BEEKEEPING HIVE TECHNOLOGY VIS-Á-VIS HONEY QUALITY IN KENYA

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Abstract

The bulk of Kenyan honey is multi-flora, harvested from the traditional log hive. It is rich in minerals and sweet to the taste, although different flavours emerge, depending on the plant source. Some customized brands qualify for unique niche markets, demanding premium prices, as per the agreed local arrangement. Major hive types, besides the log hive are: The Kenya Top Bar Hive and the Langstroth. Recent home studies on hive technology adoption by beekeepers reveal low, conditional adoption rate of modern technology in most honey producing zones. Honey was sampled from various Agro-ecological zones and different hive types and tested for quality using the standard methods. Major parameters measured were: The moisture content, acidity, total reducing sugars, sucrose, hydroxyl-methylfurfural (HMF) and honey colour. Most parameters were found to be within the recommended quality specifications, irrespective of hive technology used. Various shades of amber pre-dominated the honey colour. The water content ranged from 17.5-20.5, depending on climatic zone. Sugars too varied according to the latter. The HMF range was wide, with indication of honey overheating, either due to devastating temperatures or uninformed processing. It is recommended that beekeepers be trained on the relevant honey handling and processing skills, with focus on possible points of honey contamination/adulteration, along the value chain, in order to minimize on the incidence, if any, and maintain the required honey quality within the hive and across market establishments

Key words: Multi-flora, log hive, technology adoption, standard methods, quality

1.0 INTRODUCTION

Bees are multi-habitual, with different races occupying different habitat types. In Kenya, four races were identified: *Apis mellifera scutellata* (grassland), *Apis mellifera littoria* (coastal lowland), *Apis mellifera monticola* (high grounds/mountains) and *Apis mellifera nubica* (very arid areas, desert).

Bees play a critical role role in pollination and for productivity, besides the hive products: Honey, beeswax, Propolis, pollen, royal jelly and bee venom. A clean environment is critical for the existence of both bees and plants. Pollution is essentially the wrong substances in the wrong place, in the wrong concentration, at the wrong time.

When industrial plants or other sources of air pollution are established in areas of clean air the development of damaged vegetation zones is quickly observed. This damage is caused partly by direct pollutant effects on plant foliage, and partly via roots, when the pollution loads disturb the normal function of plant roots. All the vegetation in the immediate viscinity is affected, if phyto-toxic emissions are high. Drying trees change density and diversity of vegetation resulting in changes in light environment and microclimate. The insects respond to altered host finding, altered efficiency of natural enemies and alterations in growth of herbivores, disturbances in topography due to altered vegetation cover on soils.

Bees forage for nectar and pollen from flowers, for energy, protein and other nutrients. Nectar is the base of all honey. It is a sweet carbohydrate secreted from glands of different plants, mainly flowers. However, not all flowers can be used by honey bees. Pollen is a protein that bees use to feed brood and create royal jelly for the queen.

It is estimated that one third of the human food supply depends on insect pollination most accomplished by bees. They, in turn collect nectar and turn it into honey for immediate or later use. The Kenya Bureau of Standards is the government agency for governing and maintaining the set standards and practices in Kenya, as per the Standard Act, Cap 496 of the laws of Kenya. Currently, Kenya has set her honey and hive standards. The National Beekeeping Institute at Lenana, in Nairobi, has the honey and residue analysis laboratory facility, to certify quality for

local and other markets. The following parameters are analyzed: Color, Moisture, Total Reducing Sugars, Apparent Sucrose, Acidity and Hydroxymethylfurfuraldehyde (HMF).

2.0 METHODOLOGY: TO ASCERTAIN THE QUALITY OF HONEY BEING SOLD IN THE KENYAN MARKET (STANDARD PROCEDURES WERE USED).

2.1 Honey origin: Use of secondary data

Analyzed honey from the honey analysis register (secondary data, A total of 503 data entries)

at the National Beekeeping Institute, for the years 2000 to 2011, was used. Mapping was done to obtain honey origin. A cross section of the ecological zones of Kenya were reflected.

