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Original research article

# Beekeeping Practices, Physiochemical Properties and Consumer Acceptability of Honey Collected from the Forest and Backyard Hives in Pandamatenga, Botswana

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**Abstract** Beekeeping is an important agricultural activity in Botswana and supports the livelihoods of many people in the country. However, there is limited documented evidence on apicultural practices and quality of honey produced in different parts of the country. Pandamatenga village is located in north-eastern part of Botswana and is characterized by a hot semi-arid climate and dense natural vegetation cover. Due to its fertile soil and better rainfall relative to other parts of the country, Pandamatenga area has high agricultural potential. This study was conducted to assess beekeeping practices and determine the physicochemical properties and consumer acceptability of honey produced in Pandamatenga village. Honeybee production practices were assessed by conducting questionnaire survey. Three honey samples were obtained each from backyard hives and the forest and analysed for their physicochemical properties. Consumer acceptability test was also conducted on the honey samples using 9-point hedonic scale. Honey samples collected from backyard hives had an average moisture (%), total ash (%), free acidity (meq/kg), pH, reducing sugars (%), sucrose (%) and Hydroxymethylfurfural (HMF) (mg/kg) contents of 16.93±0.23, 0.13±0.042, 11.00±0.01, 6.67±0.01, 56.60±0.34, 1.54±0.00 and 26.00±0.10, respectively. The corresponding values for honey samples collected from the forest were 24.87±0.23, 0.35±0.144, 67.00±1.52, 4.28±0.02, 56.93±0.18, 1.17±0.14 and 33.17±0.60, respectively. Moisture, free acidity and HMF contents of forest honey samples were significantly higher ($p<0.05$) than the corresponding values for backyard honey. On the other hand, the pH and sucrose contents of backyard honey samples were significantly higher ($p<0.05$) than the corresponding values for forest honey. Backyard honey had significantly higher scores ($p<0.05$) for colour, appearance and grassy aroma as compared to forest honey. The survey result showed that Pandamatenga area has a big potential for honey production with an average of 20.7 liters of honey produced per household per year. In conclusion, honey produced in Pandamatenga area is of good quality and all the honey samples analysed were within the limits of international standards for honey.

**Keywords** Apicultural practices, Botswana, Chemical composition, Physical properties, Sensory quality

## INTRODUCTION

Beekeeping is an important agricultural activity and supports the livelihoods of millions of people in the world. Honey is the major product of honeybees and it has important nutritional and medicinal value and contributes significantly to the economic status of families. Honey is a sweet substance that bees make from nectars or juices and exudates that are found on living parts of plants (Nkoba, 2012). Honey can also be defined as the

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natural sweet substance produced by honeybees from nectars of flowers and honey dew (Codex Alimentations Commission, 2001). Honey produced by honeybees of the genus *Apis* is the most commonly utilized type worldwide. Honey is also produced by bumblebees, stingless bees, and other hymenopteran insects such as honey wasps, though the quantity is generally low and they have slightly different properties compared to honey from the genus *Apis* (Eardley, 2004).

The agriculture sector is the main source of food, income, and employment for majority of the population in rural areas in Botswana. The Government of Botswana promotes beekeeping to achieve these objectives. The total domestic production of hive products in Botswana was reported to be only 1.5% of the national demand (Turner *et al*., 2014). Botswana is a semi-arid/arid country with daily mean maximum temperature of 32°C (in summer) and mean annual rainfall varying from less than 250 mm in the southwest to over 650 mm in the extreme north (Turner and Makhaya, 2014).

Properties and composition of honey depend on its geographical flora origin, season, and environmental factors (Da Costa Leite *et al*., 2000). Honey is a remarkably complex liquid, which contains at least 181 substances including a wide range of minor constituents such as organic acids, amino acids, vitamins, phenolic compounds and volatile substances which are responsible for the characteristic flavour (Hussein, 2007). It is a high carbohydrate food and contains about 80−85% carbohydrates and the sugars are easily digestible as those in many fruits (White and Doner, 1980). According to Bogdanov *et al*. (2008), there are about 22 sugars in honey, fructose and glucose being the major sugars.

Honey is an important energy food and is used as an ingredient in hundreds of manufactured foods, mainly cereals-based products. It is easily digestible, very palatable and provides high calories for the body. Honey is known for its antioxidant and antimicrobial activity due to the presence of antimicrobial peptide defensin and phenolic compounds, which can inhibit or delay oxidation and prevent many diseases (Ilyasov *et al*., 2013).

