectors. They also lack facilities like proper containers and processing equipment.

### *Physicochemical properties of the honey*

One of the basic quality parameters of honey is moisture content. Moisture content contributes to honey quality, its viscosity, fermentation and savour. Honey has a low moisture content and this protects it from microbial attack (Tysset et al*.,* 1980). Moisture content of honey determines its shelf-life during storage (Terrab et al., 2003); a high moisture content causes honey to ferment and spoil. The values of moisture content observed in the present study are comparable to the findings of Muli et al. (2007) who reported moisture content ranging from 16.0 - 21.20% for honey obtained from Mwingi District in Kenya. The results are also in agreement with the values reported by Nyau et al. (2013), of 14.9-16.4%, Escriche et al. (2017), of 17.7-22.1 g/100g and Kinoo et al. (2012) of 17.67-24.87% for moisture content of honey produced in Zambia, Mozambique and Mauritius, respectively. Moisture content of honey is a limiting factor that determines its quality, stability and resistance against spoilage by yeast fermentation. El Sohaimy et al*.* (2015) reported an average moisture content of 18.32 ± 0.67 g/100 g for Egyptian honey. On the other hand, Buba et al*.* (2013) reported that honey samples from Nigeria had an average moisture content of 16.00 ± 2.19 g/100 g.

The ash percentage found in honey expresses its richness in mineral content and constitutes a quality parameter (Marchini et al., 2007). The mineral content may be indicative of environmental pollution or geographical origin, but the primary determinant of mineral content is the type of soil on which the plant that is used as a source of nectar was grown (Pokhrel, 2008). The ash content of honey samples observed in the present study is in agreement with values of 0.05 to 0.60% reported by Kinati et al*.* (2011) for honey produced in the Gomma district of south western Ethiopia and 0.198-0.271% reported by Nyau (2013) for Zambian honey. Similarly, Adgaba (1999) reported ash content of 0.1% -1.0% for Ethiopian honey and Rodriguez-Otero et al*.* (1994) reported that mineral content of honey from Spain varied from 0.06% to 1.34%.

During fermentation, glucose and fructose are converted into carbon dioxide and alcohol. Alcohol is further hydrolyzed in the presence of oxygen and converted into acetic acid which contributes to the level of free acidity in honey. Low levels of free acidity indicate an absence of fermentation. The values for free acidity of honey observed in the present study are in agreement with the values reported by different authors. Adenekan et al. (2010) reported that the free acidity of honey samples collected from different areas of Ibadan, Nigeria ranged from 17.4 to 32.4 meq/kg. Similarly, Kayode and Oyeyemi (2014) reported free acidity values which ranged from 21.5 to 33.6 meq/kg for honey collected from Ekiti State in southwest Nigeria and Alemu et al. (2013) reported average free acidity of honey produced in Sekota district of northern Ethiopia to be 23.54 meq/kg.

The reducing sugars observed in the present study are in line with previous findings. Rane and Doke (2012) reported that reducing sugar content of honey samples from western Maharashtra/India ranged from 42.8% to 60.6%. Similarly, Gobessa et al*.* (2012) reported reducing sugar contents ranging from 62 to 71% with a mean value of 65% for honey produced in the Homesha district of western Ethiopia. Muli et al*.* (2007) reported reducing sugars content of 57.03-61.50% for Kenyan honey. The reducing sugar content of honey observed in the present study is in agreement with values of 42.95-60.31 g/100g reported by Kinoo et al. (2012) for Mauritius honey. The sugars in honey are responsible for many of the physicochemical properties such as viscosity, hygroscopicity and degree of granulation of honey.