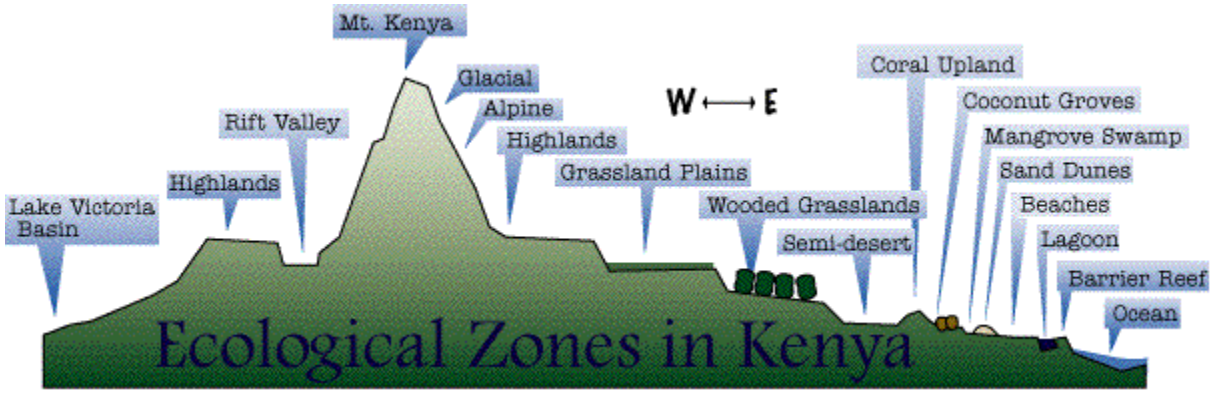
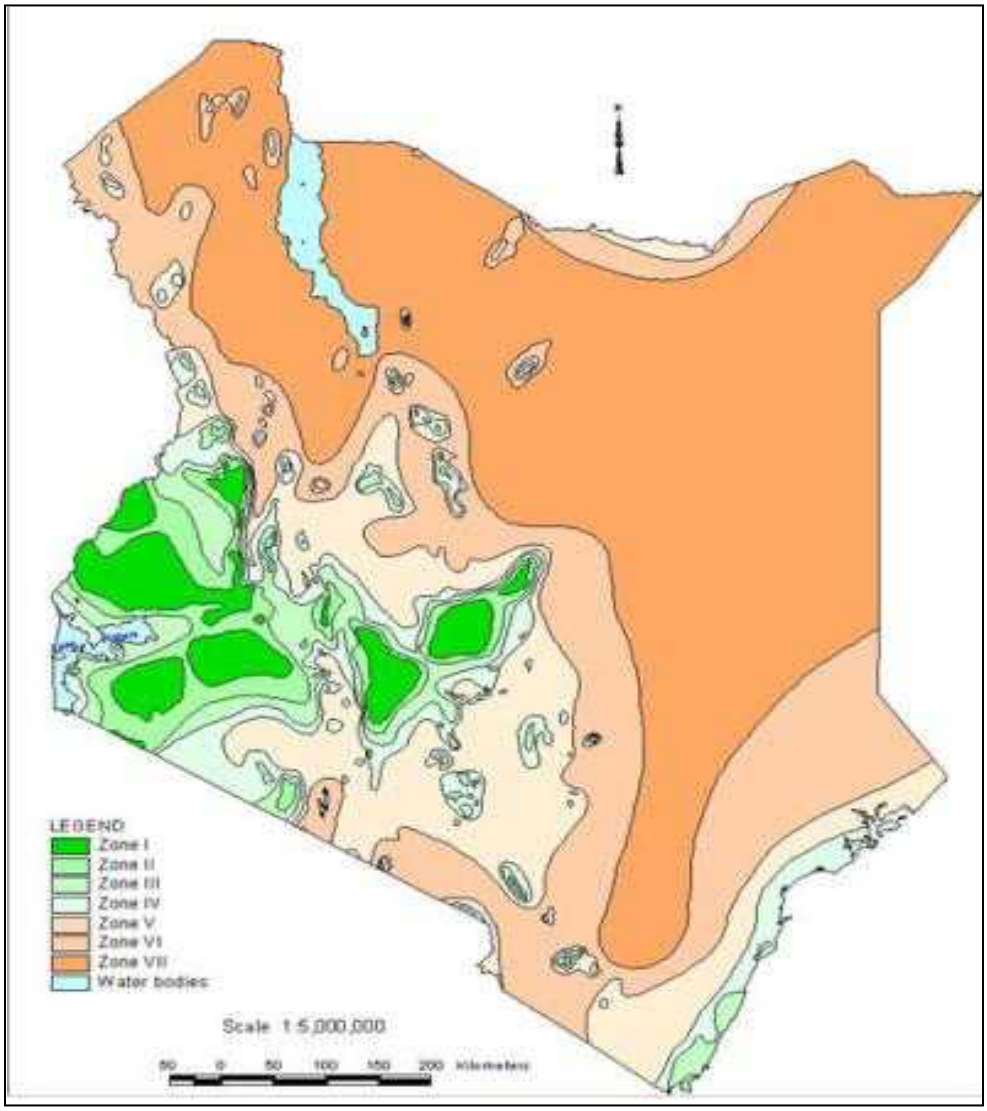


