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Assessment of Quality of Tanzanian Honey based on Physicochemical Properties

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Abstract
Quality of Tanzanian honey based on physicochemical parameters namely water content, sugar content, pH, ash content, hydroxymethyl furfural (HMF) and honey colour was studied using 26 honey samples collected from ten popular honey producing regions. Analyses were carried out in triplicates using standard methods. Data was analysed using averages, correlation and ANOVA tests. Majority of the honeybees' honey samples were light coloured while all stingless bees honey samples were dark coloured. Dark coloured honeys contained more minerals; mainly iron, copper and manganese which make them especially fit for medicinal purposes. pH values ranged from 2.61±0.12 to 4.37±0.08, stingless bees honey samples were more acidic than honeybees' honey samples. Total sugar content values (64.16-84.84 g/100g) were all above the minimum requirement of the national and international standards of not less than 60g/100g. HMF values ranged from 5.0 – 26.4 mg/kg honey, an indication of good quality, being far below the maximum limit allowed by national and international standards of 40mg/kg or 80mg/kg for honeys from the tropics. Of the 26 honey samples studied, all 5 honey samples from stingless bees and 3 from honeybees had moisture content levels above 21%, the maximum limit allowed by national and international standards.. With the exception of two samples from stingless bees, all honeybees honey samples met the minimum requirements of national and international quality standards of maximum allowable ash content of 0.6 %. ANOVA results showed significant differences in the studied physicochemical parameters between groups of honey samples, namely processed honey raw honey and stingless bees' honey at P<0.05. Pearson correlation analysis showed strong correlation coefficients at P<0.05 between some parameters studied. In conclusion honey colour and moisture content are two important physicochemical parameters that may be used to assess quality of honey.

Keywords: Honey quality, Physicochemical parameters, Honey colour, HMF, sugar content, Moisture content

1. Introduction

Traditionally, honey in Tanzania has been used as food, medicine, raw materials for industries, and as a source of income. In the recent years, honey production and trade in Tanzania has become an important income generating activity for the economic development of beekeepers, business community and the country at large, serving as a foreign exchange earner. This is evidenced by the renewed effort by the government to encourage and support beekeeping industry in Tanzania (Tanzania Honey Council, 2012). These efforts will bear fruits if the honey produced meets international honey quality standards.

Acceptability of honey depends on its quality which can be assessed by among other things its physicochemical characteristics. Many studies have been done to show the quality of honey based on its physicochemical characteristics (Amulen *et al.,* Khalil *et al.*2012, Liberato *et al*., 2013, Shahnawaz *et al*., 2013,). Natural honey is normally sticky and viscous solution, with water content of 15-20%, pH of 3-5, sugar content of 65% and above, high viscosity, hydroxymethyl furfural (HMF) levels not exceeding 40 mg/kg and ash content of up to 0.6% (Codex Alimentarius Commission, 2001a). Honey also contains small quantities of vitamins, enzymes and phenolic antioxidants (Buba *et al.,* 2013). These miner constituents confer medicinal properties on honey such as treatment of burns and wounds.

There are reports which indicate that the colour of honey play important roles in classifying or grading different samples. Lighter honeys are said to contain more sugars than darker honeys, where as darker honeys are reported to have more phenolic content than lighters honeys (Eleazu *et al*., 2012, 2013). These are among the major indicators of interest on honey quality. Honey physicochemical quality criteria are well specified in the Codex Alimentarius Commission (2001a and 2001b), EU Council (2001) and Tanzanian Honey Standards (2007).

The quality of honey is often judged by few physicochemical factors. Good quality honey has low water or moisture content, less than 20%, since higher proportion of water may enhance honey spoilage through fermentation yeasts. Hydroxymethylfurfural (HMF, 5-hydroxymethyl-2-furaldehyde) is a recognized indicator of reduced quality in numerous foods that contain carbohydrate (Rattanathanalerk *et al*., 2005). The presence of HMF in levels higher than 40 mg/Kg is a sign of honey degradation through heating or long storage in hot conditions (Morales *et al*., 2009). For most consumers, good quality honey is expected to be clean and clear. Although honey containing pollen may offer high nutritional value, its cloudy appearance makes it commercially unattractive (NHB and AIB 1990). The colour of honey is of great interest to both honey producers and consumers. It is used by producers to present a perceived value and suggest possible uses for each type of honey. Honey colour preferences are highly personal and sometimes cultural. While colour may not be an indicator of honey quality (USDA, 1985), it is generally perceived that the darker colour the honey, the higher its mineral contents and pH readings (Eleazu *et al*., 2013). Yet in many areas, light honeys are more popular and more expensive.

