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Research article

Sugar profile and sensory properties of honey from different geographical zones and botanical origins in Tanzania

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ABSTRACT

Honey composition and sensory properties depend greatly on its botanical and geographical origins. In this study, the sugar profile and sensory properties of honey samples from different geographical zones and botanical origins in Tanzania were investigated. Thirty-two samples (3 zones x 2 origins x 4 samples) + (2 zones × 1 origin x 4 samples) were collected from the seven regions in five zones as follows; Simiyu (lake zone), Tabora and Dodoma (central zone), Manyara (northern zone), Morogoro (eastern zone), and Kigoma and Katavi (western zone) and evaluated for sugar profile and sensory properties using standards methods. Honey samples were primarily composed of fructose (39.5–47 g/100 g), glucose (32.0–35.0 g/100 g) and a small amount of sucrose (5.1 ± 0.50–7.3 ± 0.7 g/100 g). The total sugar ranged from 72.6 to 75.8 g/100 g/100g. The variations in sugar contents between zones and botanical origin were significant ($p < 0.05$) except for glucose. Sample from miombo origin in the lake and eastern zones had the highest fructose value (41.9 ± 0.8–42.04 ± 4.34 g/100 g) compared to lowest values (39.5 ± 2.17 g/100g) in a western zone while northern and lake zones had significantly ($p < 0.05$) highest and lowest sucrose values respectively. In all zones, acacia samples had higher fructose and sucrose contents than their miombo counterparts. As for the sensory profile, *miombo* samples in the western zone had significantly ($p < 0.05$) higher colour (8.0 ± 0.64) and aroma (7.5 ± 1.09) intensities while the lake zone samples had higher clarity (6.9 ± 1.76) than other zones' samples. The findings have demonstrated that the geographical and botanical origins have a significant impact on the sugar profile and sensory profile of Tanzania honey. However, despite the variations, the consumption of honey from these zones and origins should be encouraged in light of their nutritional and related known health benefits.

1. Introduction

Honey is one of the main products of beekeeping and is defined as a natural sweet substance produced by honey bees (*Apis mellifera* bees) from the nectar of plants and is a sweet, flavorful liquid [1]. Honey is a natural food with high nutritional value mainly composed of readily available sugars (mainly fructose and glucose) and other constituents such as enzymes, amino acids, organic acids, carotenoids, vitamins, minerals, and aromatic substances [2,3]. It also contains a high content of flavonoids and phenolic acids that are linked to antioxidant activities [4]. Honey is widely used as food, medicine, raw materials for industrial beer production and as a

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source of income [1,5].

Beekeeping and honey production in Tanzania are now seen as crucial livelihoods and sources of revenue for ensuring people's survival while also protecting the environment [6]. This is demonstrated by the government's present efforts to promote and support Tanzania's beekeeping business [7]. Nevertheless, honey has become a target for adulteration which may play a significant role in changing the general composition of honey, especially with regards to its sugar content and physical properties [8]. The main form of honey adulteration includes the addition of low-quality sweeteners (such as cane sugar or refined beet sugar, corn syrup, high fructose or maltose syrup), and honeybees fed sucrose [9]. Generally, adulterated honey contains significantly lower fructose and glucose content and a slight decrease in the glass transition temperature of adulterated honey [10]. Therefore, understanding the chemical properties of honey, such as its sugar composition, is important for protection from adulteration [11]. According to Machado et al. [12], honey properties and composition such as sugar and sensory profile vary depending on botanical origin, and geographical, environmental and seasonal conditions. Other influencing factors include variations in nectar content, climatic conditions, soil type and beekeeper activities [13,14]. Various studies have been conducted to assess the effect of flora and geographic origin on honey properties in various countries such as Tunisia [15], Estonia [16] and Romania [17]. However, information on the effect of botanical origin and geographical zones on sugars, and sensory properties in honey Tanzania is limited. Sensory analysis is regarded as a crucial analytical tool for the quality control of honey in relation to the assessment of botanical origin. It also allows for the identification of flaws like fermentation, off-odours (such as smoke odours), metallic tastes, and other characteristics that common routine analyses do not [18]. This study was therefore conducted to establish and avail the missing information.