Figure 1. Cross section of ecological zones of Kenya. Internet, kids.earth.nasa.gov, 2007



Map 1: Agro-climatic zones of Kenya. P.M Maingi, 2009

Zone I

This zone has no direct importance in agricultural production other than being the source of rain and some rivers/streams. It is confined to mountains and immediate surrounding such as Mt. Kenya and Mt. Elgon.

Zone II

This zone is generally restricted to the highlands of Kenya between 1980 and 2700 m and occurs as a forest or open grasslands. This zone is found in the surrounding of Mt. Kenya, isolated parts of the Rift Valley and Mt. Elgon. The minimum rainfall is 1000 mm.

Zone III

This zone occurs mainly at elevations between 900-1800 m with annual rainfall between 950 and 1500 mm. This zone is the most significant for agricultural cultivation and several legume fodders are found here in crop-livestock systems. It is also the most resettled by human. It occurs in the vast parts of Nyanza, Western and Central provinces, good proportion of Central Rift-Valley and a small strip of the Coast province.

Zone IV

This zone occupies more or less the same elevation (900-1800m) as the previous or may be at times lower. However, it has lower rainfall of about 500-1000mm. This is typically represented in surroundings of Naivasha, vast parts of Laikipia and Machakos districts, vast parts of central and southern Coast province. It is the home of most Acacia trees and shrubs including *Acacia seyal, Acacia Senegal, Acacia brevispica, Acacia drepanolobium* and *Acacia gerrardii*. Euphobia trees occur in some drier parts of this zone. *Combretum and Terchonanthus* spp. are also common here.