Little research has been done in Tanzania to assess the quality of honey produced for both domestic consumption and export based on physicochemical characteristics. Gidamis *et al.* (2004) carried a quality evaluation of honey from selected areas of Tanzania with the bias on HMF. The present study is intended to provide more information on quality of Tanzanian honey based on six physicochemical parameters namely water content, sugar content, pH, ash content, HMF and honey colour. The relationship among the parameters as an indicator of honey quality will be explored. The information will be useful as a quick indicator to predicting honey quality from Tanzania.

2.0 Materials and Methods

2.1 Sample collection

A total of 26 honey samples originating from 10 popular honey producing regions in Tanzania were collected and used in this study. Among the samples, 21 were honey from the common honey bees (*Apis mellifera*) and 5 samples were honeys from the small stingless bees (M*elipona species*). Of the honey bees' honey, 16 samples were processed honey for commercial use and 5 samples were raw honey in combs (See Table 1). Raw honey bees' honeys were collected directly from the farmers, and the majority of the remaining samples we obtained from the Dar es Salaam International Trade Fair in July 2013 and July 2014 where honey exhibitors from the various regions displayed their products. The sources of origin of all processed honeys were determined by the manufacture's labels. All samples were kept in air-tight containers and preserved in room temperature (26-28 ^{0}C) in a cupboard until use.

Table 1: List of Honey samples used in this study

SN	**Sample number**	**Origin (Region)**	**Description**
Honey samples from Honey bees			
1	3 Uvinza	Kigoma	Processed and packed for commercial use
2	9 Manyoni	Singida	
3	13 Handeni	Tanga	
4	16 Ruangwa	Lindi	
5	17 Mbeya 1	Mbeya	
6	18 Dodoma	Dodoma	
7	28 Mbeya 2	Mbeya	
8	52 Tabora 2	Tabora	
9	53 Tabora 3	Tabora	
10	55 Mugumu	Mara	
11	56 Geita 1	Geita	
12	58 Kasulu	Kigoma	
13	59 Chunya	Mbeya	
14	60 Mbulu	Arusha	
15	62 Kondoa 2	Dodoma	
16	68 Tabora 6	Tabora	
Raw honey samples from honey bees			
17	23b Kondoa 1 C1	Dodoma	Raw honey in combs collected from beekeepers
18	51 Tabora 1 C2	Tabora	

19	65 Kondoa 3 C3	Dodoma	
20	66 Tabora 4 C4	Tabora	
21	67 Tabora 5 C5	Tabora	
Honey from Stingless bees			
22	19 Urambo S1	Tabora	Stingless bees' honey packed for commercial use
23	20 Kibondo S2	Kigoma	
24	22 Biharamulo S3	Kagera	
25	23a Usariver S4	Arusha	
26	57 Geita 2 S5	Geita	

2.2 Colour analysis
All 26 honey samples were placed in clean and clear McCartney bottles and observed against the colour grading chart (Figure 1) by Panaromic Hill Honey Collective (2013).