The sucrose content of honey observed in the present study is in line with values of 0.20-4.60% reported for Tunisian honey (Boussaid et al*.*, 2014). Rane and Doke (2012) reported an average sucrose content of 2.23% for honey collected from various ecological niches of western Maharashtra. The present result is also in agreement with the findings of Makhloufi et al*.* (2007) who reported sucrose content of 0.18-3.09% for Australian honey. The higher sucrose content observed in honey samples collected from the forest might be attributed to early harvesting of honey before it ripens. A high sucrose concentration in honey usually implies a premature harvest of honey as the sucrose has not been fully converted to glucose and fructose by the action of invertase enzyme (Ozcan et al., 2006; Nascimento et al*.*, 2015). The sucrose content of honey also depends on the botanical origin of the nectar (Bogdanov and Kilchenmann, 1994).

The pH of honey from modern hives is in line with values of 3.47-4.27 and 2.90-4.26 reported by Pires et al. (2009) and Agbagwa et al. (2011) for honey produced in Portugal and Nigeria, respectively. It is also in agreement with the pH values of 3.38-4.67 and 4.26-4.44 reported by Kinoo et al. (2012) and Nyau (2013) for honey produced in Mauritius and Zambia, respectively. Bogdanov et al. (1999) reported that the pH of honey samples should be between 3.2 and 4.50. On the other hand, Buba et al. (2013) reported that honey samples obtained from north-eastern Nigeria had pH values ranging from 3.5 to 4.9. pH values of 3.94 (Makhloufi et al., 2007) and 4.30 (Amir et al., 2010) were also reported for Algerian honey. Honey inhibits the growth of microorganisms and the antibacterial effect of honey is partly attributed to its low pH (Bogdanov et al., 2008). High acidity of honey indicates that the honey samples have high contents of minerals (Mohammed and Babiker, 2009; El-Metwally, 2015).

Honey’s water-insoluble matter (solids) includes wax, pollen, honey-comb and debris. Thus the amount of water-insoluble matter present in honey is used as an indicator of honey’s cleanliness. In Ethiopia, the maximum acceptable amount of water-insoluble matter in honey is 0.1% (QSAE, 2005). The water-insoluble solids content observed in the present study is in line with the values of 0.01-0.46 g/100g reported by Gobessa et al. (2012) for honey produced in the Homesha district of western Ethiopian. Alemu et al. (2013) reported a higher water-insoluble solids content of 0.53-0.70 g/100g for honey collected from Sekota district in northern Ethiopia. The low water-insoluble solids content observed in Lerala village suggests good hygienic conditions during the harvesting of honey.

The HMF concentration in honey is widely used as an index of freshness of honey. This is because it is absent in fresh honey, and its concentration increases during storage especially at elevated temperature. The HMF content of honey observed in the present study is in agreement with values of 12.07 - 27.43 mg/kg reported for

Tunisian honey (Boussaid et al., 2014) and 15.5-37.0 mg/kg reported for Mozambique honey (Escriche et al., 2017). It is also in line with HMF values of 10.30, 68.13 and 7.97 mg/kg reported for honey from Tana, Mbeeree and Taita regions of Kenya (Muli et al., 2007). Adenekan et al. (2010) reported that HMF of honey samples collected from different areas of Ibadan Nigeria ranged from 14.08 to 38.02 mg/kg. Terrab et al. (2002) reported that storage conditions, especially temperature influence the formation of HMF in honey. In addition, the HMF content of honey also depends on the type of sugars present in honey itself, i.e., fructose: glucose ratio (Doner, 1979). Also honey heating results in the formation of HMF, which is produced during acid-catalysed dehydration of hexoses, such as fructose and glucose (Fallico et al., 2004).

## CONCLUSIONS

The results indicate that honey produced in Lerala village complies with international standards and is of good quality. The study area has good potential for beekeeping and farmers need to be given support and training on improved beekeeping practices in order to increase production of honey in the area. In view of the limited study on quality parameters of honey in Botswana, more research needs to be conducted to assess properties of honey produced in other parts of the country. This will eventually lead to development of quality criteria for honey produced in the country.