Zone V

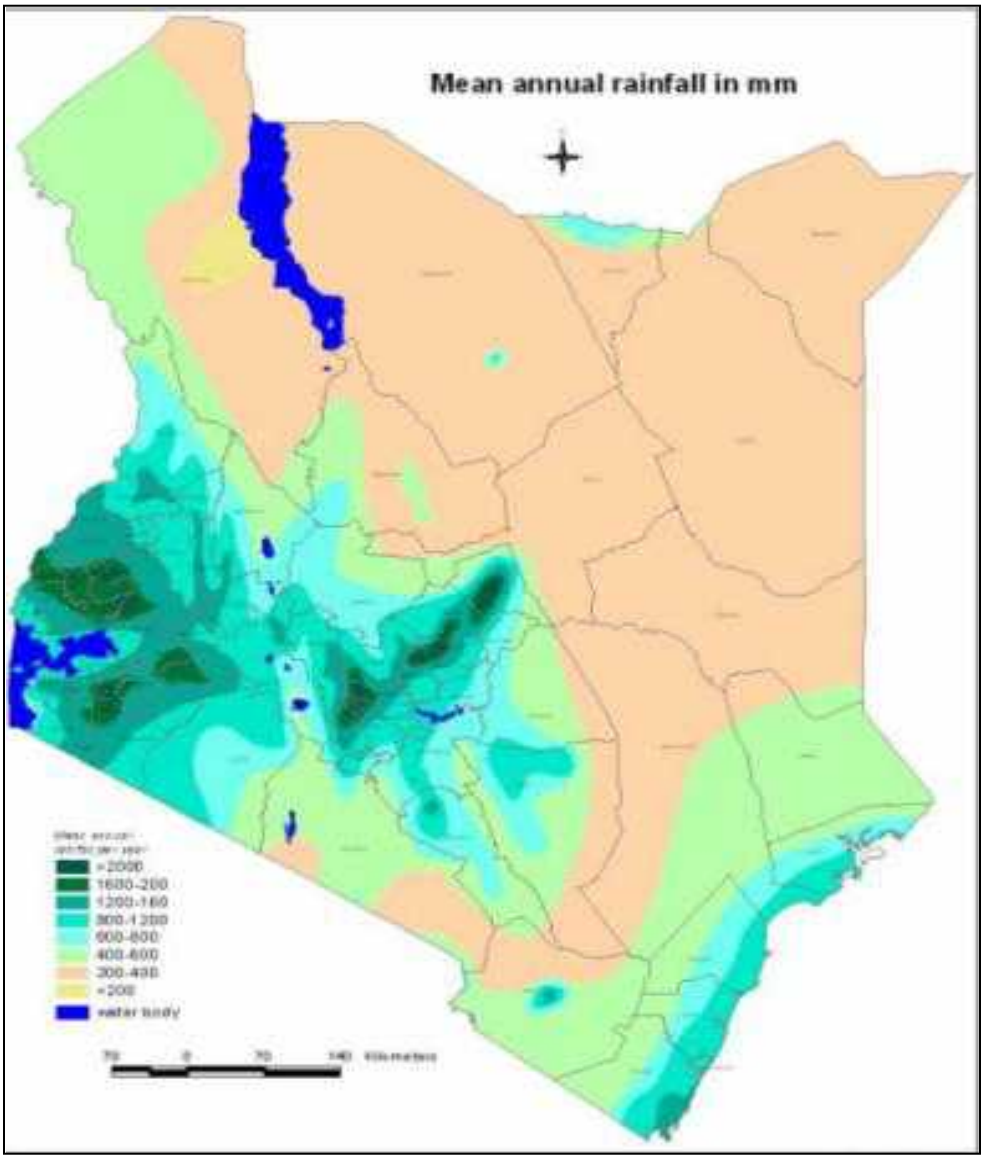
This Zone is much drier than Zone IV and occurs at lower elevations. Annual rainfall is 300-600. This zone is prevalent in Northern Baringo, Turkana, lower Makueni and vast parts of North Eastern Province. A zone for *Acacia spp, Adansonia digitata, Dobea* spp. and *Commiphora* spp.

Zone VI

This zone is considered as semi desert and is the driest part of Kenya. Annual rainfall is 200-400mm and is quite unreliable. The zone is found in Marsabit, Turkana, Mandera and Wajir districts. Dominant in this zone are *Acacia spp.* and *Commiphora* shrubs.

Zone VII

This is represented by Chalbi Desert in Marsabit district. The Chalbi is a salt desert with very sparse salt bushes as the only vegetation found. It is a vast and beautiful scenery. Pastoralists use it as a source of mineral lick for livestock, particularly during the rainy season.