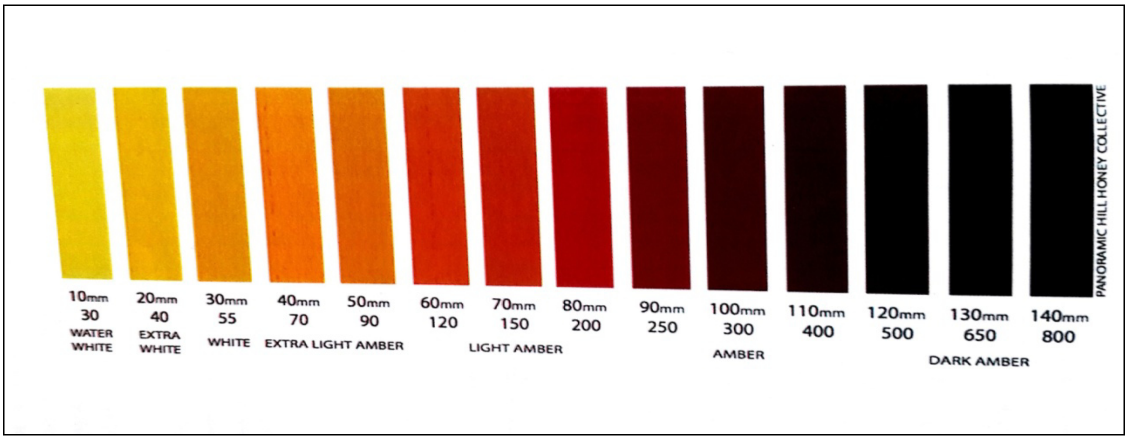

Figure 1. Honey colour grade guide *(Source:* Panaromic Hill Honey Collective, 2013).

Honey sample colours were named and assigned a rank according to USDA Honey Colour Grading Chart (USDA, 1985). The impact of honey colour on other honey quality parameters was explored by conducting Pearson correlation tests.

2.3 pH measurement
pH of honey samples was determined using a digital portable pH meter - Thermo Scientific RUSSEL RL 060P in accordance with AOAC (2,000). In between the readings of different samples, the electrode was washed with distilled water and dried with tissue paper. Occasionally, very thick honey samples were diluted two times with distilled water before inserting the electrode. The experiment was done in triplicates

2.4 Determination of total sugar content
Total sugar content was determined using a Refractometer - Metler Toledo Densito 30PX which was calibrated according to the manufacturer's instructions. One millilitre of each honey sample was weighed, diluted ten times, mixed well and was filtered using Whatman filter paper before measurement. Filtration process was necessary to remove suspended particles such as pollen grains, small pieces of combs and other impurities which could interfere with measurements. The values expressed in ^{0}Brix were later converted to g sugar/g honey (Journal paper). The experiment was repeated three times to obtain mean and standard deviation values.

2.5 Determination of Moisture content
Moisture content was determined using a standard method described by AOAC (2000). About 2 ml of honey samples in triplicates were put in pre- weighed dried crucibles, kept overnight in an oven at 110 ^{0}C and weighed. The loss in weight was taken as a measure of moisture content (Shahnawaz *et al.,* 2013) calculated by the following formula

$$Moisture\ (\%) = \left(\frac{Weight\ of\ Fresh\ Sample - Weight\ of\ Dry\ Sample}{Weight\ of\ Fresh\ Sample} \right) * 100$$

2.6 Determination of ash content

In this study, standard method by AOAC (2,000) was followed in the determination of honey ash content. Three grams of honey were put in dried pre-weighed crucibles and were heated in a furnace at 500 ^{0}C for 5 hours, until ash samples produced became white or greyish white. The ashed samples were placed in desiccators and allowed to cool and then weighed. The percentage ash content was calculated as:

$$Ash\ (\%) = \left(\frac{Weight\ of\ Sample\ afterAshing}{Weight\ of\ Fresh\ Sample} \right) * 100$$