The present study was conducted in Pandamatenga area, which is located in the north-eastern part of Botswana and characterized by a dense closed canopy forest. The vegetation of an area has a considerable influence on the physiochemical properties of honey. To date, no research has been conducted to characterise the quality of honey produced in the Pandamatenga area. There is lack of information regarding the quality of honey produced in Botswana in general and Pandamatenga area in particular. Thus, this study was conducted to assess beekeeping practices, physicochemical properties and consumer acceptability of honey produced and collected from the Pandamatenga area in Botswana.

## MATERIALS AND METHODS

### 1. Description of the study area

The study was conducted in Pandamatenga area, which is located in Chobe District at a distance of 821.2 km away from the capital city Gaborone. Chobe District is a semi-arid area, with hot and moist summer and dry/mild winter. This region is characterised by a relatively reliable growing season of 101−120 days (UNDP, 1968). Drought resistant crops such as sorghum can be grown without irrigation. The vegetation in Chobe District can be considered as a transition between the northern miombo woodlands and southern Kalahari savannas. Chobe is Botswana's wettest climate zone with annual average rainfall levels of 640 mm, January and February being the wettest months. An aquic (geology of a soil, that has been saturated by ground water at some time in the past) moisture regime occurs in poorly drained parts of the lacustrine area. This region has clay, loam soil which cracks when dry. The following are the dominant tree species found in Chobe District: *Acacia* species, *Baikiaea plurijuqa* (teak), *Beranemia* species, *Croton* species, *Combretum* species, *Cassia* species, *Sclerocarya birrea* subsp. *caffra* (marula), and *Ziziphus mucronata* (UNDP, 1968).

### 2. Survey

A semi-structured survey was conducted in Pandamatenga in January 2020 in order to determine honeybee production practices, the major tree/shrub species used as bee forage in the area, their flowering season, honey harvest time, method of collection and handling of honey, use of honey, constraints and opportunities for production of honey in the area. A total of 25 individuals/households were selected purposively based on their

experience and involvement in beekeeping and were interrogated through face-to-face interview techniques. Participants gave their informed consent prior to their participation in the study.

### 3. Sampling technique and sample size

Two types of honey samples were collected from Pandamatenga area in Chobe District. One of the honey samples was collected from the wild (forest) and the other honey sample was collected from backyard hives of farmers in Panadamatenga. Three honey samples (each 250 g) were collected from each of the two locations (forest and backyard hives).

The honey samples were transported to the Botswana University of Agriculture and Natural Resources (BUAN) and kept in the refrigerator pending analysis. Analysis of the physico-chemical properties of honey was carried out in the Food Science Laboratory at BUAN and in the Chemistry Laboratory of the University of Botswana. Sensory analysis was conducted in the Food Processing Laboratory of the Department of Food Science and Technology at BUAN.

### 4. Physicochemical properties of honey

Determinations of moisture, reducing sugars, sucrose, hydroxymethylfurfural, acidity, pH and ash contents of honey samples were carried out according to the harmonized methods of the International Honey Commission (IHC, 2009) and the revised Codex Standard for Honey (Codex Alimentarius Commission, 1987).

#### 1) Moisture content

The moisture content of honey samples was determined by measuring the refractive index of the sample using Abbe Refractometer using the relationship between refract 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. 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 closed for 4 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 the average value was recorded. The mean refractive index was converted to moisture content using the following formula:

Moisture content
= ( −log10 (Corrected Refractive Index −1) −0.2681)/ 0.002243 (Codex Alimentarius Commission, 1987).

#### 2) Reducing sugars

Reducing sugars content was determined by the modified Lane and Eynon (1923) method involving the reduction of Soxhlet 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).

An accurately weighed sample of 25 gram of honey was transferred from homogenized honey to 100 mL volumetric flask and 5 mL alumina cream was added to the flask. The honey was homogenized by stirring it with a glass rode. The sample was diluted with water to the volumetric capacity (100 mL) of the flask at 20°C and was filtered. 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 250 mL Erlenmeyer flask and approximately 5 mL Fehling's solution B was added into it and then seven mL of distilled water was added into 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 2 minutes. One mL of 0.2% methylene blue solution was added into the mixture whilst still boiling and the titration was completed within a total boiling time of 3 minutes by repeated small additions of diluted honey solution until the indicator was decolorized. The result was calculated and expressed as follows (Pearson, 1971):

$$C = (25/W) \times (1000/Y)$$

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.

