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Research Article

Quality parameters of honey produced in Silti district, southern Ethiopia

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ABSTRACT

This study was conducted to determine the quality of honey produced in Silti district of southern Ethiopia. The honey samples were collected from different locations representing two agro-ecological areas: Dega (highland) and Weyna Dega (midland). From each of these locations honey samples were obtained from traditional and movable frame hives. In addition, honey samples were also collected from the local market. Analysis of physicochemical parameters of honey was carried out at the Health and Nutrition Research Institute and the Quality and Standards Authority of Ethiopia. The analyzed samples had average moisture, ash, free acidity, water insoluble matter, pH, reducing sugars and sucrose contents of 15.95 (g/100g), 0,34 (g/100g), 19.32 (meq/kg), 0.26 (g/100g), 4.45, 69.04 (g/100g) and 4.1 (g/100g), respectively. Comparison of quality parameters of honey samples from the two agro-ecological areas and the market showed that market honey samples had significantly ($P<0.05$) higher reducing sugars content than honey samples from the two agro-ecological areas, but no significant difference ($P>0.05$) was observed for the remaining parameters. All the quality parameters analyzed for honey produced in Silti district comply with both national and international standards except the water-insoluble matter which was high in honey samples collected from traditional hives. Thus, there is a need to educate beekeepers about proper honey harvesting, straining and handling techniques.

Keywords Chemical composition, Ethiopia, honey quality, Silti

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INTRODUCTION

Beekeeping in Ethiopia is a long-standing agricultural practice. However, there is no documented evidence that indicates when and where beekeeping practice started but it is generally believed that it started between 3500–3000 BC (Kassaye, 1978). Beekeeping is been exercised as a sideline activity by many of the rural farming communities as a source of honey and beeswax. It contributes to income generation and job creation and thereby improves the livelihoods of the rural communities in the country (MoARD, 2010). The role it plays in enhancing food security, poverty reduction and food production through pollination of crops has become evident in recent years (IPBES, 2016). Owing to its varied ecological and climatic conditions, Ethiopia is home to some of the most diverse flora and fauna in Africa, making it highly suitable for sustaining a large number of bee colonies (Adgaba, 2007). The country has the largest bee population in Africa with over 10 million bee colonies, out of which about 7.5 million are confined in hives and the remaining exist in the forest (Adgaba, 2007). This makes the country one of the largest honey producers and the third largest beeswax producer in the world. Ethiopian honey production accounts for approximately 2.48% of the world and 21.73% of African honey production (EARO, 2000; MoARD, 2007).

Honey can be consumed as soon as it is harvested from the hive, stored for later use or it can be used to make a variety of value-added food products such as desserts, dressings and mead. Honey can also be used as an ingredient in other value-added products such as cosmetics and health supplements. Other harvestable products derived from honeybees include: pollen, wax, propolis, royal jelly, and venom (Adjare, 1990; EARO, 2000). The quality of honey is generally evaluated by analysis of its physicochemical properties. These constituents influence its shelf life, granulation, texture, flavor and the nutritional quality of the honey.

In recent years, the contribution of beekeeping to poverty reduction, sustainable development and conservation of natural resources has been recognized and well emphasized by the Government of Ethiopia and Non-Governmental Organizations operating in the country. As the country is endowed with varied ecological zones and different flora, there is a great potential for working with communities by introducing simple and easily adaptable apiculture production systems that will lead to considerable gains in productivity beyond family consumption needs (MoARD, 2007).

Silti district is located in Siltie Zone of Southern Nations, Nationalities and Peoples Regional State with a high potential for development of apiculture. The district has 9474 honeybee colonies (SWARDO, 2010) and has diversified natural and planted trees as well as cultivated crops which flower at different times of the year. This then provide year round forage for bees. Despite the large number of honeybee colonies and diversified flora resource in the study area, production and productivity of beekeeping is below its potential. In addition, adoption of improved honey harvesting, processing and storage techniques is limited, contributing to poor quality of marketable products. Thus, beekeepers and the country are not benefiting from the sub-sector as expected (Tadesse, 2001; Adgaba, 2002). This is because apiculture is one of the sub-sectors of agriculture that received limited attention in areas of research and development. So far little is known about quality of honey produced in Silti district. This study was, therefore, conducted to assess the quality of honey produced in Silti district in southern Ethiopia.