2. Material and methods

2.1. Honey samples

Honey samples were purchased directly from the beekeepers from different regions in the five different zones depending on the availability and distribution of *acacia spp* and *miombo* woodland. A total of 32 samples (3 zones x 2 origins x 4 samples) + (2 zones × 1 origin x 4 samples) were collected from the following regions; Simiyu (lake zone), Tabora and Dodoma (central zone), Manyara (northern zone), Morogoro (eastern zone), and Kigoma and Katavi (western zone) as summarized in Table 1. The samples were transported in well-sealed amber-coloured plastic bottles to the Tanzania Bureau of Standards laboratory for sugar analysis and to the Department of Food Science and Agro-processing at Sokoine University of Agriculture (SUA) for sensory analysis.

2.2. Experimental design

Complete randomized block design (RCBD) with replication was used in this study. The principal factors were botanical source with two levels (*miombo* and *Acacia*) and geographical location with five levels (the zones). The effects of these factors on analyzed parameters were determined using a mathematical model depicted in Equation (1).

$$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij} \tag{1}$$

Where μ is the overall (grand) mean, α_i is the effect due to the ith treatment (botanical origin), $ß_j$ s the effect due to the jth block (geographical zones) and ε_{ij} is the error term where the error terms.

Furthermore, a balanced incomplete block (BIB) design was used to examine the sensory profile and consumer acceptance of the honey samples [19]. The design is used for a sensory test where there are more samples than can be examined at once before sensory and psychological fatigue sets in. As a result, each assessor only assessed a subset of the entire number of samples in one session. The principal factors were panelists, geographical zones and botanical origins and their effects on sensory attributes and consumer acceptability were determined and compared using Equation (2).

Table 1
Geographical zone, regions, botanical origin and number of samples collected.

Zone	Region	Botanical origin	Number of samples
Central	Tabora	*Miombo* woodland	2
		Acacia species	2
	Dodoma	*Miombo* woodland	2
		Acacia species	2
Lake	Simiyu	*Miombo* woodland	4
		Acacia species	4
Northern	Manyara	*Miombo* woodland	4
		Acacia species	4
Western	Kigoma	*Miombo* woodland	–
		Acacia species	2
	Katavi	*Miombo* woodland	–
		Acacia species	2
Eastern	Morogoro	*Miombo* woodland	–
		Acacia species	4
Total			**32**

$$Yij = \mu + \tau i + \beta j + \varepsilon ij \quad (2)$$

Where μ is the overall mean, τi is the ith treatment effect (geographical zones/botanical origins), βj is the jth block effect (assessors) and εij is the random effect.

2.3. Chemical analysis

2.3.1. Determination of sugars

Determination of sugar profile and quantification was performed using a Shimadzu high-performance liquid chromatograph equipped with a refractive index detector (RID-10A) as per method 977.20 in AOAC [20]. About 5 g of the sample was dissolved in a 100 ml volumetric flask with water and 25 ml of methanol then filtered through a membrane filter. The separation was performed using a carbohydrate analysis column (4.6 mm in diameter, 250 mm in length) with a particle size diameter of 5–7 μm. The column was kept at 30 °C throughout the analysis. The mobile phase was composed of 85 % acetonitrile in water. The injection volumes of the samples were 20 μl, with a flow rate of 2 ml/min. Peaks were identified based on their retention times. Quantification was performed according to the external standard method on peak areas (Harmonized Methods of the İnternational Honey Commission [21]. Duplicate injections were performed and average peak areas were used for the peak quantification. Glucose, fructose and sucrose were used as standards to determine the sugar content of honey.

2.4. Sensory analysis

2.4.1. Quantitative Descriptive analysis (QDA)

Descriptive sensory profiling was conducted at the Department of Food Science and Agro-processing at Sokoine University of Agriculture (SUA), by a trained sensory panel of 8 assessors, comprising 4 males and 4 females with ages ranging from 22 to 27 years according to the method described by Lawless and Heymann [22]. The assessors were selected and trained according to ISO standard method 8586 [19]. Written consent was taken from the panellists for their participation before the start of the test. Panelists generated descriptors to describe sample differences during training, and they agreed on colour (hue and whiteness), whiteness, aroma, clarity, and viscosity as the study attributes (Table 2). Additionally, they created and adopted a nine-line, unstructured scale for measuring the intensity of each attribute, with the left side of the scale representing the lowest intensity (value 1) and the right side representing the maximum intensity (value 9). The samples were served to each panelist in random order and were coded with three-digit random numbers. Panel performance in terms of the agreement among panelists, ability to discriminate between samples and reproducibility were assessed by p*MSE plots using Panel Check software [23] Tomic et al., 2010). Eventually, eight (8) panelists out of twelve were selected for the final actual test.