Map 2: Mean annual rainfall in mm. Maingi P.M, 2009

Mean annual rainfall (mm)

AEZ 2 200-400 –semi arid

AEZ 3 400-600- transitional

AEZ 4 600-800 –semi humid

AEZ 5 800-1200 –sub humid

The four zones above are the sources of honey in this research.

2.2 Honey color: Using a honey color grader

Honey color grader was used. Honey colors range from light amber to dark amber. This is done by calibrating the grader with glycerol. Honey in a cuvette is placed into the grader for a reading against the Pfund color magnitude, and the results are counter checked with the color chart.

2.3 Determination of moisture content: Using Refractometric method

This involves the determination of the refractive index with a refractometer, Hand or Desk, at a constant temperature of about 20 degrees centigrade and converting the reading into moisture content (%) using a standard table (ADAC, 1980; Kenya Standards of honey, 1985 and Wedmore,1995).

2.4 Determination of Total Reducing Sugars: Using titration with indicator and reduction with copper sulphate. A more recent innovation is by use of HPLC

The method of Lane et al. (1923) involving the reduction of a Soxhelt, a modification of Fehling solution by at boiling point with honey solution using methylene blue solution as indicator (FAO/WHO Codex Alimentarious, 1960; ADAC, 1980). TRS should be above 65%.

2.5 Determination of apparent sucrose: Using titration and hydrolysis method

The method involves hydrolysis by heating with 6.34 N hydrochloric acid and subsequent titration, the sucrose content is obtained from percent invert sugar using the formula

Sucrose content = (invert sugar content after inversion – invert sugar before inversion) x 0.95

Sucrose content was determined by inversion method (Walker, 1917; Codex Alimentarious. 1969 and Kenya Standards for honey, 1985). Sucrose should not be more than 5%.

2.6 Determination of free acidity: Using a pH meter(8.3)

It involves the titration of 10g of honey in 75ml of water against carbonate free 0.1N Sodium Hydroxide using neutralized Phenopthaline indicator (ADAC,1980). Acidity is expressed in miliequivalents/kg honey, where v=milliliters of 0.1N NaOH used for neutralization of 10g of honey.

2.7 Determination of Hydroxymethylfurfural (HMF): Using a UV Spectrophotometer or HPLC

2.7.1 The photometric method of Winker (1955) using Barbituric-p-toluidine is used in the method. 5ml of 10% p-toluidine in Isopropanol containing 10% Acetic acid was added to 2ml of 20% honey solution. 1ml of 0.5% Barbituric acid was added and the absorbance read against a blank, containing water instead of Barbituric acid at 550nm. HMF is calculated: Mg/100mg HMF = Absorbance x 19.2 over thickness of layer (cuvette). HMF should not be more than 40mg/kg.

2.7.2 Hydroxymethylfurfural is determined in a clear, filtered, aqueous solution using HPLC, equipped with UV detector and reverse phase column. The signal is compared with that of known concentration.

3.0 RESULTS

3.1 Honey sample collection points in zones II, III, IV and V:

	Zones			
II	III	IV	V	
East Mau	Mariakani	Kinangop	Baringo	
Meru	Bungoma	Limuru	Samburu	
Nyeri	Kariokor	Kibwezi	Makueni	
Mbeere	Kakamega	Makindu	Kapenguria	
Embu	Thika	Machakos	West Pokot	
	Makuyu		Marigat	
	Kinangop		Kitui	
	Kiambu			
	Kilifi			
	Nandi			
	Koibatek			
	Masaai Mara			
	Laikipia			
	Marigat			
	Keiyo Marakwet			
	Njoro			
	Rongai			
	Kilgoris			
	Kajiado			
	Kapenguria			
	Loitokitok			

Analyzed honey in the years 2000 - 2011,was sourced from 37 areas

Results for honey samples from zones II,III,IV and V

Source	Moisture	TRS	Sucrose	Acidity	HMF
Embu	17.4	72.3	3.7	34	3.35
Meru	17.57	74.77	2.5	25.61	15.3
Nyeri	19.2	60.76	15	23	75.46
Mbeere	17.83	71.43	3	39.55	18.2
East Mau	16.3	73.65	3.45	33.5	31.17
Mean	17.66	70.58	5.53	31.13	28.69