#### 3) Apparent sucrose content

Sucrose content of the honey samples was determined according to the procedures of Pearson (1971). Honey solution was prepared as for the determination of redu-

cing 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 into it. The solution was allowed to cool for 15 minutes and brought to 20°C and neutralized with 5 M sodium hydroxide 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 similar procedure as for the determination of reducing sugars. The apparent sucrose content was calculated by a difference and expressed as follows (Pearson, 1971):

Apparent sucrose content
= (invert sugar content after inversion − invert sugar content before inversion) × 0.95.

The result was expressed as gram apparent sucrose per 100 g honey.

#### 4) Free acidity

Free acidity of honey samples was determined according to the procedures of Codex Alimentarius Commission (1987). 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 to a final pH of 8.50. Then the amount of NaOH solution used for titration was recorded. The result is expressed in milliequivalent (meq) of acid per kg of honey using the following equation (Codex Alimentarius Commission, 1987).

$$\text{Acidity} = 10V$$

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

#### 5) pH

Ten grams of honey sample was dissolved in 75 mL of carbon dioxide-free water (distilled water) in 250 mL beaker and stirred with magnetic stirrer. Then the pH was measured with pH-meter, which was calibrated using pH 4.0 and 7.0 buffer solutions (Codex Alimentarius Commission, 1987).

#### 6) Total ash

Ash content of honey samples was determined according to the procedures of Codex Alimentarius Commission (1987). 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 0.001 g ($m_0$) and added into the dish. Two drops of olive oil was added into 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:

$$\text{Ash (\% by mass)} = (m_1 - m_2)/m_0 \times 100$$

Where $m_0$ = mass of sample, $m_1$ = weight of dish and ash, $m_2$ = mass of dish used.

#### 7) Hydroxymethylfurfural (HMF)

Determination of hydroxymethylfurfural content of honey samples was based on the measurement of absorbance of HMF at 284 nm using UV Spectrophotometer. 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 was determined. The HMF content was then calculated after subtraction of the background absorbance at 336 nm (Codex Alimentarius Commission, 2001).

Five grams of honey sample was accurately weighed in 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 into the mixture to suppress foam. The mixture was filtered through filter paper (general purpose filter paper); rejecting the first 10 mL of the filtrate. Five mL of the solution was pipetted into each of the two test tubes (18 × 150 mm). Then five mL of water was added to one of the test tubes and mixed well (the sample solution) and five mL of sodium bisulphite solution (0.2%) was added to the second test tube and mixed well (the reference solution) using Vortex mixer. The absorbance of the sample solution against the reference solution at 284 and 336 nm, respectively was deter-

mined in 10 mm quartz cells within one hour of preparation.

The result was calculated as follows (Codex Alimentarius Commission, 2001):

$$\text{HMF in mg/kg} = (A284 - A336) \times 149.7 \times 5 \times D/W$$

Where: A284 = Absorbance at 284 nm, A336 = Absorbance at 336 nm, 149.7 = Constant, 5 = theoretical nominal sample weight, W = Weight in gram of the honey sample, D = Dilution factor.

### 5. Consumer acceptability test

Honey samples (i.e., honey collected from the wild and honey obtained from backyard hives of farmers) were served to 30 untrained panelists to evaluate how much they like the sensory qualities (grassy aroma, woody aroma, colour, thickness, sweetness and overall acceptability) of the honey using a 9-point hedonic scale (where 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither dislike nor like; 6 = like slightly, 7 = like moderately; 8 = like very much and 9 = like extremely). Bread was used as the carrier and honey was spread on the bread and the samples were labelled with three-digit random numbers. After and in between evaluation of each sample, the panelists rinsed their mouth with water to avoid carrying over effect (Lawless and Heymann, 2010).

### 6. Statistical analysis

Descriptive statistics was used to present the results of the survey study. Comparison of the physicochemical properties and consumer acceptability of honey samples was made between honey samples obtained from the forest and honey samples obtained from backyard hives. The data generated was analysed using a T-test.

