J Food Sci Technol (September–October 2011) 48(5):628–634
DOI 10.1007/s13197-011-0329-9

SHORT COMMUNICATION

Effects of harvesting methods on physicochemical and microbial qualities of honey

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Revised: 12 February 2011 / Accepted: 18 February 2011 / Published online: 1 March 2011

Abstract Honey harvesting is accomplished using two main methods: traditional and modern methods; the former involves the use of naked flames to rid off or even destroy honey bees, while the latter involves use of smoke to suppress bees' aggressiveness. This research work investigated the effect of the method of harvesting on the quality of honey. The quality attributes investigated include: colour, total solids, viscosity, pH, diastase activity, acidity, sugars, ash, nitrogen, total antioxidants, hydroxymethylfurfural (HMF) content and microbial properties. The results revealed that the honey samples harvested using modern harvesting method had better quality in terms of ash content, total antioxidants, diastase activity, colour, sugars and microbiological attributes. The lower quality of honey harvested using traditional method could be attributed to the adverse effect of the burning during traditional harvesting on the quality of the honey. It is therefore concluded that modern method of harvesting honey produces better quality of honey and should be encouraged.

Keywords Honey quality · Traditional harvesting · Modern harvesting · Physico-chemical properties

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Introduction

Honey is a sweet fluid produced by honey bees from nectar derived from flowers. It is the nectar and saccharine exudation of plants, gathered, modified and stored in comb by honeybees (*Apis mellifera* and *Apis dorsata*) (Singh and Bath 1997). Bees also make natural blends of honey from many different flowers in areas where no flower predominates. Honey stipulates a pure product that does not allow for the addition of any other substance. Honey is a semi liquid which contains a complex mixture of carbohydrates, mainly fructose and glucose; other sugars are present as traces, depending on the floral origin. Moreover, organic acids, lactones, amino acids, minerals, vitamins, enzymes, pollen, wax and pigments are present (Fallico et al. 2004). Honey grading is performed voluntarily based on USDA standards. The quality of honey is graded based upon a number of factors including soluble solids, water content, flavours, aroma, clarity, absence of defects and colour. Because of its unique composition and the complex processing of nectars by the bees which changes its chemical properties, honey is suitable for long term preservation and is easily assimilated even after long conservation. One of the most important nonconventional dough improvers is honey (Kotoki and Deka 2010). Selomulyo and Zhou (2007) reviewed that honey is a good dough improver and improves the overall baking quality of dough/frozen dough. It also decreases staling and has a desirable effect on the colour development of crust and crumb of bread.

There are broadly two methods of harvesting honey which are the traditional (honey hunting) and modern methods of harvesting. These methods of harvesting could however have different effects on the quality and acceptability of the honey and create impression of adulteration

when on shelves. Because honey hunting usually takes place under difficult circumstances (swinging from a rope on a cliff face, high in trees at night time), the product from honey hunting is usually a mixture of ripe and unripe (i.e. high water content) honey, beeswax, dead bees and other debris. However, this is not to conclude that the product is of low value (Bradbear 2009). It is therefore essential to investigate the actual effects of these harvesting methods on the quality of honey and its acceptability; this will help in establishing the method of harvesting that produces the best quality of honey and will in turn provide information to consumers on the type of honey to purchase. The objective of this study was to investigate the effect of methods of harvesting on the physical, chemical, sensory and microbial attributes of honey.

Materials and method

Highlights of traditional method of harvesting honey

Traditional honey hunter visited wild honey bee colony established in wood logs and used naked flame to destroy the insects in order to prevent their aggressiveness. The honey, brood (immature bees) and pollen combs were harvested together without sorting. The combs were then pressed manually without sorting in order to extract the honey. Harvesting was done without prior assessment of the colony for honey maturity, since other rival(s) could harvest it ahead of the first hunter who discovered the wild colony.