2.5. Statistical data analysis

Data obtained were analyzed by using the R commander statistical package, version 3.0.0 [24]. Analysis of variance (ANOVA) was used to determine the significant differences between the main factors. Means were separated using Tukey's Honest Significant difference ($p < 0.05$). Principal component analysis (PCA) was used to determine the systematic variations in sensory data using Latentix Software version 2.12 [25]. Results were presented as the arithmetic mean and standard deviation in Tables and graphs as well as in PCA bi-plots.

3. Results and discussion

3.1. Sugar profile of honey samples

Table 3 shows the variation of sugars within and between zones in each botanical origin. It shows that honey samples were

Table 2
Definitions of sensory attributes used in descriptive sensory analyses.

Category	Attribute	Definition	Scale ranges (1–9)
Appearance	Colour (Hue)	Perceived light to deep brown colour	1 - Light brown 9 - Deep brown
	Whiteness	Degree of loss of natural colour	1 - Not white 9 - Very white
	Clarity	Liquid appearance associated with the presence or absence of particles of visible size	1 - Not clear 9 - very clear
Aroma	Honey Aroma	Aromatics associated with honey	1 - Less aromatic 9 - Very aromatic
Texture	Viscosity	The force required to draw a liquid from a spoon over the tongue.	1 - Less viscous 9 - Very viscous

Source: Trained panelists in the study

composed primarily of fructose and glucose as well as a small amount of sucrose which is composed of fructose and glucose linked together. In all zones, fructose dominated significantly ($p < 0.5$) higher with values ranging from 39.5 to 42 g/100 g followed by glucose with values ranging from 32.0 to 33.7 g/100 g and sucrose with lowest values of 5.1–7.1 g/100 g. The total sugar ranged from 72.6 to 75.8 g/100 g.

The variations of sugars between zones in each botanical origin were not significant ($p > 0.05$) except for *acacia* samples whereby lake zone samples had a higher fructose value of 47 g/100 g followed by the central zone with 45 g/100 g and the lowest value in the northern zone with 44.7 g/100 g.

The results for sugar profiles between botanical origins in each zone are presented in Table 4. There was significant variation in sugars between flora origins with samples from *acacia* origin in central and lake zones having higher fructose (45.3 ± 0.89 and 7.3 ± 0.75 g/100 g), sucrose (7.3 ± 0.75 and (6.67 ± 0.0 g/100 g) and total sugar (78.3 ± 9.45 and 79.0 ± 00 g/100 g) respectively than respective lower values of 40.6 ± 8.97 and 41.89 ± 0.81, 6.04 ± 0.72 and 5.14 ± 0.50 and 74.9 ± 5.20 and 75.4 ± 3.45 g/100 g in *miombo* samples. Furthermore, *acacia* samples had higher sucrose values of 7.25 and 6.67 g/100 g respectively than *miombo* samples with respective values of 6.04 and 5.14 g/100 g. No significant ($p > 0.05$) variation was observed in sugars between origins in the northern zone and glucose contents between *miombo* and *acacia* origins within each zone. No *acacia* data was collected from the western and eastern zones (Table 4).

The observed higher fructose and glucose levels in the honey samples show that these are the major sugar constituents of honey as previously reported [26–28]. However, the observed values are higher and lower than those observed by Velásquez-Giraldo et al. [29] and Chua and Adnan [30] respectively. Fructose has been associated with the sweet taste of honey and its predominance over glucose is one way in which honey is differentiated from commercial sugars and one of the quality signs [31,32]. Variations observed in fructose contents between botanical origins could be due to the differences in the amount of sugars present in the nectar collected, and the invertase enzymes present in the bee [14,33]. The sugars are responsible for many of the physicochemical properties such as viscosity, hygroscopic and granulation characteristics of honey [34]. All of the investigated honey samples contained higher total invert sugars (fructose + glucose) than the recommended requirements of >60 g/100 g recommended by the Codex Alimentarius Standard for Honey [35]. The higher total sugar in *acacia* samples than in *miombo* samples is similar to results observed in Malaysian honey [36]. However, Marghitas et al. [37] reported lower values of total sugars than the results observed in this study. The observed variation in sugar between zones suggests that the composition of sugars in honey is affected by the geographical location where the honey was produced and harvesting time as previously reported [38].