MATERIAL AND METHODS

Description of the study area

Silti district is located between 7°38’ and 8°07’ N latitude and 38°12’ and 38°30’ E longitude in Siltie Zone of Southern Nations, Nationalities and Peoples Regional State of Ethiopia. Silti is one of the eight districts in Siltie Zone and is located 25 km north of Worabe town and 147 km south of the capital city Addis Ababa. The district borders Gurage Zone in the north, Dalocha district and Worabe town administration in the south, Lanfuro district and Oromia Region in the east and Alicho Weriro district in the west. According to the information obtained from the Silti District Agriculture and Rural Development Office (SWARDO), there are 38 rural and 3 urban kebeles (kebele is the smallest administrative unit in the country) in the district. The total human population of the district is estimated to be 188,560 of which 49.39% and 50.61% are male and female, respectively (CSA, 2008). The number of agricultural households in the district is 37,186 of which 28,618 are male-headed and 8568 female-headed households (SWARDO, 2010).

Silti district covers approximately 53,112 ha of land out of which 36,673 ha is cultivated , 5,211 ha is for grazing , 3,471 ha is covered with forest/bush, 1,255 ha is covered with water, and the remaining 6,502 ha is allocated to other uses. The average land holding *per* household is 0.65 ha (SWARDO, 2010). Silti is one of the most densely populated districts in Siltie Zone with 369.5 persons *per* km^2 (CSA, 2008).

Topography, climate and vegetation cover

According to SWARDO (2010), the altitude of the district ranges from 1650 to 3100 m and it has two agro-ecological zones where 20.3% is highland (2300–3100 m) and 70.70% is mid-altitude (1650–2300 m). The annual average temperature of the district ranges from 12°C to 25°C (SWARDO, 2010). The dominant and most important plants in the district are Acacia spp., Eucalyptus spp., *Cordia africana*, *Coroton macrostachy*, *Podocarpus* spp., *Euphorbia* spp., *Millettia ferruginee*, *Dovyalis abyssinica*, *Rosa abyssinica*, *Echinops* spp., *Rubus* spp., *Guizotia scabra*, *Bidens* spp. and other trees, shrubs and climbers that provide nectar and pollen for honeybees (SWARDO, 2010). Rain-fed agriculture is mainly practiced in Dega area (SWARDO, 2010). There are two major rivers and more than three springs in the Weyna Dega part of the district.

Sampling technique and sample size

Stratified random sampling procedure was followed to select the rural kebeles based on their agro-ecological zone. Accordingly, the district was stratified into two zones (Dega and Weyna Dega) and from each zone, three rural kebeles were selected. From each kebele, two honey samples were collected: one from traditional hive and the other from moveable frame hive which makes up six honey samples from each of the two agro-ecological zones. In addition, six honey samples were collected from a honey market in Kebet town. Thus, the total number of honey samples analyzed was 18 and the honey samples were collected in November 2010.

The honey samples were put in clean plastic containers and delivered to the laboratory for analysis. The parameters analyzed were moisture, reducing sugars, sucrose, ash, water insoluble solids, acidity and pH. Among these, reducing sugars and sucrose were analyzed at the Ethiopian Health and Nutrition Research Institute laboratory. The rest of the parameters were analyzed at the Quality and Standards Authority of Ethiopia (QSAE) according to the procedures of the honey specification of QSAE (2005).

Moisture

The moisture content was assessed by measuring the refractive index of the sample using Abbe Refractometer (Leica Mark II plus 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 (Bogdanov, 2002). Refractive index of distilled water (1.3330) was used as reference. After the measurement of four honey samples (8 measurements), the instrument was calibrated using the refractive index of distilled water. Measurements were in duplicate and 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 (QSAE, 2005).