Highlights of modern method of harvesting honey

Modern harvesting method involved harvesting from colony established in man-made bees' accommodation called hives. The beekeeper did not use flame, but rather he used smoke to suppress the bees' aggressiveness. Hence, the tendency of destroying the bees was greatly reduced. Thereafter, he selectively harvested matured honey combs. Comb was adjudged to be matured if up to 70% of its cells were capped with wax by the bees. Brood and pollen broods were left in the hives. Honey extraction was done manually by pressing the combs without the insects or other extraneous materials.

Collection of honey samples

Freshly extracted honey samples (500 ml each) were obtained from four sources within south western Nigeria. Two samples were obtained from modern harvesting method: (a) Ladoke Akintola University of Technology (LAUTECH), Ogbomoso Teaching and Research Apiary (Bee Farm) (b) Private Apiary, Saki. The other two samples were obtained from traditional harvesting method from Badagry and Saki. Ogbomoso (Lat. 8° 08′ 00″ N, Long. 4° 16′ 00″ E) was chosen because it hosts the office of the Beekeepers Association of Nigeria with modern beekeeping practices adopted in the university apiary for both teaching and research. Saki (Lat. 8° 39′ 06″ N, Long. 3° 25′ 34″ E) was chosen because it has a natural vegetation that supports beekeeping and it is known for merchandise of different shades of traditionally harvested honey. Badagry (Lat. 6° 26′ 38″ N, Long. 2° 54′ 23″ E) is also known for its honey market where honey is available almost all year round. The honey samples were stored in air tight plastic containers and protected from direct sunlight.

Qualitative analyses of honey samples

The specific gravity of honey was determined by dividing the weight of pycnometer (50 ml) filled with honey to the weight of the same pycnometer filled with recently distilled water (AOAC 1990 # 970.56). Colour was determined as its optical density without dilution (of honey) at 420 nm using spectrophotometer (AOAC 1990 # 985.25). Viscosity measurements were performed at ambient temperature. Viscosity of the undiluted honey was determined via viscometer. Sample was thoroughly mixed and filtered and was passed through a well calibrated digital viscometer (Brookfield digital viscometer USA (model DV-E MA 02346–1031) (AOAC 1990 # 925.10). Total solid was read on Abbe refractometer at 20° and the reading was recorded (AOAC 1990 # 925.23). For the estimation of total colloids, 10 g of honey was mixed with 10 ml of distilled water and centrifuged at 15,000 rpm for 15 min and percent sediment colloid residue was reported as total colloid contents according to the method described by Singh and Bath (1997). The pH was measured using a pH meter (Jenway Digital®). The pH meter was first calibrated at 4.0 and 7.0 buffers. The pH of honey samples was determined according to AOAC (1990) # 962.19.

The titratable acidity was determined by weighing 10 g of the sample which was diluted to about 100 ml with water and titrated to phenolphthalein end point with 0.1 N NaOH. The result was calculated as milliequivalents per kilogram (AOAC Official Method 962.19).

Diastase activity was also determined according to the method described by AOAC (1990) # 958.09. 5 g sample was weighed into 20 ml beaker; dissolved in 10–15 ml water and 2.5 ml buffer solution. It was transferred to 25 ml volumetric flask containing 1.5 ml NaCl solution. Five millilitre of starch solution was carefully dispensed into the side of reaction tube. The tube was placed into water bath at 40 °C. Contents were mixed by tilting tube back and forth several times. One millilitre aliquot was removed at 5 min and was determined in a photometer.