Nevertheless, despite significant differences in the sucrose content in honey samples between zones, all samples had levels above the maximum limit of 5 % allowed by the Codex Alimentarius Standard for Honey [35] and Tanzania national standard (TBS, [39]. Sucrose content is used to monitor honey quality and adulteration as honey adulterated with sugar is usually high in sucrose level [30]. High sucrose content indicates that the honey was harvested before its "ripening", causing an incomplete transformation of sucrose into fructose and glucose by the action of the invertase enzyme secreted by bees [40]. Similar high sucrose content was reported by Dos Santos et al. [41] while Ouchemoukh et al. [42] reported lower values of 0.23–3.41 % for Algerian poly-botanical honey.

3.2. Sugar ratios

The results for sugar ratios between zones in each flora origin are presented in Fig. 1(a and b). In *miombo* origin samples, the fructose/glucose ratio ranged from 1.23 to 1.27 while the glucose water ratio ranged from 1.6 to 1.97. Significant ($p < 0.05$) variation was observed in the glucose water ratio only between zones with the central zone scoring a higher value of 1.97 and the lowest value of 1.6 in the northern zone (Fig. 1 a). As for *acacia* samples, the fructose-glucose ratio ranged from 1.1 to 1.5 while the glucose-water ratio ranged from 1.9 to 1.2 (Fig. 1 b). Significant ($p < 0.05$) variation was observed in both parameters between the zones where the lake zone had the highest value of 1.5 while the northern zone had the lowest value of 1.1. Furthermore, a significantly ($p < 0.05$) higher glucose/water ratio was observed in the northern zone and a lower value in the central zone.

The variation of fructose/glucose ratio and glucose water ratio between flora origins in each zone are shown in Fig. 2(a and b). The fructose/glucose ratios differed significantly ($p < 0.05$) between the botanical origins within each zone with *acacia* samples having higher ratio values than in *miombo* counterparts *(*Fig. 2 a*)*. The glucose/water ratios differed significantly ($p < 0.05$) between the botanical origins within each zone with *miombo* samples having higher ratio values except in the northern zone (Fig. 2 b).

Table 3
Sugar profile of honey samples between zones in *miombo* and *acacia* botanical origins.

Origin	Zone	Sugars (g/100 g)			
		Fructose	**Glucose**	**Sucrose**	**Total**
Miombo	Central	40.6 ± 0.89^{ab}	33.2 ± 512^{a}	6.0 ± 0.72^{b}	73.8 ± 5.20^{a}
	Lake	41.9 ± 0.81^{a}	33.5 ± 2.88^{a}	5.1 ± 0.50^{c}	75.4 ± 3.45^{a}
	Northern	40.8 ± 2.64^{ab}	32.8 ± 3.65^{a}	7.1 ± 2.511^{a}	73.6 ± 5.15^{ab}
	Western	39.5 ± 2.17^{b}	33.13 ± 4.5a	6.50 ± 1.15^{ab}	72.6 ± 3.49^{b}
	Eastern	42.04 ± 4.34^{a}	33.7 ± 0.57a	5.7 ± 0.51^{bc}	75.8 ± 4.70^{a}
Acacia	Central	45.3 ± 8.97^{ab}	33.0 ± 1.46^{a}	7.3 ± 0.7^{b}	78.3 ± 9.45^{a}
	Lake	47.0 ± 0.00^{a}	32.0 ± 0.00^{a}	6.7 ± 0.00^{a}	79.0 ± 0.00^{a}
	Northern	44.7 ± 1.04^{b}	35.0 ± 1.32^{a}	6.8 ± 0.28^{a}	79.7 ± 2.25^{b}

Mean values are expressed as mean ± SD. Mean values with different superscript letters along the columns are significantly different at $p < 0.05$.

Table 4
Sugar profile between *miombo* and *acacia* botanical origins in each zone.