## RESULTS AND DISCUSSION

### 1. Overview of beekeeping practices in the study area

Demographic characteristics of the respondents interviewed in the Pandamatenga area is reported in Table 1. The results showed that the majority of the respondents (96%) were aged between 20–50 years, which indicates that most of the beekeepers were in their economically active and productive age group, and were actively engaged in beekeeping activities. All of the interviewed farmers were exposed to formal education (Table 1). Most of the respondents completed secondary education (56%), 28% went to tertiary institutions while only a few (16%) attended primary school (Table 1). The findings of the present study are in agreement with the findings of Kalayu *et al*. (2017) who reported that 59.9% of the respondents in Ethiopia who were involved in beekeeping were aged between 15–49 years, which is similar to the present study. According to Bareki *et al*. (2019), most of the respondents involved in beekeeping in Lerala village in Botswana were aged between 31 and 50 years in line with the present study. These researchers also indicated that most of the respondents in Lerala village completed secondary education. On the contrary, Beyene and Verschuur (2014) found out that 33.3% of the respondents involved in beekeeping in Waghimara Zone in Ethiopia were illiterate and they could not read and write.

Hive types, sources of honey and equipment used by respondents interviewed in the study area are reported in Table 2. Modern hive is the predominant type of hive used in the area for honey production. In the study area, honey is mainly produced using the backyard production system (76%); however, a quarter (24%) of the honey produced in the study area comes from the forest. In Russia in the Ural Mountains, the local people Bashkirs also practice ancient breeding style of a dark forest bee, *Apis mellifera mellifera* in the hollows of trees in the wild forests. However, the wild honey obtained from

**Table 1.** Demographic characteristics of the interviewed beekeepers in Panadamatenga village (n = 25)

| Variables | Response | Percentage (%) of total respondents |
|---|---|---|
| Age (years) | 20–30 | 28.0 |
| | 31–40 | 40.0 |
| | 41–50 | 28.0 |
| | 51 + | 4.0 |
| Educational status | Primary school complete | 16.0 |
| | Secondary school complete | 56.0 |
| | Tertiary education | 28.0 |

n = total number of respondents.

the forest accounts for only 1% of all honey, and honey obtained in apiaries is 99% (Ilyasov *et al*., 2015). The present observation is in line with the findings of Bareki *et al*. (2019) who reported that most farmers in Lerala village use modern hives for honey production. This suggests that beekeeping is slowly growing in the country and people are starting to move from traditional ways of keeping bees to modern apicultural practices.

Almost all the respondents use the same types of equipment for beekeeping in the study area. The major equipment used for beekeeping in the study area include smoker, brush, gloves, bee knife, bowl and protective clothing (bee suit) (Table 2).

**Table 2.** Hives types, sources of honey and equipment used in beekeeping in Pandamatenga village (n = 25)

| Variables | Response | Percentage (%) of total respondents |
|---|---|---|
| Types of beehives | Traditional hive | 40.0 |
| | Modern hive | 60.0 |
| Sources of honey | Forest honey | 24.0 |
| | Backyard honey | 76.0 |
| Equipment used in beekeeping | • Smoker<br>• Bee knife<br>• Clean bowl<br>• Bee suit<br>• Gloves<br>• Bee brush | 100.0 |

n = total number of respondents.

Factors that determine choice of hive location, uses of honey and the quantity of honey harvested are reported in Table 3. According to the respondents, factors that determine the location of beehives in the study area include presence of shade, type of vegetation, supply of water, seclusion from human activity, indigenous plant species present in the area.

Honey is used for many purposes in the study area: honey is used for human consumption, used as body ointment, for wine making, used for medicinal purposes (wound healing) and as sweetener in drinks and food (Table 3). Honey promotes fast wound healing through its regenerative tissue growth and epithelization effects, with little or no scar formation (Molan, 2001; Al-Mamary *et al*., 2002; Bilsel *et al*., 2002; Chua *et al*., 2013). The average quantity of honey harvested per household per year in Pandamatenga villages was 20.7 ± 10.74 L (Table 3). The amount of honey produced depends on the climate, availability of water and availability of forage for the bees (Molan, 2001). Jiwa (2013) reported that annual honey production per beehive in Tanzania varies from 4 to 17 kg with a mean amount of 9.66 kg.

The dominant vegetation, flowering season and honey harvesting season in the study area are reported in Table 4. The findings showed that the dominant vegetation used as forage or nectar in the study area include *Helianthus annuus* (sunflower), *Sclerocarya birrea* (marula), *Citrus*

**Table 3.** Factors that determine choice of hive location, uses of honey and quantity of honey harvested per year per household in Pandamatenga village (n = 25)

| Variables | Response | Percentage (%) of total respondents |
|---|---|---|
| Factors that determine beehive location | • Presence of shade<br>• Type of vegetation<br>• Supply of water<br>• Seclusion from human activity<br>• Indigenous plants (wild lilac, borage) | 100.0 |
| Uses | • Human consumption<br>• Body ointment<br>• Medicinal purpose (wound healing)<br>• Wine making<br>• As a sweeter in drinks and food | 100.0 |
| Average quantity of honey harvested (liter) per household per year | 20.7 ± 10.74 L | |

n = total number of respondents.