## RECOMMENDATIONS

The following are important areas of intervention that deserve due attention in the future:

modern/improved beekeeping practices need to be implemented in order to increase honey yield and improve the productivity of the beekeeping sector in the study area;

proper extension services and training on the use of modern hives and improved beekeeping techniques are also required in order to improve the skills and knowledge of the beekeepers;

provision of inputs such as improved hives and honey processing equipment to the farmers in the study area needs to be given due attention;

beekeepers should be trained on the relevant honey handling and processing skills, with focus on possible points of honey contamination/adulteration along the value chain, in order to minimize spoilage of honey and maintain the required honey quality across market establishments.

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## CONFLICT OF INTEREST

None.

## REFERENCES

**Adenekan, M.O., Amusa, N.A., Lawal, A.O. and Okpeze, V.E. (2010).** Physico-chemical and microbiological properties of honey samples obtained from Ibadan. *Journal of Microbiology and Antimicrobials* 2(8): 100–104.

**Adgaba, N. (1999).** Quality state and grading of Ethiopian honey. In: Proceedings of the First National Conference of Ethiopian Beekeepers Association (EBA), pp. 74–82. 7–8 June 1999, Addis Ababa, Ethiopia.

**Agbagwa, O.E., Otokunefor, T.V. and Frank-Peterside, N. (2011).** Quality assessment of Nigeria honey and Manuka honey. *Journal of Microbiology and Biotechnology Research* 1(3): 20–31.

**Alemu, T., Seifu, E. and Bezabih, A. (2013).** Physicochemical properties of honey produced in Sekota district, northern Ethiopia. *International Food Research Journal* 20(6): 3061–3067.

**Amir, Y., Yesli, A., Bengana, M., Sadoudi, R. and Amrouche, T. (2010).** Physico-chemical and microbiological assessment of honey from Algeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry* 9(9): 1485–1494.

**Bogdanov, S., Lullmann, C., Mossel, B.L., D'Arcy, B.R., Russmann, H., Vorwohl, G., Oddo, L., Sabatini, A.G., Marcazzan, G.L., Piro, R., Flamini, C., Morlot, M., Lheretier, J., Borneck, R., Marioleas, P., Tsigouri, A., Kerkvliet, J., Ortiz, A., Ivanov, T., Vit, P., Martin, P. and von der Ohe, W. (1999).** Honey quality, methods of analysis and international regulatory standards: review of the work of the International Honey Commission. *Mitteilungen Aus Dem Gebiete Der Lebensmittel-untersuchung Un Hygiene* 90: 108–125.

**Bogdanov, S., Jurendic, T., Sieber, R. and Gallmann, P. (2008).** Honey for nutrition and health: a review. *American Journal of the College of Nutrition* 27: 677–689.

**Bogdanov, S. and Kilchenmann, V. (1994).** Sugar profiles and conductivity of stingless bee honeys from Venezuela. *Apidologie* 25: 271–288.

**Boussaid, A., Chouaibi, M., Rezig, L., Hellal, R., Donsi, F., Ferrari, G. and Hamdi, S. (2014).** Physicochemical and bioactive properties of six honey samples from various floral origins from Tunisia. *Arabian Journal of Chemistry* http://dx.doi.org/10.1016/j.arabjc.2014.08.011

**Buba, F, Gidado, A. and Shugaba, A. (2013).** Physicochemical and microbiological properties of honey from north east Nigeria. *Biochemistry and Analytical Biochemistry* 2(4): 1–7.

**Cantarelli, M.A., Pellerano, R.G., Marchevsky, E.J. and Camina, J.M. (2008).** Quality of honey from Argentina: study of chemical composition and trace elements. *The Journal of Argentine Chemical Society* 96(1-2): 33–41.

**Codex Alimentarius Commission (2001).** Revised standard for honey. Codex Standard 12-1981. Food and Agriculture Organization of the United Nations, Rome, Italy.

**Doner, L.W. (1979).** Isomerization of D-fructose by base: Liquid-chromatographic evaluation and the isolation of D-psicose. *Carbohydrate Research* 70(2): 209–216.