Table1: Zone II

Source	Moisture	TRS	Sucrose	Acidity	HMF
Bungoma	18.7	38.85	18.8	11.6	23
Kakamega	22.3	64	2.63	36.66	13.73
Thika	17.8	75.9	2.1	25	
Makuyu	17.36	74.66	2.2	29.33	4.2
Kiambu	15.1	71.5	2.2	36	9.6
Nandi	18	71.7	0	31	1.5
Marigat	17.7	72.5	4.75	20	4.85
Rongai	17.4	73.8	2.3	37	17.3
Kilgoris	16.8	69.3	4.6	18	2.5
Kajiado	19.65	70.77	2.5	28.25	1.3
Kapenguria	17.6	75.05	0.6	25.5	1.25
Loitokitok	16.59	78.5	3.28	56.8	35
Laikipia	17.47	76.65	4.18	20.84	0.97
Masai Mara	19	75.9	1.25	18	0.5
Kilifi	18.2	73.3	1.02	28.42	10.1
Tana River	16.62	73.72	2.2	40	28.29
Mariakani	19.5	69.3	4.8	20	0.6
Keiyo	18	73.7	1.67	29.33	32.87
Mean	17.98	71.06	3.39	28.42	11.03

Table2: ZoneIII

Source	Moisture	TRS	Sucrose	Acidity	HMF
Kinagop	17.73	74.31	1.73	33.16	15.9
Limuru	18	67.5	4.4	24	
Machakos	18.69	73.13	2.29	31.47	5.4
Naivasha	16.5	74.3	2.1	35	28.8
Makindu	19.2	71.7	2.1	28.5	14
Kibwezi	19.93	86.46	2.55	36.5	43.9
Njoro	16.4	73.8	0.3	17	0.48
Mean	18.06	74.45	2.21	29.37	18.08

Table3:ZoneIV

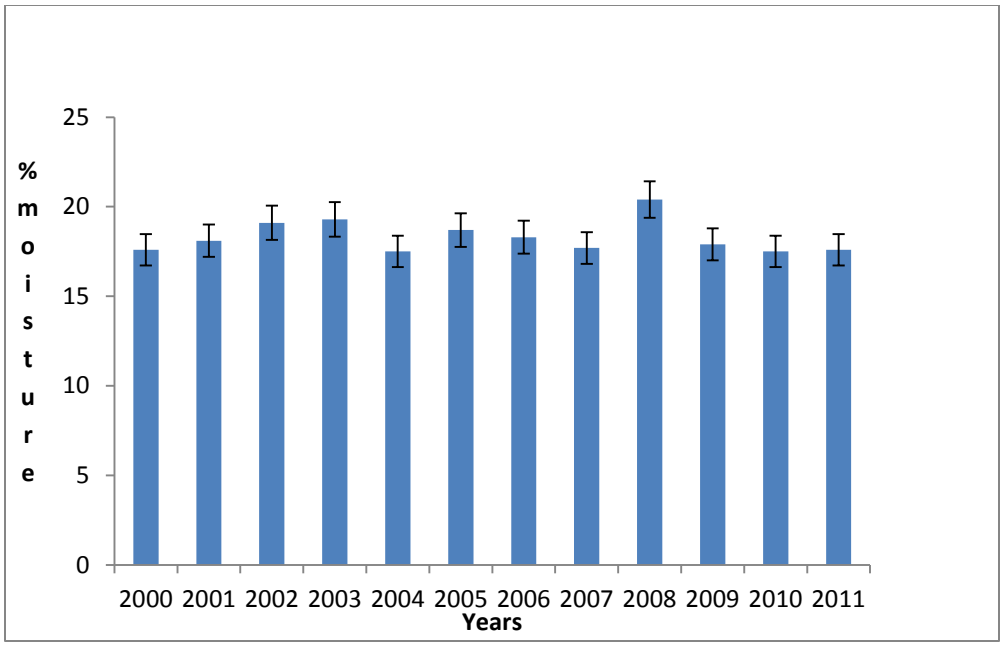
Source	Moisture	TRS	Sucrose	Acidity	HMF
Baringo	17.5	74.03	2.04	24.8	10.9
Makueni	17.73	71.34	1.98	34.02	31.18
Kapenguria	17.6	75.05	0.3	25.5	1.25
West Pokot	18.98	72.64	1.97	38.47	37.25
Marigat	17.7	72.5	4.75	20	4.85
Samburu	16.9	76.3	2.8	4.5	
Kitui	18.7	74.1	3.0	30.5	16.5
Mean	17.9	73.7	2.4	25.4	17