**Table 4.** Dominant vegetation used as bee forage, flowering season and honey harvesting time in Pandamatenga village (n = 25)

| Variables | Response | Percentage (%) of total respondents |
|---|---|---|
| Dominant vegetation used as bee forage | • Sunflower (*Helianthus annuus*)<br>• Lemon trees (*Citrus limon*)<br>• Knob thorn trees (*Acacia nigrescens*)<br>• Marula tree (*Sclerocarya birrea*)<br>• Motsentsela (*Berchemia discolor*)<br>• Small plants that bear flowers (wild lilac) | 100 |
| Flowering season | Jan–Feb | 24 |
| | Autumn (March to June) | 44 |
| | Winter and summer (June to March) | 32 |
| Honey harvesting season | April | 16 |
| | February | 20 |
| | Winter (May, June, July) | 64 |

n = total number of respondents.

*limon* (lemon tree), *Acacia nigrescens* and *Berchemia discolor* (Table 4). Pandamatenga is a region where sunflower is grown at a large scale; hence it serves as the major bee forage in the area. The current results are in agreement with those of Bareki *et al.* (2019) who found out that sunflower, paw paw and citrus trees are used as bee forage in Lerala village. According to the respondents, honey harvesting season in the study area is February to June, which is different from the report of Bareki *et al.* (2019) who indicated honey harvesting time for Lerala village to be from November to May.

## 2. Physiochemical properties

Moisture content is one of the important parameters that determines honey quality. Moisture content influences taste, viscosity and fluidity of honey (Salazar *et al.*, 2017). The average moisture content of honey samples collected from backyard hives in the present study was 16.93% while the moisture content of honey samples collected from the forest was 24.87% (Table 5), which is in line with the findings of Ibrahim (1985) who reported moisture content ranging from 13.1–26.8% for honey samples produced in Sudan. The present finding is also similar to those of Terrab *et al.* (2004), Lazaridou *et al.* (2004) and Gobessa *et al.* (2012). However, according to EU Council (2002) and Codex Standard (Codex Alimentarius Commission, 2001), the recommended maximum moisture content of honey is set to be 20%. Variations in moisture content may be attributed to the floral source, temperature, relative humidity, method of extraction and storage conditions (Hussien, 2007).

**Table 5.** Physiochemical properties (mean ± SD) of honey samples collected from backyard hives and the forest in Pandamatenga village (n = 3)

| Parameters | Types of hives | |
|---|---|---|
| | Backyard hive | Forest |
| Moisture content (% by mass) | $16.93^{a} \pm 0.23$ | $24.87^{b} \pm 0.23$ |
| Total ash (% by mass) | $0.13^{a} \pm 0.042$ | $0.35^{b} \pm 0.144$ |
| Free acidity (meq/kg) | $11.00^{a} \pm 0.01$ | $67.00^{b} \pm 1.52$ |
| pH | $6.67^{b} \pm 0.01$ | $4.28^{a} \pm 0.02$ |
| Reducing sugars (% by mass) | $56.60 \pm 0.34$ | $56.93 \pm 0.18$ |
| Sucrose (% by mass) | $1.54^{b} \pm 0.00$ | $1.17^{a} \pm 0.14$ |
| HMF (mg/kg) | $26.00^{a} \pm 0.10$ | $33.17^{b} \pm 0.60$ |

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

The moisture content of honey samples collected from the forest was significantly ($p < 0.05$) higher than the moisture content of honey obtained from backyard hives (Table 5). According to Salazar *et al.* (2017), moisture content may compromise the shelf life of honey since it directly influences water activity and microbial growth and it also leads to fermentation of the honey in the package. High moisture maybe a result of lack of good

manufacturing practices at some harvest stages or it may be a sign of early harvesting which might have occurred when the honey was "green" or unripe (Salazar *et al*., 2017). Crane (1999) indicated that moisture content of honey depends on the temperature and relative humidity of the geographical region where the honey is produced. Terrab *et al*. (2003) reported that low moisture content helps promote longer shelf life of honey during storage.