Sugars were determined and Lane-Eynon titration method was carried out. Ten millilitre of Fehling reagent

was placed in a 250 ml Erlenmeyer flask. 12.5 g of honey was dissolved in water and 25 ml of 10% neutral lead acetate solution was added. Some alumina cream was also added and was made up to 250 ml in a volumetric flask. The mixture was thoroughly shaken and filtered. Ten millilitre of 10% potassium oxalate was added to 100 ml of the fitrate and was made up to 500 ml which was then filtered. The solution was transferred into a burrette and was suspended over the Erlenmeyer flask which has been placed on asbestos wire gauze. Fifteen millilitre of the solution was added to the flask and heated to boiling. The solution was boiled for about 15 s and portion of honey solution was rapidly added until faintest perceptible blue colour remains. Two to five drops of 1% aqueous solution of methylene blue was added and the heating and addition of sugar solution continued until the titration was complete which was shown by the reduction of the dye. The result was calculated to percentage invert sugars. Fifty millilitre of the filtrate was inverted and polarized at 20 °C and 87 °C to obtain corresponding invert polarizations. Reducing sugars after inversion was also determined. The percentage of total reducing sugars before and after inversion was calculated as invert sugar. The sucrose content was determined by multiplying the invert sugar before and after inversion by 0.95. The dextrose content was determined by iodometric method. Fructose content = invert sugar−dextrose (FDALS 1982).

The ash contents were determined according to the method described by Williams et al. (2009). Two grams of the sample was ashed by incineration in a furnace at 600 °C to a constant weight. Ash percentage was calculated as:

$$\%\,\text{ash} = \frac{\text{Weight of Ash} \times 100}{\text{Weight of Sample}}$$

Nitrogen was determined by weighing 300 mg sample of honey in 30 ml digestion flask and 3.0 ml H_2SO_4; 1.9 g K_2SO_4 40±10 mg HgO and boiling chips were also added and was digested for 1 h after all water was distilled and acid came to true boiling. The mixture was cooled and water was added to dissolve solids. The digest was transferred into distillation apparatus and the flask was rinsed with 2 ml of water. One hundred twenty-five millilitre Phillips beaker containing 5 ml saturated H_3BO_3 solution and two to four drops methyl red methylene blue indicator. Eight millilitre NaOH was added to still. Fifteen millilitre distillate was collected and titrated with HCl to gray end point (AOAC 1995 # 969.38). Blank determination was made and % N was calculated.

$$\%\text{N} = \{(\text{ml HCl} - \text{ml blank}) \times \text{normality} \times 14.007 \times 100\}/\text{mg sample}$$

The antioxidant in honey was determined according to FDALS (1982). One millilitre of the above extract was oxidized with 1 ml of Folinciocalteau reagent diluted with reverse osmosis de-ionized water and incubated for 6 min in an incubator. Immediately after incubation, the reaction was neutralized with 3 ml of 70 g/l Na_2CO_3 (*v*/*v*). Standard Gallic Acid solutions of range 0.1 mg/ml–0.5 mg/ml were prepared from 1 mg/ml stock Gallic Acid solution. The standard solutions were treated like sample and incubated for same period of time. The absorbance of the resulting blue colour solutions for sample and standard solutions were read at a wavelength of 750 nm on a spectronic 21DUV spectrophotometer.

$$\text{Total Antioxidant} = \frac{\text{Absorbance} \times \text{Gradient} \times \text{Dilution factor}}{\text{Wt of sample} \times 10,000}$$

The hydroxymethylfulfural was determined according to FDALS (1982). Ten grams of the honey was weighed and dissolved in 20 ml of oxygen-free water. Fifty (50) ml transferred to volumetric flask and made up to the mark. 2.0 ml of the honey solution was pipette into each of two test tubes. 5.0 ml of p-toludine solution was added to each of the tubes. One millilitre of water was added to one test tube and 1 ml of the barbituric acid solution to the other. Both test tubes were mixed by shaking. The whole procedure was done without pausing and took 1–2 min. The absorbance of the sample was determined against the blank (the test tube to which barbituric acid was not added) at 550 mm using a 1 cm cell. This was done immediately the maximum colour intensity was reached.