Zone	Botanical origin	Sugars			
		Fructose	**Glucose**	**Sucrose**	**Total**
Central	*Acacia*	45.3 ± 0.89[a]	33.0 ± 1.46[a]	7.3 ± 0.75[a]	78.3 ± 9.45[a]
	Miombo	40.6 ± 8.97[b]	33.2 ± 5.12[a]	6.04 ± 0.72[b]	74.9 ± 5.20[b]
Lake	*Acacia*	46.98 ± 0.0[a]	32.01 ± 0.0[a]	6.67 ± 0.0[a]	79.0 ± 00[a]
	Miombo	41.89 ± 0.81[b]	33.49 ± 2.88[a]	5.14 ± 0.50[b]	75.4 ± 3.45[b]
Northern	*Acacia*	44.7 ± 1.04[a]	35.0 ± 1.32[a]	6.75 ± 0.28[a]	72.8 ± 2.25[a]
	Miombo	40.8 ± 2.64[b]	32.8 ± 3.65[a]	7.1 ± 2.51[a]	73.6 ± 5.15[a]
Western	*Acacia*	–	–	–	–
	Miombo	39.5 ± 2.17	33.1 ± 4.46	6.50 ± 1.15	72.6 ± 3.49
Eastern	*Acacia*	–	–	–	–
	Miombo	42.04 ± 4.3.4	33.73 ± 0.57	5.69 ± 0.51	75.8 ± 4.70

Mean values are expressed as mean ± SD. Mean values with different superscript letters along the columns are significantly different at $p < 0.05$.

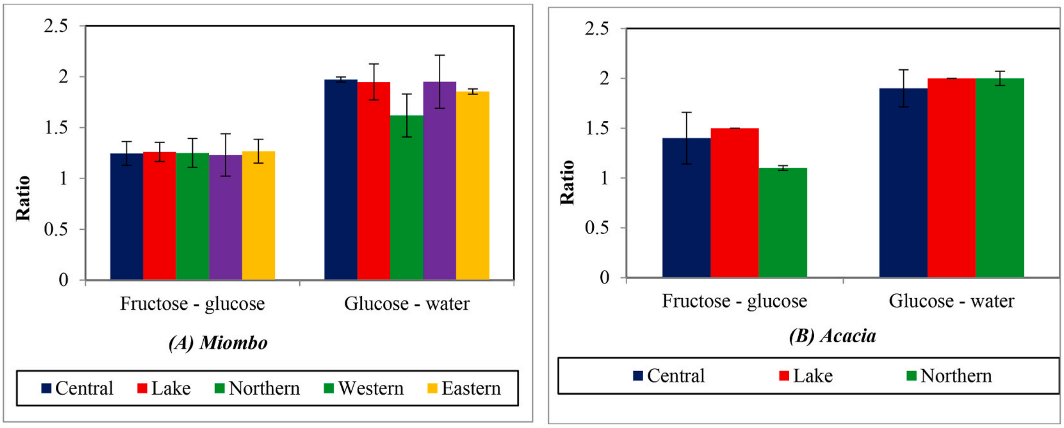

Fig. 1. (a and b): Variations of fructose–glucose and glucose–water ratios between zones in *Miombo (A)* and *Acacica (B)* samples.

Fructose-glucose ratio and glucose-water ratios are parameters that are used to predict the tendency of honey to crystallize. The speed of honey to crystallize depends on the relative amount of each sugar Ouchemoukh et al. [42]. A high fructose-glucose ratio of more than 1.5 indicates that honey would remain liquid for longer periods due to modification of the saturated level of glucose by the presence of the larger amount of fructose while a ratio of 1.1 or less, would enhance crystallization [43]. Similar fructose-glucose ratios ranged from 1.23 to 1.27 and 1.27–1.49 for *miombo* and *acacia* honey respectively obtained from this study were also reported ratio by Alves et al. [44] who observed a range of 1.18–1.29. The ratios obtained were above one and this means that fructose content was higher than glucose in the evaluated samples. Relating to actual samples, some *miombo* samples could have started the crystallization process as samples were very viscous with no clear separation sugars, especially in samples from the central and lake zones. In addition, the fructose-glucose ratio is said to have an impact on honey flavour, since fructose is much sweeter than glucose [45].