The total ash content of honey samples collected from the forest was significantly ($p<0.05$) higher than the total ash content of honey obtained from backyard hives (Table 5). The average total ash content of honey in the present study was found to be 0.35% and 0.13% for forest and backyard honeys, respectively (Table 5). This result is in agreement with values reported in the literature. Ouchemoukh *et al*. (2007) reported that the ash content of honey from Algeria was found to be between 0.06−0.54%. The present observation is also in line with findings of Gobessa *et al*. (2012) who reported that honey produced in Homesha District in western Ethiopia ranged between 0.02−1.00%. The maximum ash content of honey allowed by the Codex standard (Codex Alimentarius Commission, 1987) is 0.6%. The values for ash content of honey observed in the present study are different from the findings of Terrab *et al*. (2004) who reported ash content of honey to range from 0.16−0.60%. According to Silva *et al*. (2009), ash content of honey gives an indication of the overall mineral content of honey. Vanhanen *et al*. (2011) indicated that ash is considered to be a quality criterion of honey which indicates possible botanical origin of the honey and also ash depends on the soil and climatic characteristics of honey origin.

Free acidity in honey is mainly due to the presence of organic acids particularly gluconic acid and it is an important parameter that is characterized by the presence of organic acids and some inorganic ions such as phosphates and chlorides (Moreira *et al*., 2007). Free acidity depends on the floral origin and storage conditions which can lead to variation in acidity of honey (Alves *et al*., 2013; Tornuk *et al*., 2013). Free acidity was found to be significantly different ($p<0.05$) for the two honey types (Table 5). The free acidity of honey samples obtained from backyard hives (11 mEq/kg) was significantly lower ($p<0.05$) than the free acidity of honey collected from the forest (67 mEq/kg). Honey with low acidity is a sign of good conservation as strong acidity promotes degradation of hexose to HMF (Finola *et al*., 2007; Ajlouni and Sujirapinyokul, 2010; Azonwade *et al*., 2018). The low free acidity observed in the backyard honey suggests that it is still fresh as compared to the forest honey. High free acidity can indicate fermentation of sugars and release of organic acids (de Silva *et al*., 2016) and it is related to deterioration of honey. Variation of free acidity among different honey samples can be explained by the blossom origin, the presence of different organic acids and inorganic ions, geographical origin and harvest seasons (Alves *et al*., 2013; Tornuk *et al*., 2013).

Similar observations were reported by Finola *et al*. (2007) and Ibrahim (1985) for free acidity of honey which were found to range from 11.9 to 29.4 mEq/kg and 6−171 mEq/kg, respectively. However, the values for free acidity of honey obtained in the present study are different from those of Terraab *et al*. (2004), Costa *et al*. (1999) and Serrano *et al*. (2004) who reported values ranging from 17.59−39, 81, 24.4−53.3 and 17.1−50.9 mEq/kg, respectively. According to Adgaba (1999), the national limit for free acidity of Ethiopian honey is 40 mEq/kg while according to Codex standard (Codex Alimentarius Commission, 2001), the maximum limit for free acidity of honey is 50 mEq/kg. Honey samples collected from the forest in the present study exceeded these limits. This may be because the forest honey samples might have been stored for a longer period after harvest, as storage affects the acidity of the honey.

The pH of honey samples obtained from the two sources (backyard and forest) showed significant ($p<0.05$) difference (Table 5). pH of forest honey (4.28) was significantly lower ($p<0.05$) than pH of honey samples obtained from backyard hives (6.67) (Table 5). The pH values of honey samples observed in the present study are in agreement with values reported in the literature. Terrab *et al*. (2004) reported that the pH of honey ranges between 3.56−4.79. Serrano *et al*. (2004), on the other hand, reported pH values ranging from 3.72−4.64 for honey, while Ouchemoukh *et al*. (2007) found pH value of honey to be 3.49−4.43. Moreover, Downey *et al*. (2005) indicated the pH of honey samples to be 3.75−4.61. All these values are in agreement with the pH of backyard hive honey observed in the present study. However, Pires *et al*. (2009) and Agbagwa *et al*. (2011) found very low pH values of 3.47−4.27 and 2.90−4.26, respectively for honey, which are different from pH val-

ues of honey observed in the present study. According to Terrab *et al*. (2002), honey is a naturally acidic food irrespective of the geographical origin which may be due to the presence of organic acids which contribute to flavor and stability against microbial spoilage. Acidity influences texture and is important in extraction process as it affects the honey as well as its stability and shelf life (Terrab *et al*., 2002; Terrab *et al*., 2014).