Total viable count and yeast counts were determined according to Harrigan and McCane (1976). One millilitre of the honey was aseptically measured into a sterilized McCartney bottle and 9 ml of sterilized distilled water was added and shaken vigorously on a vortex mixer which gave homogenous suspension to be serially diluted. From the homogenous suspension, 1 ml of 10^{-1} to 10^{-6} dilution was placed on a plate containing nutrient agar and incubated for 24 h at 37 °C. After 24 h, the slide was observed and read under microscope for microbial growth. The same ml was aseptically poured on a plate containing potato dextrose agar (PDA) and incubated for 6 days at 28 °C. After 6 days, the slide was observed and read under microscope for any yeast growth.

The sensory evaluation was done by a panel of 20 judges drawn from the students of the Department of Food Science and Engineering and other departments, LAUTECH, Ogbomoso, Nigeria. The sensory evaluation was done by ranking tests.The panelists received coded samples and were asked to rank them for intensity of colour, odour, taste and overall acceptability. The honey samples were ranked in order of preference with the most preferred ranking first, the second preferred ranking second, the third preferred ranking third and the least preferred ranking fourth. The

ranks were converted to scores and the scores were then subjected to analysis of variance.

Experimental design and statistical analysis

The experiment was designed in Completely Radomized Design (CRD). The results were subjected to analysis of variance (ANOVA) with turkey's multiple comparisons used to check for significant difference among the samples.

Results and discussion

The value obtained for the physical quality attributes of the honey samples are presented in Table 1.

Total solids The percentage of total solids found in the honey samples ranged between 72.2% in the honey harvested using traditional method to 76.5% in the honey harvested using modern method (Table 1). The total solids content of honey harvested using modern method was significantly higher at $P \leq 0.05$ than that of honey harvested using traditional method. The total solids of honey are mainly sugars with fructose and glucose accounting for about 85% (Crane 1990).

Total colloids Percentage total colloids in the honey samples ranged from 22.1% in honey harvested using traditional method to 50.5% in honey harvested with modern method and was significantly different at $P \leq 0.05$ (Table 1).

Specific gravity The specific gravity of the honey samples ranged from 1.2 g/cm^3 in honey harvested using traditional method to 1.4 g/cm^3 in honey harvested using modern method (Table 1). The values were significantly different at $P \leq 0.05$. Specific gravity of honey is dependent mainly on water content and floral sources. The higher specific gravity in honey harvested using modern method could be as a result of floral sources fed on by the bees as also reflected in total solids of honey harvested from bee hives. The variation in specific gravity could be due to chemical composition. Singh and Bath (1997) reported specific gravity of 1.5 g/cm^3 in Trifolium honey.

Colour The honey samples had absorbance values ranging from 0.27 nm in honey harvested using modern method to 0.38 nm (Table 1) in honey harvested using traditional method and were significantly different at $P \leq 0.05$. Honey harvested using modern method had a lighter colour. This implies that honey harvested using modern method from man-made bee hives was of higher quality in colour compared to the honey harvested using traditional method from the wild. The darker colour of honey harvested using traditional method confirms the findings of White and Landis (1980) who reported that climate and heat may modify colour through darkening action of heat. Also, Wintersteen et al. (2005) reported that amino acids are known to react rapidly with sugars while heating to produce yellow or brown materials. The darker colour of the honey harvested using traditional method could also be due to presence of soot produced while harvesting.

Total viable count Total viable count of micro-organism in the honey samples ranged from 2.9 log cfu/g in honey harvested using modern method to 3.1 log cfu/g in honey harvested using traditional method (Table 1). From the results obtained, the total viable count in honey harvested using traditional method was higher. This could be as a result of inadequate hygienic practice during harvesting and extraction of honey from its combs and storage.