Table4: Zone V

3.2 Honey colors

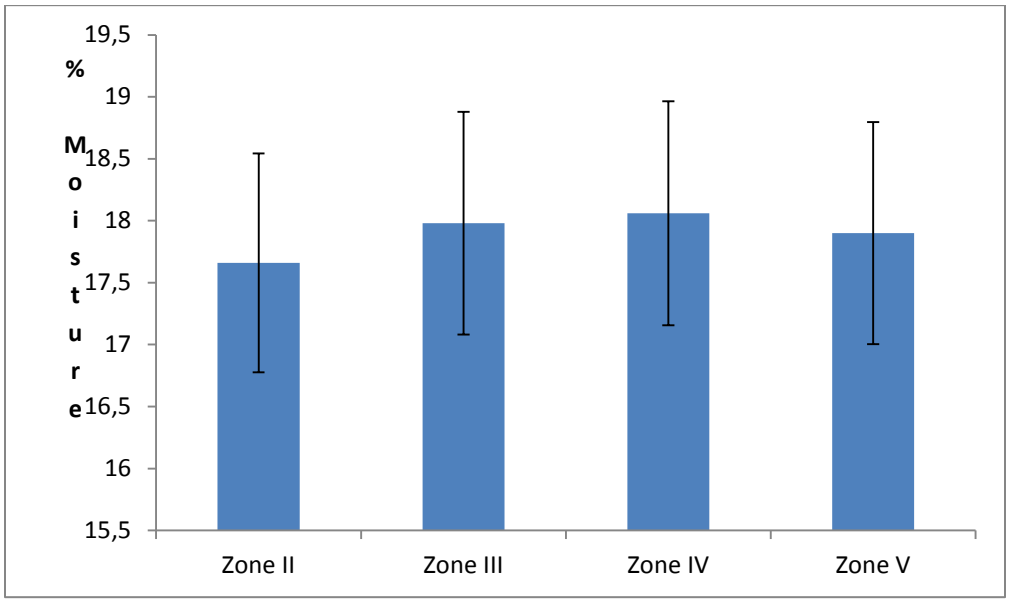
The common colours found in the market include: Light amber=163, D amber =85, Amber=235, Light yellow=5,Yellow=1,Golden=5, Water white=6, Dark brown=1, Light=1,White=1.