**EL-Metwally, A.A.E. (2015).** Factors affecting the physical and chemical characteristics of Egyptian beehoney. *PhD Thesis*, Cairo University, 320p.

**El Sohaimy, S.A., Masry, S.H.D. and Shehata, M.G. (2015).** Physicochemical characteristics of honey from different origins. *Annals of Agricultural Sciences* 60(2): 279–287.

**Escriche, I., Tanleque-Alberto, F., Visquert, M. and Oroian, M. (2017).** Physicochemical and rheological characterization of honey from Mozambique. *LWT - Food Science and Technology* 86: 108–115.

**EU Council (2002).** Council Directives 2001/110/EC of 20 December 2001 relating to honey. *Official Journal of European Communities L*. 10: 47–52.

**Fallico, B., Zappala, M., Arena, E. and Verzera, A. (2004).** Effects of conditioning on HMF content in unifloral honeys. *Food Chemistry* 85: 305–313.

**Gobessa, S, Seifu, E. and Bizabih, A. (2012).** Physicochemical properties of honey produced in Homesha district of western Ethiopia. *Journal of Apicultural Science* 56(1): 33–40.

**Government of Botswana (2005).** Botswana: Investment project profile *"Beekeeping development"*. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/3/a-af292e.pdf (retrieved 9 June 2017).

**IHC (2009).** Harmonised methods of the International Honey Commission. International Honey Commission (IHC), Bern, Liebefeld, Switzerland.

**Kayode, J. and Oyeyemi, S.D. (2014).** Physico-chemical investigation of honey samples from bee farmers in Ekiti State, southwest Nigeria. *Journal of Plant Sciences* 2(5): 246–249.

**Kinati, C., Tolemariam, T. and Debele, K. (2011).** Quality evaluation of honey produced in Gomma Woreda of south western Ethiopia. *Livestock Research for Rural Development* Volume 23(9), Article #190. http://www.lrrd.org/lrrd23/9/kina23190.htm (retrieved 8 June 2017).

**Kinoo, M.S., Mahomoodally, M.F. and Puchooa, D. (2012).** Anti-microbial and physico-chemical properties of processed and raw honeys of Mauritius. *Advances in Infectious Diseases* 2: 25–36.

**Lane, J. and Eynon, L. (1923).** Determination of reducing sugars by means of Fehling's solution with methylene blue as internal indicator. *Journal of Society of Chemistry of India* 42: 32–36.

**Lepetu, J.P., Thelo, O. and Sebina, N.V. (2008).** The potential of the beekeeping industry in enhancing rural household incomes in Botswana. *Bees for Development Journal* 104: 1–5.

**Makhloufi, C., Schweitzer, P., Azouzi, B., Oddo, L.P., Choukri, A., Hocine, L. and D'Albore, G.R. (2007).** Some properties of Algerian honey. *Apiacta* 42: 73–80.

**Marchini, L.C., Moreti, A.C.C.C., Otsuk, I.P. and Sodré, G.S. (2007).** Physicochemical composition of *Apis mellifera* honey samples from São Paulo State, Brazil. *Quimica Nova* 30(7): 1653–1657.

**McNally, L.C. and Schneider, S.S. (1996).** Distribution and nesting biology of colonies of the African honey bee *Apis mellifera scutellata* (Hymenoptera: Apidae) in Botswana, Africa. *Population Ecology* 25(3): 643–652.

**Mohammed, S.E.A.R. and Babiker, E.E. (2009).** Protein structure, physicochemical properties and mineral composition of *Apis mellifera* honey samples of different floral origin. *Australian Journal of Basic & Applied Sciences* 3(3): 2477–2483.

**Muli, E., Munguti, A. and Raina, S.K. (2007).** Quality of honey harvested and processed using traditional methods in rural areas of Kenya. *Acta Veterinaria Brno* 76: 315–320.