Total yeast count Total yeast count of the honey samples ranged between 1.1 log cfu/g in modern harvested honey

Table 1 Quality of honey samples harvested using different harvesting methods

Sample	Physical properties				Microbial analysis		Sensory attributes			
	Total solids (%)	Total colloids (%)	Specific gravity (g/cm3)	Colour (nm)	Total viable count (log cfu/g)	Total yeast count (log sfu/g)	Taste	Colour	Odour	General acceptability
A	76.5±0.52a	43.0±0.10a	1.3±0.05a	0.27±0.04a	3.1±0.02b	1.1±0.01a	2.5±0.03a	2.4±0.01a	2.0±0.19a	2.5±0.04b
B	76.3±0.06a	50.5±0.86a	1.4±0.01a	0.29±0.02a	2.9±0.07a	1.2±0.02a	2.6±0.01a	2.5±0.03a	2.5±0.15a	3.1±0.11a
C	74.1±1.12b	22.1±1.27b	1.2±0.03b	0.30±0.03b	3.1±0.01b	1.1±0.01a	2.3±0.02a	2.0±0.05b	2.4±0.12a	2.7±0.08b
D	72.2±0.22b	24.3±0.15b	1.3±0.01a	0.38±0.01b	3.1±0.02b	1.2±0.02a	1.1±0.01b	1.5±0.02c	1.1±0.01b	1.6±0.03c

Mean±SD with the same alphabet in a column are not significantly different ($P<0.05$) ($n=3$). *A* Honey harvested from Ladoke Akintola University of Technology (LAUTECH) Apiary Ogbomoso using modern method, *B* honey harvested from a private apiary in Saki using modern method, *C* honey harvested using traditional method from Saki, *D* honey harvested using traditional method from Badagry, *Cfu* colony forming per unit, *Sfu* spore forming per unit

and 1.2 log cfu/g in honey harvested using traditional method. There was no significant ($P>0.05$) difference between the two harvesting method (Table 1). Higher yeast count in honey harvested using traditional method could be as a result of fermentation due to inappropriate method of harvesting which involves immature combs and broods that accelerated rate of fermentation.

Sensory evaluation From Table 1, it was observed that samples A and B which are honey samples harvested using modern harvesting method had the highest preference for colour. This is attributed to their light golden colour which is more attractive and desirable by consumers. Burning led to darkening of honey (White and Landis 1980). It was also observed that for taste and odour, there is no significant difference ($P>0.05$) between the preference for samples A, B and C but was significantly different ($P\leq0.05$) for sample D. The possible reason for this could be higher adverse influence of burning on sample D. Though sample C was also harvested using traditional method, the effect was milder and therefore acceptable to the consumers. In terms of overall acceptability, sample B which was harvested using modern method was the most preferred.

Hydroxymethylfulfural (HMF) content From the result in Table 2, the HMF content of the different honey samples ranged from 23.9 mg/kg in honey harvested using modern method to 27.2 mg/kg in honey harvested using traditional method. The values obtained in this study are below the maximum limit of 40 mg/kg specified by Codex Standard. There was no significant difference ($P>0.05$) between the HMF content of honey samples; however, the value of HMF in honey harvested using traditional method was higher than the value in honey harvested using modern method. Tosi et al. (2002) reported that thermal treatment can increase HMF content of honey. Overheating of honey sample during processing or storage for very long period could lead to conversion of sugars to HMF (Saxena et al. 2010). Therefore honey treatment temperature and time must be limited when pasteurizing and stabilizing. According to Fallico et al. (2004), HMF concentration in honey is also related to honey composition (pH, acidity) particularly at low heating temperatures. HMF is produced in honey to some degree all the time and is a breakdown product arising from the action of normal honey acidity on sugars (glucose and fructose) at ambient temperature. Naturally, occurring levels of HMF are about 10 mg/ kg (Crane 1990). The amount formed however increases with increase in heat treatment.