2.7 Determination of Hydroxymethylfurfural (HMF)

HMF, an aldehyde that is often used as an indicator for quality of honey is generated by the decomposition of fructose in acidic conditions (Keppy and Allen, 2009). It occurs naturally over time in honey but high levels may be a result of inadequate storage, adulteration with sugar additives or severe heat treatment (Moralles *et al*., 2009). In this study, the HMF content in 26 honey samples was determined using a spectrophotometric method (White, 1979) elaborated by Keppy and Allen (2009). For each honey sample, 5 grams of honey were dissolved in 25 mg of double distilled water. Then 0.5 ml of Carrez Solution I (150 mg/ml Potassium ferrocyanide) was added to the sample and mixed well. Thereafter, 0.5 ml of Carrez Solution II (300 mg/ml zinc acetate) were added and mixed well. Each sample was brought to a final volume of 50 ml in volumetric flasks using double distilled water. Samples were then filtered using Whatman filter paper No.1 with the aid of filter funnels. The first 10 ml of filtrates were discarded. Aliquots of 5 ml of the remaining filtrates were put in two test tubes; to one tube was added 5 ml distilled water (test sample solution); and to the second was added 5 ml of 0.2% sodium bisulphite solution (reference solution). The absorbance of the test sample was measured against the reference sample at 284 nm and 336 nm using Genway 6305 spectrophotometer. The HMF content was calculated using the following equation (Bogdanov *et al.,* 1997):

$$HMF\ (mg/100g\ of\ honey) = \left(\frac{A_{284} - A_{336}}{W} \right) * Factor$$

Where W = weight of sample in grams

$$Factor = \left(\frac{126 * 100 * 1000 * 100}{16830 * 1000} \right) = 74.87$$

and 126 = the molecular weight of honey
16830 = the molar absorptivity of HMF at 283 nm

2.8 Statistical analysis

All analyses were performed in triplicates and data was presented as mean standard deviation. Differences in performance between individual/group of honey samples were analyzed using analysis of variance (ANOVA) determined by IBM SPSS Statistics version 22. Pearson's correlation test was employed to find out the relationship between and among the parameters. Differences at $P \leq 0.05$ were considered statistically significant.

3.0 Results and Discussion

3.1 Colour

Figure 2 shows colour of honey samples arranged from lightest honey sample (water white) to darkest honey sample (dark amber). When colour ranking was done in the same order; honey samples clustered in 11 different colour intensity categories from number 1 (extra white) to number 11 (dark amber). As depicted in Table 2, majority of the honeybees' honey samples (18 out of 21) had lighter colour intensity (1 -5) and only 3 samples namely 16 Ruangwa, 23b Kondoa1C1 and 53Tabora3 had darker colour intensity ranked 9, 7 and 6, respectively. However, all samples of honey from stingless bees had darker colour intensity (6 - 11).

Figure 2: Honey samples arranged in the order of increasing colour intensity.

Honey colours are a function of many factors including the type of vegetation from which bees forage, soil and associated minerals, age of honey, storage factors and honey processing. There are however varying opinions on the association of honey colour with taste, quality, traditions and marketability. According to United States Standards for Grades of Extracted Honey (USDA, 1985), the colour of extracted honey is not a factor of quality honey for the purpose of colour grade designations of extracted honey.

Table 2: Honey samples ranked based on colour intensity

S/N	**Sample no.**	**Colour name***	**Equival. to Pfund scale (mm)****	**Colour intensity rank*****
Honeybees' processed honey				
1	3 Uvinza	Extra Light Amber	40-70	**3**
2	9 Manyoni	Light Amber	60-120	**5**
3	13 Handeni	Extra light amber	50-90	**4**
4	16 Ruangwa	Amber	100-300	**9**
5	17 Mbeya 1	Light amber	60-120	**5**
6	18 Dodoma	White	30-55	**2**
7	28 Mbeya 2	Extra light number	40-70	**3**
8	52 Tabora 2	Extra light number	40-70	**3**
9	53 Tabora 3	Light amber	70-150	**6**
10	55 Mugumu	Light amber	60-120	**5**
11	56 Geita	Extra white	10--30	**1**
12	58 Kasulu	Extra light amber	50-90	**4**
13	59 Chunya	White	30-55	**2**
14	60 Mbulu	White	30-55	**2**
15	62 Kondoa 2	Extra light amber	40-70	**3**
16	68 Tabora 6	Extra light amber	50-90	**4**
Honey bees' raw honey				
17	23b Kondoa 1 C1	Light amber	80-200	**7**
18	51 Tabora 1 C2	Light amber	60-120	**5**
19	65 Kondoa 3 C3	Extra light amber	40-70	**3**
20	66 Tabora 4 C4	Extra light amber	40-70	**3**