Reducing sugars

Reducing sugars content was determined by the modified Lane and Eynon (1923) method involving the reduction of Soxlet modification of Fehling's solutions by titrating at boiling point (60^{o}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 glass rode. The sample was diluted with water to the volumetric capacity (100 ml) of the flask at 20^{o}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 using a burette. The mixture was heated to boiling 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 3 minutes by repeated additions of small quantities of diluted honey solution until the indicator was decolorized. The result was calculated and expressed as follows (Pearson, 1971): C = (25/W)*(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.

Apparent sucrose

Sucrose content of the honey samples was determined according to the procedures of Pearson (1971). The apparent sucrose content was calculated by a difference and expressed according to Pearson, (1971) as follows;

Apparent sucrose content = (invert sugar content after inversion - invert sugar content before inversion) x 0.95. The result was expressed as gram apparent sucrose per 100 g honey.

Ash content

Ash content of honey samples was determined according to the procedures of QSAE (2005). Ash (% by mass) was calculated using the following formula;

Ash (% by mass) = (m1- m2)/Mo*100 Where, m2 = weight of empty crucible, m1 = weight of the ash and crucible, and Mo= mass of the sample taken for the test

Free acidity

Free acidity of honey samples was determined according to the procedures of QSAE (2005). Honey sample (10 g) was dissolved in 75 ml distilled water in a 250 ml beaker and stirred with a magnetic stirrer. The solution was titrated with standardized 0.1 M NaOH to a final pH of 8.50. Then the amount of NaOH solution used for titration was recorded. The result was expressed in milliequivalent (meq) of acid per kg of honey using the following equation (QSAE, 2005). Acidity =10V

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

pH

Ten grams of honey samples 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 (Inolab, Germany), which was calibrated using pH 4.0 and 7.0 buffer solutions (QSAE, 2005).

Water-insoluble solids

The water insoluble solids content of the honey samples was determined according to the procedures of QSAE (2005) according to the following formula.

Percent of water-insoluble matter (g/100 g) = (M/ M1) x 100
Where, M = mass of dried insoluble matter; M1 = mass of honey used.

Statistical analysis

The data was analyzed by one-way ANOVA using SAS software version 9.2 (SAS, 2002). The mean values of honey samples obtained from the two hive types (traditional and movable frame hives) and the three locations (Dega, Weyna Dega and market) were compared and mean separation was made using the least significant difference (LSD) technique whenever ANOVA showed statistically significant difference. Significant difference was declared at 5% significance level. The following statistical model was used to compare honey quality between hive types and between locations independently. Yij = μ+Hi+Li + eij

Where Yij = honey quality parameter (response variable); μ = overall mean; Hi = the effect of ith hive type, Li = effect of the ith location and eij = random error.

RESULTS

The minimum, maximum and mean values for each physicochemical parameter of the analyzed honey samples are reported in Table 1. Majority of the honey samples collected from the study area (89%) had a moisture content of less than 17.5%.

Table 1. Physicochemical properties of honey produced in Silti district (n=18)

Parameters	Range	Mean ± SD
Moisture (g/100g)	14.61-19.54	15.94 ± 1.15
Reducing sugars (g/100g)	66.44-71.64	69.04 ± 1.49
Sucrose (g/100g)	2.160-6.01	4.1 ± 1.2
Water-insoluble solids (g/100g)	0.006-1.53	0.26 ± 0.44
Ash (g/100g)	0.12-1.67	0.34± 0.38
Acidity (meq/kg)	12.41-33.67	19.32 ± 5.24
pH	4.13-5.02	4.450 ± 0.21

meq = milliequivalent; n: Number of samples; SD = standard deviation

Mean values of the physicochemical parameters of honey samples collected from different hive types and locations are reported in Tables 2 and 3, respectively. There were no significant differences (P>0.05) in moisture, reducing sugars, sucrose, ash, and pH values between honey samples obtained from traditional hives and honey obtained from movable frame hives (Table 2). However, the water-insoluble matter of honey obtained from traditional hives was significantly higher (P<0.05) than that obtained from movable frame hives (Table 2). The honey samples from traditional hives had the highest percentage of impurities as indexed by water-insoluble matter. On the other hand, acidity of honey samples obtained from movable frame hives was significantly higher (P<0.05) than honey samples collected from traditional hives (Table 2).