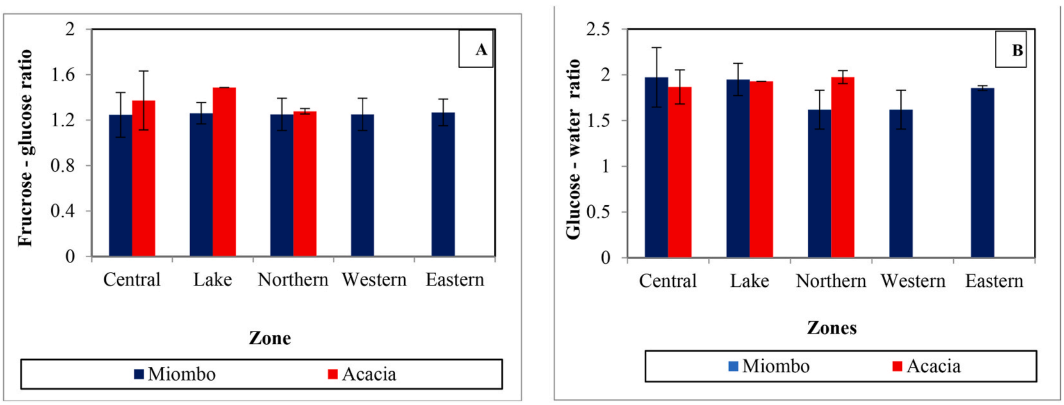

Fig. 2. (a and b): Variations of fructose–glucose ratio (A) and glucose – water ratio (B) ratio between botanical origin in each zone.

In addition to fructose and glucose, honey contains other sugars such as maltose, turanose, etc. and insoluble substances like dextrin, colloids, etc. which also influence the crystallization process. Due to this influence, the glucose-water ratio is considered to be more appropriate than the fructose-glucose ratio for the prediction of honey crystallization [46]. It has been stated that when the glucose/water ratio is < 1.3 honey crystallization is very slow or even zero, and it is complete and rapid when the ratio is > 2.0 [47]. The observed high ratio means the evaluated honey samples were in the crystallization stage but this could only be correlated to honey samples from the central zone which were very viscous either from crystallization or having low moisture content.

3.3. Sensory analysis

3.3.1. Sensory profile of honey samples

Table 5 shows the mean sensory attribute intensities of honey samples between geographical zones for each botanical origin. The mean honey attribute intensities varied significantly ($p < 0.05$) between geographic zones with western zone *miombo* samples exhibiting notably higher intensity values for the colour (8.0 ± 0.64) and aroma (7.5 ± 1.09) than other zones' samples. In contrast, lake and eastern *zone miombo samples* had higher intensity values for clarity (6.9 ± 1.76) and viscosity (7.8 ± 1.02). Similar patterns were observed in samples of *Acacia* origin from the same zones as depicted in Table 5 and Plate 1).

Furthermore, variations in mean attribute intensity scores of the honey samples between botanical origins for each zone were also significant ($p < 0.05$) as depicted in Table 6. In all zones, the *miombo* samples had higher intensity scores for colour (6.6 ± 1.20–7.6 ± 1.21), aroma (6.8 ± 1.4–6.9 ± 1.74), and viscosity (6.0 ± 1.30–7.8 ± 1.02) than the *acacia* origin samples, which had respective lower score of 4.3 ± 1.50–5.6 ± 1.80, 5.3 ± 1.89–5.8 ± 1.45, and 6.1 ± 1.87–7.0 ± 1.33. On the other hand, *acacia* samples had significantly ($p < 0.05$) higher whiteness and clarity intensities than *miombo* samples.

The systematic variation in sensory attribute intensity between honey samples from different origins and zones is further shown by the principal component analysis bi-plot (Fig. 3). PC 1 explains 84.2 % of the total variability and it is a contrast between *miombo* samples with high colour and aroma intensities and *acacia* samples with high whiteness and clarity intensities. PC 2 explains 11.7 % of the variability, mainly separating geographical zones. Generally, three major groups of samples from different origins, zones and their associated attributes are depicted by the plot.

The sensory properties are among the essential quality aspects that influence consumer decision-making about the selection, purchase, and consumption of honey [48]. These findings have demonstrated that geographic and botanical origins have a significant effect on the sensory profiles of honey samples as previously reported by Stolzenbach et al. [49]. Other reported influencing factors are physicochemical composition, pigments and mineral contents [50,51]. Furthermore, the observed higher colour intensity in *miombo* samples from the western, lake, and northern zones could be attributed to variations in the bee species, environment, weather conditions, soil type, type of flowers used, fertilization and mineral content at the place where the honey was produced [52,53]. According to the United Republic of Tanzania [54] and Shekilango et al. [55], minerals are among the component that affects honey colour whereby very light-coloured honey contains few minerals while dark colour contains more nutrients as observed in samples from these zones. The high whiteness and clarity intensities in *acacia* samples suggest their purity and pale-coloured nature as previously reported by Shekilango et al. [55]. Similar low colour and aroma intensity values in *acacia* honey samples compared to other types of honey were previously reported by Marcazzan et al. [18] and it was associated with environmental factors, botanical and soil variations in various geographical regions [49,56].