21	67 Tabora 5 C5	White	30-55	**2**
Stingless bees' honey				
22	19 Urambo S1	Light amber	70-150	**6**
23	20 Kibondo S2	Dark amber	120-500	**10**
24	22 Biharamulo S3	Amber	90-250	**8**
25	23a Usariver S4	Dark amber	120-650	**11**
26	57 Geita S5	Amber	90-250	**8**

**Colours named according to the USDA Honey colour Grading Chart (Manley, 1985)*

*** Source: The Honey Collective Honey Colour Grade Guide*

****Colour intensity ranked from 1: lightest (Extra white) to 11:darkest (Dark amber)*

However, there are reports to indicate that honey colours could play important role in grading different samples of honey. Scientists have reported significance of colour of honey samples by suggesting that darker honeys were characterized by higher pH values, phenolic content and antioxidant activities but lower amount of sugars than lighter honeys (Maeda *et al*., 2005, Eleazu *et al.,* 2012, 2013). Dark coloured honeys contain more minerals; mainly iron, copper and manganese which make them especially fit for medicinal purposes (Gonzales *et al*., 2000, Buldini *et al*., 2001). In addition, there is a connection with flavour as light coloured honeys are mild where as darker types have stronger flavours. Exceptions to the rule are that depending on the vegetation, some good quality honeys like honeys from Acacia vegetation are naturally light coloured and vice versa. All honey samples from stingless bees reported in this study are generally characterized as dark coloured, a feature most likely derived from their rich mineral composition. This observation is of interest in support of traditional practices which attach high therapeutic value to stingless bees' honeys across the Tanzanian communities.

3.2 pH values

Honey is naturally acidic irrespective of its geographic origin, which may be due to the presence of organic acids that contribute its flavour and its stability against microbial spoilage (Khalil, 2012). In this study, pH values of honey samples ranged from pH 2.61±0.15 to pH 4.37±0.08 (see Table 3). All five honey samples from stingless bees were found to be more acidic (pH 2.61 to pH 3.76) than honeybees' honey samples. The pH values obtain are typical of honey samples reported in literature (Andrade *et a1.,* 1999, Azeredo *et al.* 2003, Kayacier and Karaman 2008, Conwa *et al.* 2010, Saxena *et al.,* 2010, Kinoo *et al.,* 2012, Khalil *et al.,* 2012). pH values have great importance during the extraction and storage of honey, as they influence the texture, stability and shelf life of honey (Terrab *et al.,* 2002).

Table 3. pH, Total sugars and HMF contents of honey samples. Values obtained are means of triplicate determinations

SN	**SAMPLES**	**HMF** (mg/100g)	**TOTAL SUGAR** (g/100g)	**pH**
	Processed honey from honeybees			
1	3 Uvinza	1.63±1.53	84.84±1.24	3.84±0.10
2	9 Manyoni	0.70±0.46	64.16±1.21	3.67±0.05
3	13 Handeni	0.75±0.60	73.96±1.41	3.70±0.05
4	16 Ruangwa	1.57±0.85	75.67±1.10	4.30±0.57
5	17 Mbeya 1	1.02±0.40	73.73±6.87	4.29±0.21
6	18 Dodoma	0.75±0.44	81.01±1.60	3.00±0.20
7	28 Mbeya 2	0.54±0.43	79.16±0.90	4.37±0.08
8	52 Tabora 2	0.64±0.55	77.67±1.33	3.85±0.06
9	53 Tabora 3	2.07±1.28	75.10±0.69	4.23±0.03
10	55 Mugumu	0.87±0.36	76.10±1.70	4.18±0.03
11	56 Geita	1.02±1.00	82.79±0.90	4.11±0.09
12	58 Kasulu	0.69±0.65	76.86±0.38	4.08±0.07