**Nascimento, A.S., Marchini, L.C., Carvalho, C.A.L., Araújo, D.F.D., Olinda, R.A. and Silveira, T.A. (2015).** Physical-chemical parameters of honey of stingless bee (Hymenoptera: Apidae). *American Chemical Science Journal* 7(3): 139–149.

**Nyau, V., Mwanza, E.P. and Moonga, H.B. (2013).** Physico-chemical qualities of honey harvested from different beehive types in Zambia. *African Journal of Food, Agriculture, Nutrition and Development* 13(2): 7415–7427.

**Ozcan, M., Arslan, D. and Ceylan, D.A. (2006).** Effect of inverted saccharose on some properties of honey. *Food Chemistry* 99: 24–29.

**Pearson, D. (1971).** The chemical analysis of foods. 6$^{th}$ Edition. Chemical Publishing Company Inc., New York, pp. 123–126.

**Pires, J., Estevinho, M.L., Feás, X., Cantalapiedra, J. and Iglesias, A. (2009).** Pollen spectrum and physico-chemical attributes of heather (*Erica* sp.) honeys of north Portugal. *Journal of the Science of Food and Agriculture* 89(11): 1862–1870.

**Phokedi, K.M. (1985).** Apiculture and its problems in Botswana. In: Proceedings of the 3$^{rd}$ International Conference on Apiculture in Tropical Climates, pp. 64–65. 5–9 November 1984, Nairobi, Kenya.

**Pokhrel, S. (2008).** The ecological problems and possible solutions of beekeeping in hills and terai of Chitwan, Nepal. *Journal of Agriculture and Environment* 9: 23–33.

**QSAE (Quality and Standard Authority of Ethiopia) (2005).** Ethiopian honey standard ES 1202:2005. Quality and Standard Authority of Ethiopia, Addis Ababa, Ethiopia, 17 pp.

**Rane, M.D. and Doke, K. (2012).** Physicochemical properties, antioxidant features of honey samples from ecological niches of western Maharashtra. *International Journal of Science and Research* 3(8): 1723–1727.

**Rodriguez-Otero, J.L., Paseiro, P., Simal, J. and Cepeda, A. (1994).** Mineral content of the honeys produced in Galicia (North-West Spain). *Food Chemistry* 49: 169–171.

**Statistics Botswana (2014).** Botswana in figures 2012/13. Statistics Botswana, Gaborone. http://www.statsbots.org.bw/sites/default/files/documents/Botswana%20in%20Figures.pdf (retrieved 9 June 2017).

**Terrab, A., Díez, M.J. and Heredia, F.J. (2002).** Characterisation of Moroccan unifloral honeys by their physicochemical characteristics. *Food Chemistry* 79(3): 373–379.

**Terrab, A., Diez, M.J. and Heredia, F.J. (2003).** Palynological, physico-chemical and colour characterization of Moroccan honeys: I. River red gum (*Eucalyptus camaldulensis* Dehnh) honey. *International*

*Journal of Food Science and Technology* 38(4): 379–386.

**Turner, Q. and Makhaya, B. (2014).** Beekeeping in Botswana. Paper presented at the ApiExpo Africa 2014 held in Harare Zimbabwe, 6–11 October 2014. http://www.apitradeafrica.org/Documents/CS_Papers-ApiExpoAfrica2014/Botswana_Apiculture_Situation_Paper_2014.pdf (accessed 13 June 2017).

**Tysset, C., Rousseau, M. and Duran, C. (1980).** Microbism and wholesomeness of commercial honey. *Apiacta* 15: 51–60.

**Vit, P., Oddo, L.V., Marano, M.L. and Mejias, E.S. (1998).** Venezuelan stingless bee honey characterized by multivariate analysis of physiochemical properties. *Aipdologie* 29(5): 377–389.

**White, J.W.Jr. (1975).** Physical characteristics of honey. In: Crane E. (ed.) Honey: A comprehensive survey. Crane, Russak & Company, Inc., New York. pp. 207–229.