Carbohydrates in the form of sugars are major constituents of honey (Sato and Miyata, 2000). Solayman *et al*. (2016) reported that reducing sugars are reported to make up the largest portion of the sugars of honey. The average reducing sugars content of honey samples in the present study were found to be 56.60% and 56.93% for backyard and forest honey samples, respectively (Table 5). No significant difference ($p > 0.05$) in reducing sugars was observed between the two honey samples (Table 5). The present results are in agreement with the findings of Gobessa *et al*. (2012) who reported a value of 42–71% for honey samples collected from western Ethiopia. However, the values observed in the current study are lower than the values reported for Indian honey (62.2–70.2%) (Kumar *et al*., 2013) and Pakistani honeys (57.7–70.5%) (Fahim *et al*., 2014) but higher than values (34.5–50.3%) reported for Algerian honey (Ouchemoukh, 2007). Feàs *et al*. (2010) reported reducing sugars content of 64.5–80.0% for Portuguese honeys. Variations in honey's reducing sugar can be caused by many factors. According to Escuredo *et al*. (2012) and Tornuk *et al*. (2013), reducing sugar composition of honey depends on the honey's botanical and geographical origin and is affected by climate and storage condition.

The sucrose content of honey samples collected from backyard hives and those obtained from the forest was 1.53 and 1.17%, respectively (Table 5). The sucrose content of backyard honey samples was significantly higher ($p < 0.05$) than that of forest honey (Table 5). The sucrose content of honey samples assessed in the present study is in agreement with values reported in the literature. Serrano *et al*. (2004), Gobessa (2012) and Ouchemoukh *et al*. (2007) reported sucrose contents of honey to be 0.14–11.49%, 0.18–4.60%, 0.08–5.31%, respectively. Moreover, the values observed in the present study have not exceeded the recommended limit of 5% as stated in the Codex standard (Codex Alimentarius Commission, 2001). The present results are in line with the limits for (not more than 10%) Sudanese honey (SSMO, 2007).

Hydroxymethylfufural (HMF) is formed by decomposition of monosaccharides when honey is heated or stored (da Silva *et al*., 2016). HMF is also used to indicate the extent of heat applied on honey. Honey collected from backyard hives and the forest showed significant difference in HMF ($p < 0.05$) (Table 5). HMF of honey samples analysed in the present study were 26.00 and 33.16 mg/kg for backyard and forest honeys, respectively (Table 5). These findings are in agreement with literature values, which state that honey should have HMF value of less than 40 mg/kg (Codex Alimentarius Commission, 2000; Gobessa *et al*., 2012). HMF is used to indicate the freshness of honey, hence it is present in trace amounts in fresh honey and its concentration is reported to increase with storage and prolonged heating of honey. HMF is an important parameter used to show honey purity and adulteration. Thus, both the honeys samples considered in this study were fresh. HMF can be influenced by many factors including, heating, storage conditions, pH of honey and adulteration of honey with simple sugars from external sources (Pasias *et al*., 2017).

## 3. Sensory evaluation

The sensory acceptability of honey samples collected from backyard hives and the forest is presented in Table 6. The sensory attributes considered were colour, appearance, grassy aroma, woody aroma, sweetness, thickness and overall acceptability.

**Table 6.** Consumer acceptability of honey samples collected from backyard hives and the forest from Pandamatenga village (n = 30)

| Attributes | Types of hives | |
|---|---|---|
| | Forest | Backyard hive |
| Colour | $5.2^{a} \pm 0.00$ | $6.7^{b} \pm 0.00$ |
| Appearance | $5.4^{a} \pm 0.01$ | $6.9^{b} \pm 0.01$ |
| Grassy aroma | $4.8^{a} \pm 0.00$ | $6.4^{b} \pm 0.00$ |
| Woody aroma | $5.6 \pm 0.06$ | $6.4 \pm 0.06$ |
| Sweetness | $6.1 \pm 0.33$ | $6.7 \pm 0.33$ |
| Smoothness | $6.1 \pm 0.18$ | $6.8 \pm 0.18$ |
| Thickness | $5.6 \pm 0.62$ | $5.8 \pm 0.62$ |
| Overall acceptability | $5.7 \pm 0.28$ | $6.3 \pm 0.28$ |

Means with different superscript letters in a row are significantly different ($p \leq 0.05$); n = total number of panellists. Values in the Table are means and standard deviations of scores for each attribute.