13	59 Chunya	0.67±0.49	76.51±0.65	4.41±0.13
14	60 Mbulu	0.60±0.70	83.38±2.00	4.09±0.03
15	62 Kondoa 2	0.78±0.66	82.58±1.69	4.03±0.09
16	68 Tabora 6	0.76±0.76	72.45±2.18	3.85±0.04
	Raw honey with combs			
17	23 Kondoa 1 C1	0.50±0.07	70.98±3.67	4.27±0.06
18	51 Tabora 1 C2	0.70±0.27	68.56±1.68	4.10±0.05
19	65 Kondoa 3 C3	1.08±0.97	78.88±0.78	3.93±0.04
20	66 Tabora 4 C4	2.14±1.16	77.85±2.40	4.03±0.17
21	67 Tabora 5 C5	0.62±0.49	77.88±1.60	3.57±0.08
	Honey from Stingless bees			
22	19 Urambo S1	1.87±1.39	69.35±2.03	2.61±0.15
23	20 Kibondo S2	1.19±0.79	71.75±2.19	3.76±0.11
24	22 Biharamulo S3	2.64±0.62	71.66±2.42	3.25±0.11
25	23a Usariver S4	1.92±0.67	69.46±0.79	3.64±0.08
26	57 Geita S5	0.94±0.70	73.73±3.04	3.71±0.04

3.3 Total Sugar content

Honey samples used in this study had total sugar content ranging from 64.2 - 84.8g/100g (Table 3). The results conform well with findings reported previously for honeys from other places (Khalil 2012, Ouchemoukh *et al*. 2007, Gommes *et al.,* Buba *et al*., 2013, Eleazu *et al.,* 2013). All studied honey samples had total sugar content above the minimum requirement of the Codex Standard (1993) of not less than 60g/100g, EU Standard and Tanzanian Guidelines for Quality Assurance of Bee Products (2007) of not less than 65g/100g. The amount of sugar content in honeys have been reported by other researchers to range from 45.3 to 86.0 g/100g for total sugar (Ajlouni and Sujirapinyokul 2009, Saxena *et al*., 2010) and 43.3 to 93.70 g/100g for total reducing sugars.

3.4 Hydroxymethylfurfural (HMF)

Honey is the only food for which legal limit on HMF has been set (Vorlova *et al*., 2006). Previous studies have shown that honeys obtained directly from beekeepers after extraction contained very low HMF concentrations, but exceeded the limit of 40 mg/kg permitted by law during storage and transportation (Kalabova *et al.,* 2003). In this study, HMF levels of raw and processed honeybees honey and stingless bees honeys are reported (Table 3). In the overall, HMF values for all samples ranged from 5.0 – 26.4 mg/kg honey. Comparing the three categories of honey samples, stingless bees honey had the highest values ranging from 9.4 – 26.4 mg/kg. These values are, however, far below the maximum limit allowed by EU (≤40mg/kg), Codex (≤40 mg/kg) and Tanzanian (≤40 mg/kg) standards. This is an indication that honey samples studied were not subjected to heat or long storage in hot conditions. In actual fact, most samples were obtained in the period April - July, which is considered a fairly cool season for most of the areas in Tanzania. These findings are in agreement with results from a similar study on HMF levels on Tanzanian honeys by Gidamis *et al*., (2004) which revealed very low HMF levels compared to honey samples from other places. Based on these findings, it can safely be generalized that honeys from Tanzania have very low HMF levels and they meet national and international quality standards. HMF levels of honeys from the tropics like Tanzania is expected to go higher even without heating the honey. As such the EU Council Directive (2001), Codex Alimentarius (2000) and Korean Food Code have set the maximum levels of HMF for honey from tropical climates to be 80 mg/kg (Keppy and Allen 2009).

3.5 Moisture content

The moisture content of honey is one of the criteria that determine its shelf life and ability to resist spoilage by microbial fermentation. Thus, the higher the moisture, the higher the probability that honey will ferment upon storage. The moisture content reported in this study for honeybees' honey ranged between 13.9 – 27.9% and 24.64 – 30.9% for stingless bees honey (Table 4).