Table 2. Comparison of physicochemical properties of honey samples collected from different hive types

Variables	Hive type	
	Traditional (n = 9) Mean ± SD	Movable frame (n = 9) Mean ± SD
Moisture (g/100g)	15.95 ± 0.735	15.93 ± 1.504
Reducing sugars (g/100g)	69.65 ± 0.780	68.42 ± 1.802
Sucrose (g/100g)	4.42 ± 0.768	3.69 ± 1.474
Water-insoluble solids (g/100g)	0.49 ± 0.53^{a*}	0.025 ± 0.02^{b*}
Ash (g/100g)	0.17 ± 0.055	0.5 ± 0.49
Acidity (meq/kg)	17.38 ± 3.4^{b*}	21.25 ± 6.21^{a*}
pH	4.52±0.21	4.37 ± 0.19

SD = Standard deviation; meq = milli equivalent; n= Number of samples; Means followed by different superscript letters in a row are; significantly different (p<0.05).

Comparison of the physicochemical parameters between honey samples collected from the three locations showed no significant difference (P>0.05) for pH, ash, water-insoluble matter, sucrose and moisture contents (Table 3).
However, honey samples collected from the market had significantly (P<0.05) higher reducing sugars content as compared to honey samples collected from Weyna Dega areas (Table 3). But no significant difference (P>0.05) in reducing sugars was observed between honey samples collected from the two agro-ecological zone of Silti (Table 3). The acidity of honey samples collected from Dega areas was significantly (P<0.01) higher than honey samples collected from Weyna Dega and the market (Table 3). However, no significant difference (P>0.01) in acidity was observed between honey samples collected from Weyna Dega and the market (Table 3).

Table 3. Comparison of physicochemical properties of honey samples collected from different locations

Variables	Location		
	Dega (n = 6) Mean ± SD	Weyna Dega (n = 6) Mean ± SD	Market (n = 6) Mean ± SD
Moisture (g/100g)	16.07 ± 0.87	15.58 ± 0.67	16.18 ±1.75
Reducing sugars (g/100g)	68.89 ± 1.4^{ab*}	68.17 ± 1.4^{b*}	70.05 ± 1.2^{a*}
Sucrose (g/100g)	4.10 ± 1.02	4.35 ± 1.24	3.726 ±1.45
Water-insoluble solids (g/100g)	0.192 ± 0.21	0.326 ± 0.59	0.26 ± 0.48
Ash (g/100g)	0.47 ± 0.59	0.37 ±0.272	0.158 ± 0.03
Acidity (meq/kg)	24.39 ± 5.8^{a**}	16.848 ±3.1^{b**}	16.71 ± 1.9^{b**}
pH	4.368 ± 0.15	4.57 ± 0.29	4.41 ± 0.1

SD = standard deviation; * significantly different (p<0.05); ** significantly different (p<0.01).meq = milli equivalent; n=number of samples; means followed by different superscript letters in a row are significantly different.