4. Conclusion

In view of the obtained results, flora and geographic origins had significant effects on the sugar profile of Tanzania honey. Fructose was the dominant sugar in all evaluated honey followed by glucose. Between the botanical origin, *acacia* honey was found to contain a higher content of fructose and total sugars than *miombo* honey. Honeys varied from each other in total sugar and the northern zone was found to have the highest content. As for sensory properties, *miombo* samples had significantly higher intensity values for colour, aroma, and viscosity attributes across all zones, whereas *acacia* samples had significantly higher intensity values for whiteness and clarity attributes. The findings have demonstrated that the geographical and botanical origins have a substantial impact on the sugar profile and sensory profile of Tanzania honey. However, despite the variations, the consumption of honey from these zones and origins should be encouraged in light of their nutritional and related known health benefits.

Table 5
Mean intensity scores of honey sample attributes between geographic zones for each botanical origin.

Origin	Zone	Hue	Whiteness	Aroma	Clarity	Viscosity
Miombo	Central	7.0 ± 1.20^{c}	2.0 ± 1.00^{c}	6.8 ± 1.57^{b}	6.5 ± 1.3^{ab}	6.7 ± 1.44^{c}
	Lake	6.6 ± 1.20^{c}	2.4 ± 0.94^{b}	6.8 ± 1.4^{b}	6.9 ± 1.76^{a}	7.8 ± 1.02^{a}
	Northern	7.6 ± 1.21^{b}	1.4 ± 0.62^{d}	6.9 ± 1.74^{b}	6.1 ± 1.77^{b}	6.0 ± 1.30^{d}
	Western	8.0 ± 0.64^{a}	1.1 ± 0.33^{e}	7.5 ± 1.09^{a}	5.1 ± 2.16^{c}	7.2 ± 0.97^{b}
	Eastern	4.6 ± 1.59^{d}	3.4 ± 0.65^{a}	5.8 ± 1.42^{c}	6.9 ± 1.41^{a}	5.4 ± 1.76^{e}
Acacia	Central	5.6 ± 1.80^{a}	3.6 ± 0.61^{a}	5.4 ± 1.89^{b}	7.0 ± 1.71^{b}	6.1 ± 1.87^{b}
	Lake	4.3 ± 1.50^{c}	3.7 ± 0.62^{a}	5.3 ± 1.89^{b}	8.2 ± 0.89^{a}	7.0 ± 1.30^{a}
	Northern	4.7 ± 1.68^{b}	3.2 ± 0.85^{b}	5.8 ± 1.45^{a}	6.9 ± 1.30b	6.1 ± 1.13^{b}

Values are expressed as mean SD (n = 8). Mean values with different superscript letters along the columns are significantly different at $p < 0.05$.

Table 6
Mean intensity scores of honey sample attributes between botanical origins for each zone.

Zone	Origin	Hue	Whiteness	Aroma	Clarity	Viscosity
Central	*Miombo*	7.0 ± 1.20^{a}	2.0 ± 1.00^{b}	6.8 ± 1.57^{a}	6.5 ± 1.3^{b}	6.7 ± 1.44^{a}
	Acacia	5.6 ± 1.80^{b}	3.6 ± 0.61^{a}	5.4 ± 1.89^{b}	7.0 ± 1.70^{a}	6.1 ± 1.84^{b}
Lake	*Miombo*	6.6 ± 1.20^{a}	2.4 ± 0.94^{b}	6.8 ± 1.4^{a}	6.8 ± 1.76^{b}	7.8 ± 1.02^{a}
	Acacia	4.3 ± 1.50^{b}	3.7 ± 0.62^{a}	5.3 ± 1.89^{b}	8.2 ± 0.89^{a}	7.0 ± 1.30^{b}
Northern	*Miombo*	7.6 ± 1.21^{b}	1.4 ± 0.62^{b}	6.9 ± 1.74^{a}	6.1 ± 1.77^{b}	6.0 ± 1.30^{a}
	Acacia	4.7 ± 1.68^{b}	3.2 ± 0.85^{a}	5.8 ± 1.45^{b}	6.9 ± 1.30^{a}	6.1 ± 1.87^{a}

Values are expressed as mean SD ($n = 8$). Mean values with different superscript letters along the columns are significantly different at $p < 0.05$.