Table 4: % Moisture and Ash contents of honey samples. Values obtained are means of triplicate determinations

SN	SAMPLES	MOISTURE CONTENT(%)	ASH CONTENT (%)
	Processed honey from honeybees		
1	3 Uvinza	16.95±0.95	0.08±0.04
2	9 Manyoni	18.97±1.62	0.07±0.03
3	13 Handeni	17.33±0.77	0.05±0.05
4	16 Ruangwa	22.75±1.55	0.58±0.33
5	17 Mbeya 1	22.04±1.76	0.18±0.05
6	18 Dodoma	13.90±1.76	0.06±0.02
7	28 Mbeya 2	19.91±0.68	0.12±0.01
8	52 Tabora 2	20.56±1.18	0.19±0.09
9	53 Tabora 3	19.29±0.37	0.10±0.06
10	55 Mugumu	19.87±0.83	0.18±0.08
11	56 Geita	18.96±0.38	0.06±0.05
12	58 Kasulu	18.03±0.66	0.08±0.07
13	59 Chunya	16.80±0.18	0.05±0.04
14	60 Mbulu	16.57±0.94	0.12±0.07
15	62 Kondoa 2	19.63±0.63	0.15±0.04
16	68 Tabora 6	19.99±0.86	0.07±0.04
	Raw honey with combs		
17	23 Kondoa 1 C1	27.98±0.80	0.55±0.36
18	51 Tabora 1 C2	15.71±2.92	0.14±0.05
19	65 Kondoa 3 C3	17.57±0.35	0.16±0.12
20	66 Tabora 4 C4	17.96±0.86	0.04±0.02
21	67 Tabora 5 C5	20.63±0.41	0.12±0.07
	Honey from Stingless bees		
22	19 Urambo S1	24.64±1.43	0.19±0.06
23	20 Kibondo S2	30.89±0.63	4.10±1.15
24	22 Biharamulo S3	25.86±2.02	0.15±0.06
25	23a Usariver S4	27.34±0.92	0.74±0.13
26	57 Geita S5	30.30±1.06	1.24±0.15

Values obtained are means of triplicate determinations

The recommended limits by international and national honey quality regulations are that moisture content should not exceed 20% (Codex 1982) or 21% (EU Council 2001 and Tanzanian Honey Quality Guidelines 2007). Of the 21 honeybees' honey samples studied, 3 had moisture content levels above 21%. The most deviant sample with highest moisture content was raw honey (23Kondoa1C1) with 27.9% moisture content which could be associated to harvesting of unripe honey. Honeys with higher moisture content of up to 23.36% have been reported elsewhere (Nuru 1999, Fredes and Montenegro 2006). On the other hand, all stingless bees' honey samples reported in this study had exceeded by far the set moisture content limits. Naturally observed, these honeys are less viscous than honeybees' honeys but offer more aesthetic and cultural values in our communities.

3.6 Ash content

The ash values from this study for majority of samples varied from 0.04% to 0.58% (Table 4). The exception was with two samples of honey from stingless bees (20 Kibondo S2 and 57 Geita S5), which had extraordinarily high ash content of 4.1 and 1.24%, respectively. It is suspected that these two samples had other impurities which contributed to the high ash content. The maximum allowable ash content under European Honey Commission

(Bogdanov *et al.,* 1997) and Tanzanian Honey Quality Guideline is 0.6 %. With the exception of stingless bees honey, all honeybees honey samples met the minimum requirements of national and international quality standards. Other workers (White 1975a, Liberato *et al*., 2013, Eleazu *et al*., 2013) reported higher ash content in honey samples they studied. Al *et al*. (2009) and White Junior (1978) associated ash content with honey colours, that darker honeys had higher ash content (up to 0.71%) which reflected their higher mineral content. Indeed, stingless bees' honey samples used in this study had very strong dark colours. Whether or not dark colour intensity recorded in this study fully accounts for the extreme ash content value of 4.1% recorded in this study needs further scrutiny.