DISCUSSION

Moisture content of honey depends on the environmental conditions such as temperature, relative humidity of the area and manipulation of honey by beekeepers during the harvest period, and it can vary from season to season (Acquarone *et al*., 2007). Moisture variability also depends on climatic factors, season of production and maturity of honey (Cantarelli *et al*., 2008). The low moisture content of honey from the study area might be attributed to low relative humidity of the area when the honey samples were harvested (November, which has an average rainfall of 11.6 mm) (Doilicho, 2007). In the study area, the peak honey flow season is between October-November and the relative humidity of the area during this time is low as compared to other seasons. October to January are months with the lowest amounts of moisture (11.6-48.0 mm rainfall) in the district (Doilicho, 2007). The low moisture content of the honey samples could also be attributed to the experience of the beekeepers on harvesting ripened honey. Moisture content of all honey samples are below the maximum limit (21%) set by Quality and Standards Authority of Ethiopia (QSAE), Codex Alimentarius Commission (CAC) and the European Union (EU) for honey. The mean moisture content of honey in the present study is lower than the country's average (20.6%) (Adgaba, 1999). It is also lower than the moisture contents of honey reported for Burie (18.80 %) (Belie, 2009), Sekota (15.98%) (Alemu *et al*., 2013) and Homesha (16.4%) (Gobessa *et al*., 2012) districts. The low moisture content of honey samples in the present study indicates good keeping quality since high moisture content could lead to fermentation during storage.

Sugars are the main constituents of honey, comprising about 95% of honey's dry weight (Bogdanov, 2011). Reducing and non-reducing sugars together, account for 85-95% of the carbohydrate in honey; the amount depends on the source of honey (Cavian, 2002). The sugars of honey are responsible for many of the physicochemical properties such as viscosity, hygroscopic and granulation characteristics of honey. Honey in the present study had a total reducing sugar content above the minimum limit

(≥65%) recommended by local (QSAE, 2005) and international honey quality bodies (CAC, 2001; EU Council, 2002). The reducing sugars content observed in the present study is also higher than the values of Belie (2009), Alemu *et al*. (2013) and Gobessa *et al*. (2012) who reported 65.73%, 67.33% and 65% for honey samples collected from Burie, Sekota and Homesha districts, respectively. Similarly, the mean reducing sugars content of honey from the study area is higher than the Ethiopian national average (65.5%) reported by Adgaba (1999). Thus, the result shows that honey from the study area meets quality requirements for reducing sugars set by local and international legislations. Non-reducing sugars (apparent sucrose) are set to be 5 g/100 g for the majority of honeys, except for citrus and eucalyptus honeys, which have higher limits (10 g/100 g), as well as lavender honeys (15 g/100 g) (EU Council, 2002). Higher sucrose contents could be the result of an early harvest of honey, when the sucrose has not yet been converted to fructose and glucose (Azeredo *et al*., 2003). The amount of sucrose in honey differs according to the degree of maturity and nectar compound of the honey. Unripened honeys that were harvested very early contain too much sucrose (White *et al*., 1962; White, 1980; Belitz and Grosch, 1999). As the degree of ripeness increases, the amount of sucrose found in honey decreases, this indicates that the level of sucrose decrease with the maturity of honey.

Sucrose content of honey lower than 0.20% can be attributed to enzymatic activity of invertase which causes a decrease in the amount of this non-reducing disaccharide during storage (Anklam, 1998). Both physical and chemical actions are involved in transformation of nectar into honey, with the activity of enzymes being most prominent. The long noted decrease in the sucrose content of honey after extraction has been ascribed to a continuing action of the invertase added by the bee (White et al., 1962). However, sucrose content does not reach zero even after several years of storage though the honey may still contain an active invertase (White *et al*., 1962). The determination of sucrose and fructose:glucose ratio is valuable for assessing adulteration by sucrose and to predict honey crystallization tendency (Ruoff, 2006).

Out of the total honey samples analyzed, 28% had sucrose content above the maximum limit (≤ 5g/100g) set by EU (EU Council, 2002) and Codex Alimentarius Commission (CAC, 2001) whereas the sucrose content of all honey samples is within the limit recommended by the Ethiopian Quality Standards Authority (<10 g/100 g) (QSAE, 2005). Alemu *et al*. (2013) reported a sucrose content of 3.11% for honey collected from Sekota district in northern Ethiopia whereas Gobessa *et al*. (2012) reported a sucrose content of 6.1% for honey samples collected from Homesha district in western Ethiopia. The mean sucrose content of honey from the study area (Table 1) is higher than the national average of 3.6% (Adgaba, 1999). However, it is lower than the maximum limit (5 g/100g) set by CAC (2001) and EU Council (2002). These results showed that all the honey samples from the study area is within the CAC, EU and QSAE standards, with respect to sucrose content. The sucrose content of honey could be due to botanical origin and mixture of honeydew with flower blossom.