Diastase activity The honey harvested from both traditional and modern harvesting methods have diastase ratio ranging between 19.1 to 21.8 schade units (Table 2). The honey harvested using traditional method had significantly lower value of diastase activity when compared with the honey harvested using modern method. The lower value can be attributed to the effect of heat applied during harvesting. This confirms the findings of Fallico et al. (2004) who reported deactivation of natural enzymes by heating and Wintersteen et al. (2005) who reported that high temperature lowers enzymes activity. Sahinler and Gul (2004) also reported diastase activity in honey produced in Turkey from sunflower, cotton, orange and pine to be 23.4, 23, 10.9 and 29.4 respectively. In Spain, Perez-Arquille et al. (1995) reported diastase activity to depend on botanical origin of honey and ranged from 16.9 to 46.6 schade unit.

Acidity The values of acidity obtained ranged from 22.3 meq/kg in honey harvested using modern method to 37.5 meq/kg (Table 2) in honey harvested using traditional method. This is within the range specified by CAC (1998) with a maximum limit of 40 meq/kg and confirms the findings of Williams et al. (2009) who reported variation in acidity due to source of nectar. The values were significantly different at 5% probability level. Baroni et al. (2009) reported total acidity of honey from southern and northern Cordoba, Argentina to range from 24.4 to 25.4 meq/kg and this indicated the absence of undesirable fermentation. Sahinler and Gul (2004) also reported varying acidity values for honey produced from sunflower, cotton, orange and pine to be 40.73, 25.24, 34.96 and 25.76 meq/kg respectively. Higher acidity value in honey harvested using

Table 2 Physicochemical properties of honey samples harvested using different harvesting methods

Samples	HMF content (mg/kg)	Diastase Activity (Schades unit)	Acidity (meq/kg)	Viscosity (centipoise)	pH	Sucrose (%)	Fructose (%)	Glucose (%)	Ash content (%)	Nitrogen (%)	Total antioxidant (%)
A	27.2±0.10a	21.8±0.41a	22.3±1.25a	14.7±0.33a	3.4±0.08a	0.83±0.07a	37.0±0.14a	28.8±0.48a	0.37±0.03a	0.26±0.01a	13.5±0.09a
B	26.3±0.39a	21.5±0.10a	27.0±1.00a	13.6±0.25b	3.3±0.05a	0.80±0.01a	36.3±0.01b	27.4±0.03a	0.37±0.01a	0.26±0.05a	13.3±0.03a
C	25.1±0.22a	20.0±0.16	33.0±1.63b	16.5±0.25c	3.5±0.22b	0.58±0.07b	35.7±0.45c	26.6±0.76b	0.28±0.03b	0.20±0.01b	11.9±0.14b
D	23.9±0.24a	19.1±0.16c	37.5±1.50b	15.6±0.15c	3.7±0.10b	0.54±0.02b	34.1±0.19c	25.0±0.12b	0.28±0.02b	0.21±0.01b	11.5±0.01b

Mean±SD with the same alphabet in a column are not significantly different ($P<0.05$) ($n=3$)

traditional method could be due to floral sources i.e source of nectar and pollination by wild bees due to unrestricted environment. High value of acidity could also be due to fermentation of honey due to inappropriate method of harvesting which involves immature combs and broods that accelerate rate of fermentation. According to Costa et al. (1999), xerotolerant yeast may also be responsible for high total acidity.

Viscosity The values of viscosity obtained ranged from 13.6 cP in honey harvested using modern method to 16.5 cP in honey harvested using traditional method (Table 2). The values were significantly different at 5% probability level. The higher values in honey harvested using traditional method are an indication of heat application as the viscosity of a heat-treated honey increases with increasing ultimate heating temperature (Abu-Jdayil et al. 2002).

pH The pH values of all the honey samples ranged from 3.3 to 3.7 (Table 2) and these agreed with findings of Bogdanov (1999) and CAC (1998) which specified a pH range of 3.42 to 6.10. The values obtained were significantly different ($P \leq 0.05$) with honey harvested using traditional method having higher values. The pH of honey collected in south and north Cordoba, Argentina ranged between 3.14 and 5.05 (Baroni et al. 2009). In another study in India, Saxena et al. (2010) reported pH values that ranged from 3.9 to 4.4. This parameter is of great importance during extraction and storage of honey as it influences the texture, stability and shelf life of honey (Terrab et al. 2004). According to Kamal et al. (2002), difference in pH may be due to variation of different acids and minerals present in honey. Higher pH values obtained from honey harvested using traditional method could be as a result of fermentation due to inappropriate method of harvesting.