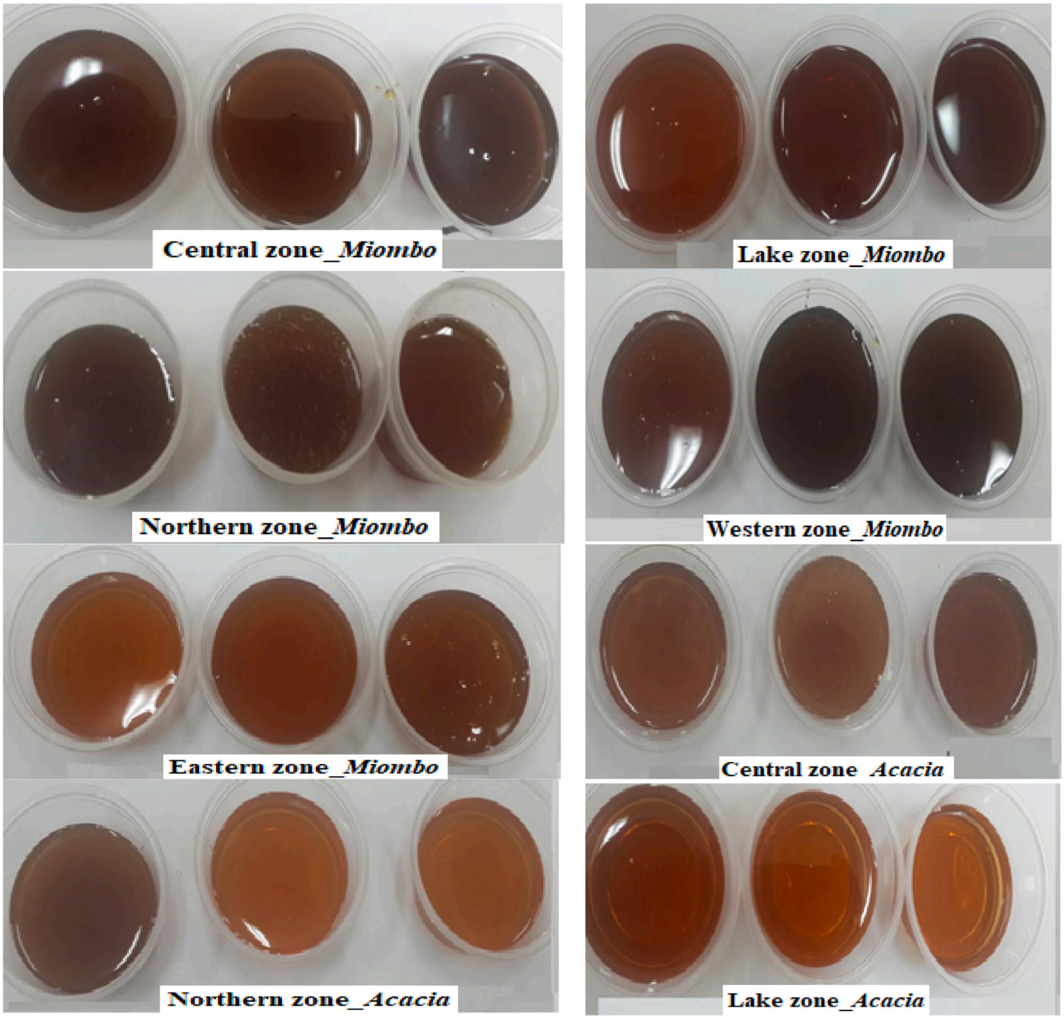

Fig. 3. Variation of honey samples from different geographical and botanical origins according to their average sensory attribute intensity values.

Ethical statement

The ethics committee of the Board of the College of Agriculture Studies at Sokoine University of Agriculture (SUA) provided its approval for the study (MFQ/E/2014/0017).

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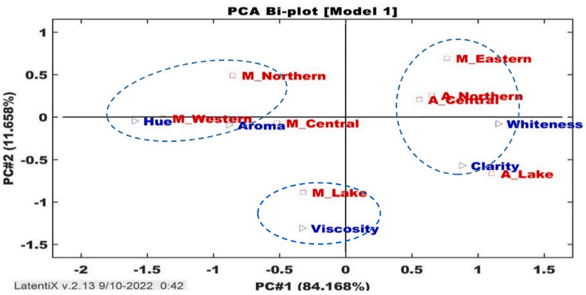

Plate 1. Honey samples from different origins in different geographical zones and botanical origins.

Additional information

No additional information is available for this paper.

Data availability statement

The authors do not have permission to share data.

CRediT authorship contribution statement

Richard John Mongi: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Carolyne Charles Ruhembe:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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