The water-insoluble solids content depends on honey handling and the high concentration is a sign of improper handling during harvest. The water-insoluble solids of honey include wax, pollen, honey-comb debris, bees and filth particles (Mendes *et al*., 1998). Water-insoluble matter of honey is used as a criterion of honey cleanliness. The higher water-insoluble matter content observed in traditional hives might be due to inappropriate extraction and handling methods employed by producers and traders, as they lack harvesting, storage and processing equipment such as honey extractor, strainers and honey containers as well as limited skills in these processes. The mean water-insoluble solids content of honey observed in this study (Table 1) is lower than that of Alemu *et al*. (2013) who reported a mean value of 0.62% for honey collected from Sekota district, Ethiopia. According to the Ethiopian honey quality standards (QSAE, 2005), EU Council (2002) and CAC (2001), the limit for water-insoluble solids for extracted honey is 0.1g/100g and that for pressed honey is 0.5%. Giving practical training to local beekeepers on harvesting, handling, processing, packaging and sale of honey would improve the quality of honey. In addition, provision of quality apicultural equipment to the beekeepers can contribute in reducing water-insoluble solids in honey collected from traditional hives.

The mean ash content of honey samples analyzed in the present study (Table 1) is lower than the maximum limit (0.6%) set for ash content of honey by EU Council (2002), CAC (2001) and QSAE (2005). However, the ash content is higher than values (0.14 and 0.17%) reported by Alemu *et al*. (2013) and Gobessa *et al*. (2012) for honey samples from Sekota and Homesha districts, respectively. These differences may be associated to botanical origin. The mineral content of honey is related to the geographical and botanical origin of the honey. Mineral content is an important indicator of possible environmental pollution and an indicator of the soil types of the area (Anklam, 1998). Rodriguez-Otero *et al*. (1994) suggested that ash content of honey depends on the material contained in the pollen collected by the bees during foraging.

Free acidity of honey may be explained by the presence of organic acids, which are proportional to the corresponding lactones, or internal esters, and some inorganic ions such as phosphates or sulphates (Finola *et al*., 2007). Variation in free acidity among different honeys can be attributed to floral origin or to differences in the harvest season (Pérez-Arquillué *et al*., 1994). The variations in free acidity observed between honey samples in the present study might have been attributed to differences in the sources of nectar from the different agro-ecological zones of the district. The mean acidity values of honey samples analyzed in the present study (Table 1) are within the acceptable limit (≤40 meq/kg) set by QSAE and CAC, whereas the limit for honey acidity according to EU (EU Council, 2002) honey standard is ≤ 50 meq/kg. None of the honey in the present study exceeded the limit of ≤40 meq/kg, which indicates freshness (Finola *et al*., 2007).

Most honeys are acidic and have low pH values. The low pH of honey has great importance during storage, as it influences the texture, stability and shelf life of honey (Terrab *et al*., 2004). The low pH of honey also inhibits the growth of microorganisms. The pH value of honey observed in this study is consistent with the findings of Belie (2009) who reported pH of 3.49 to 5.58 for honey from Burie, Ethiopia and Alemu *et al*. (2013) who reported pH value ranging from 3.55 to 4.75 for honey from Sekota district in northern Ethiopia. The mean pH value of honey of the study area conform to the recommendation of Bogdanov (1997) who indicated that honey pH should be between 3.2 and 4.5.

CONCLUSION

Honey obtained from Silti district meet quality requirements of honey according to national and international standards for all the parameters analyzed except water-insoluble solids which was high in honey samples collected from traditional hives. To improve the quality of honey especially associated with higher water-insoluble solids, there is a need to provide practical training to local beekeepers and traders about proper ways of harvesting, handling, processing, packaging and sale of honey.

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Conflict of interest None.

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