Sucrose content The sucrose content of the honey samples ranged between 0.54% for honey harvested using traditional method and 0.80% (Table 2) for honey harvested using modern method and was significantly different at $P=0.05$. The presence of sucrose below 5% as specified by CAC (1998) indicates that the bees were not artificially fed with sugar.

Fructose and glucose Reducing sugars which include mainly glucose and fructose are the major constituent of honey (Kucuk et al. 2007). A lime honey from Romania had 42.49% of combined glucose and fructose content (Al et al. 2009). The sum of fructose and glucose in all the honey samples were above 60 g/100 g (Table 2) as specified by CAC (1998) and accounts for more than 60% of the honey weight (Finola et al. 2007). Crane (1990) reported that glucose and fructose which are the two major sugars in honey are the main factor in determining the tendency of honey to crystallize. Generally, the higher the glucose, the faster honey crystallizes, and the higher the fructose, the slower it crystallizes. From the result in Table 2, all the honey samples had higher values of fructose, thus indicating they are less susceptible to early crystallization. Other factors that may cause crystallization include higher molecular weight sugars (oligosaccharides), acidity and available water (Crane 1990).

Ash content Ash content represents the mineral content of the honey. The values of the ash content of the honey samples ranged between 0.27% in honey harvested using traditional method to 0.37% in honey harvested using modern method (Table 2). The ash content values were within the range (0.095–0.518%) reported by Adebiyi et al. (2004). Saxena et al. (2010) reported a range of 0.03–0.43% ash content in some Indian honeys of different botanical origins. Baroni et al. (2009) reported 0.2% and 0.07% ash content ash in northern and southern Cordoba Provenance, Argentina, respectively. dos Santo et al. (2008) reported the ash contents of honey from three geographical zone ranged from 0.04 to1.03 and the zones had significant effect on the ash contents of honey samples. Values obtained in this study are in agreement with standard values of less than 0.6% specified by the Codex Standard. According to White and Landis (1980), dark honey is higher than lighter honey in ash (mineral) and contains significant qualities of minerals. In this study, the honey harvested using modern method, though lighter in colour, had significantly higher ash content. The higher percentage of ash could be due to the nectar and flora of plant fed on by the bees which in turn increased the honey's mineral content.

Nitrogen content The nitrogen content which is an indication of the presence of protein was found highest in modern harvested honey. The values obtained ranged between 0.20% and 0.26%. At probability of 5%, nitrogen content in modern harvested honey was found higher than that in traditional harvested honey (Table 2). This implies that more nitrogen is retained in modern harvesting method.

Total antioxidants The total antioxidants values obtained for the honey samples ranged between 11.5% in honey harvested using traditional method to 14.7% in honey harvested using modern method (Table 2). Total antioxidants in honey harvested using modern method were significant at 5% probability. The antioxidant capacity of honey is primarily due to their phenolic composition. Lower antioxidant in traditional harvested honey could be

due to adverse effect of heat during harvesting. This confirms the findings of Wintersteen et al. (2005) who reported that heat treatment has the potential to alter the antioxidant capacity by changing the phenolic profiles.

Conclusion

The results obtained from the analyses revealed that honey harvested with modern harvesting method from bee hives was better in terms of physical attributes, physicochemical composition and microbial activities. The honey samples harvested using modern methods also had lower bacterial and yeast counts, an indication of a safe hygienic procedure during harvesting and extraction of honey from combs. Bush burning or exposure of colony to naked fire also kills adult bees and hampers the natural process of cross pollination in flowering vegetation and may lead to consumption of the whole forest.

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