(A) Wild honey (B) Backyard honey

**Fig. 1.** Picture of forest (A) and backyard (B) honey samples collected from Pandamatenga village.

There was a significant difference ($p<0.05$) in the acceptability of the colour of the two honey samples collected from the forest and backyard hives in Pandamatenga (Table 6). The scores for the colour and appearance of the honey from backyard hives were liked significantly more than that from the forest honey. The difference in the acceptability of the colours and appearance of the honey maybe attributed to the source of forage, the type of trees (flowers) and the storage time after harvesting. Honey samples collected from the forest had dark brown colour while honey samples collected from backyard hives had light brown colour (Fig. 1). The difference in colour between the two honey samples might be attributed to the long time that the honey might have stayed in the hive in the case of the forest honey and the good management practiced in the case of backyard honey. The results are in agreement with the findings of Kaakeh and Gadelhak (2005) who reported a significant difference among 13 honey samples collected from Arab Gulf region for colour, smell, thickness, mouth feel (texture) taste, sweetness and aftertaste. However, Belay *et al*. (2015) found no significance difference in colour acceptance for honey samples collected from Harenna forest in Bale Zone of Ethiopia. They further explained that Harenna forest honeys had extra light amber and light amber colours. Colour is an indication of flavour concentration, usually a lighter colour indicates a milder flavour (Amril and Ladjama, 2013).

There was a significant difference ($p<0.05$) in the acceptance of the grassy aroma between backyard and forest honey samples (Table 6). Backyard honey had significantly higher acceptance scores ($p<0.05$) than the forest honey (Table 6). The panellists liked the grassy aroma of honey samples obtained from backyard hives than those obtained from the forest. The difference in the grassy aroma observed might be attributed to the location of the hives. According to Mousa *et al*. (2019), that aroma of honey is usually derived from the plant origin.

No significant difference was observed in the woody aroma between the honey samples (Table 6). Azenedo *et al*. (2003) and Alvarez-Suarez *et al*. (2010) stated that aroma and texture of honey vary with the flower nectar from which it was made. Honey can be made from a variety of different flowers including thyme, lavender, colver, alfalfa, heather and *Acacia*.

Sweetness is determined by the taste bud of the panellists. No significant difference ($p>0.05$) in liking of sweetness was observed between the two honey samples although backyard honey had numerically higher scores for sweetness (Table 6).

Similarly, no statistical difference ($p>0.05$) was observed between the two honey samples for thickness and smoothness (Table 6). Ndife *et al*. (2014) found out that honey from Nigeria scored 6.13–6.48 for smoothness which is in line with the present results for forest honey which scored 6.08 in smoothness. Backyard honey scored 6.76 for smoothness which is higher than that of the forest honey. Texture of honey is affected greatly by temperature and water content and to a lesser extent by the composition of honey (Durrani *et al*., 2011). Therefore, this may explain the reason why forest honey was liked less because of the high moisture content it had which might have attributed to the low scores.

Castro-Vazquez *et al*. (2010) and Alissandrankis *et al*. (2003) stated that variation of sensory attributes is generally a consequence of different types of honey, different geographical and botanical origin (floral change), chemical composition, weather conditions, and beekeeping practices. In general, there were significant differences ($p < 0.05$) in colour, appearance and aroma between the two honey samples; however, there was no significant difference ($p > 0.05$) in the overall acceptability, woody aroma, sweetness, smoothness and thickness of the two honey samples (Table 6).

## CONCLUSION

The results showed that honey is used in Pandamatenga for direct human consumption, body ointment, medicinal purposes and wine making. Honey produced in Pandamatenga meets the quality criteria described in the Codex standard. All the parameters are in agreement with limits of international standards for honey. In Pandamatnga, honey is mainly produced in the backyards of farmers and the honey harvesting season in the area is from May to July. On the average, 20.7 litres of honey are harvested per household per year. The physiochemical analysis showed that honey from the forest had higher values for moisture content, free acidity and HMF. The consumer acceptability test showed that honey from backyard hives was liked more as compared to honey from the forest. There were significant differences ($p < 0.05$) in the colour, appearance and aroma of the two honey samples; however, there was no difference ($p > 0.05$) in the taste, texture and overall acceptability of the two honey samples.

The information generated in this study on the physicochemical and sensory quality of honey produced in Pandamatenga will contribute to future efforts of setting quality standards for honey produced Botswana.

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