3.7 Analysis of Variance
ANOVA results provided in Table 5 show significant differences in the studied physicochemical parameters between groups of honey samples, namely processed honey, raw honey and stingless bees' honey at $P_{<}$ 0.05. Of all the parameters studied, differences in colour and moisture content among the three honey groups were extremely significant ($P < 0.01$). From the average values of each honey category, honeys from stingless bees were more acidic, much darker in colour, had highest HMF values, highest ash content, highest moisture content, lowest sugar content and were lightest in terms of viscosity compared to processed and raw honeys from honeybees. The author of this paper is of the opinion, the fact that the honeys originate from insects belonging to two different genera (*Apis mellifera* and *Melipona* species) may possibly explain the difference observed between honeybees' honey and stingless bees' honey. Significant difference observed between raw and processed honeybees' honeys is a reminder to the honey producers, consumers and the government on the need to harmonize and standardize honey processing in order to preserve quality.

Table 5. ANOVA Analysis of honey groups on the physicochemical parameters

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
HMF	Between Groups	2.300	2	1.150	4.106	.030
	Within Groups	6.442	23	.280		
	Total	8.742	25			
SUGAR CONTENT	Between Groups	1403.316	2	701.658	4.547	.022
	Within Groups	3548.818	23	154.296		
	Total	4952.134	25			
pH	Between Groups	1.457	2	.729	5.497	.011
	Within Groups	3.048	23	.133		
	Total	4.505	25			
MOISTURE CONTENT	Between Groups	309.997	2	154.999	18.244	.000
	Within Groups	195.401	23	8.496		
	Total	505.398	25			
ASH CONTENT	Between Groups	7.445	2	3.723	4.535	.022
	Within Groups	18.879	23	.821		
	Total	26.324	25			
HONEY COLOUR	Between Groups	90.978	2	45.489	11.938	.000
	Within Groups	87.638	23	3.810		
	Total	178.615	25			

3.8 Correlation of honey parameters
Tables 6 shows the Pearson correlation between the analyzed physicochemical parameters of studied honey samples put together. There were strong positive correlations (Pearson correlation coefficient significant at

P≤0.05) between moisture content and HMF, moisture and ash contents, ash content and HMF levels and between colour and HMF. There was also a good negative correlation between sugar and moisture content and sugar and colour.

Table 6: Pearson Correlation between physicochemical parameters of studied honey

	Colour	Sugar	pH	Moisture	Ash
Sugar	-0.146				
pH	-0.318*	0.237			
Moisture	0.279	-0.466*	-0.17		
Ash	0.053	-0.236	-0.06	0.669**	
HMF	0.460*	-0.643**	-0.142	0.807**	0.593**

*** Strong Pearson correlation coefficient, significant at P≤0.05*

. Weak correlation, significant at P≤0.05*

The positive correlation between moisture content and HMF can be attributed to the problems during processing and storage. Due to hygroscopic nature of honey, increase in moisture can cause increase in HMF values if storage conditions are not appropriate, contributing to deterioration of honey (Silva *et al*., 2004). It is however difficult to explain the strong positive correlation between moisture content and ash and between ash content and HMF levels observed in this study. The positive correlation between colour intensity and HMF levels is due to the fact that light coloured honeys turn darker when heated or stored in hot conditions for longer periods. Thus dark coloured honeys may partly be a result of heating or long storage, the processes that generate high levels of HMF. The negative correlation between colour and sugar suggest that darker honeys may have lower amount of sugars than lighter honeys. This study has also reported a weak negative correlation (-0.318) between honey colour and pH. In the contrary, Eleazu *et al* (2013) reported a very strong positive correlation of 0.879 between honey colour and pH. Lastly, a negative correlation observed in this study between moisture and sugar confirms the known fact that the higher the moisture, the lower the sugar and the higher the probability that honey will ferment upon storage as it may serve as a substrate for growth of microorganisms.

4.0 Conclusion

Based on the physicochemical parameters studied, Tanzanian honeys from honeybees were found to be of high quality meeting recommend national and international standards. However, all stingless bees' honey samples deviated from these standards on moisture content and two samples on ash content. With few exceptions, colour and moisture content are two most important physicochemical parameters that may give a fair clue on the quality of the honey. The two parameters are also easy to measure. The results of this study indicate that Tanzanian honey samples compare well with samples in many parts of the world but also fall within the limit of international standards. Nevertheless, more studies are needed to evaluate the quality of Tanzanian honeys based on medicinal, nutritional and antioxidant properties.

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