Figure1: Honey colors



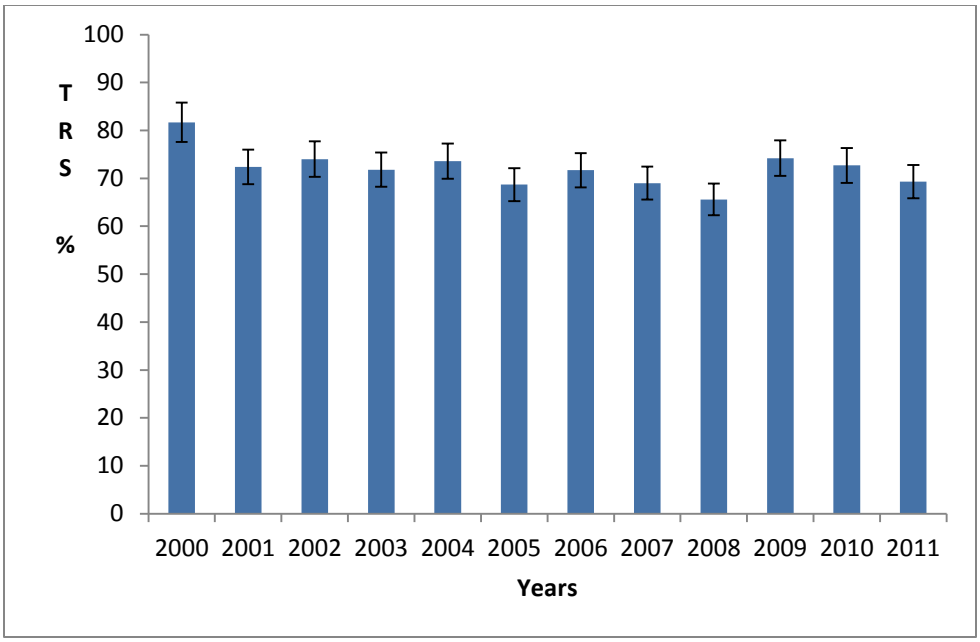
3.3.1 Histogram of water content found in the honey samples analyzed between 2000-2011

Water content ranged between 17.5-20.5 % .Standard error = 5 % value



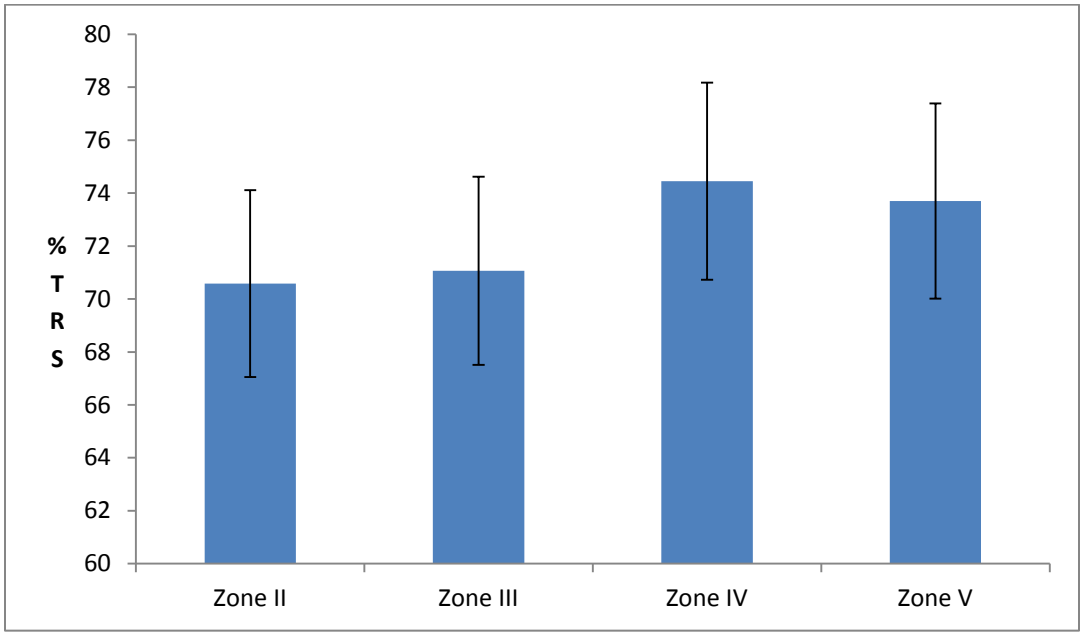
3.3.1 Histogram for moisture levels found in climatic zones II, III, IV, and V

The range was 17.6-18.05 %. Standard error = 5% value



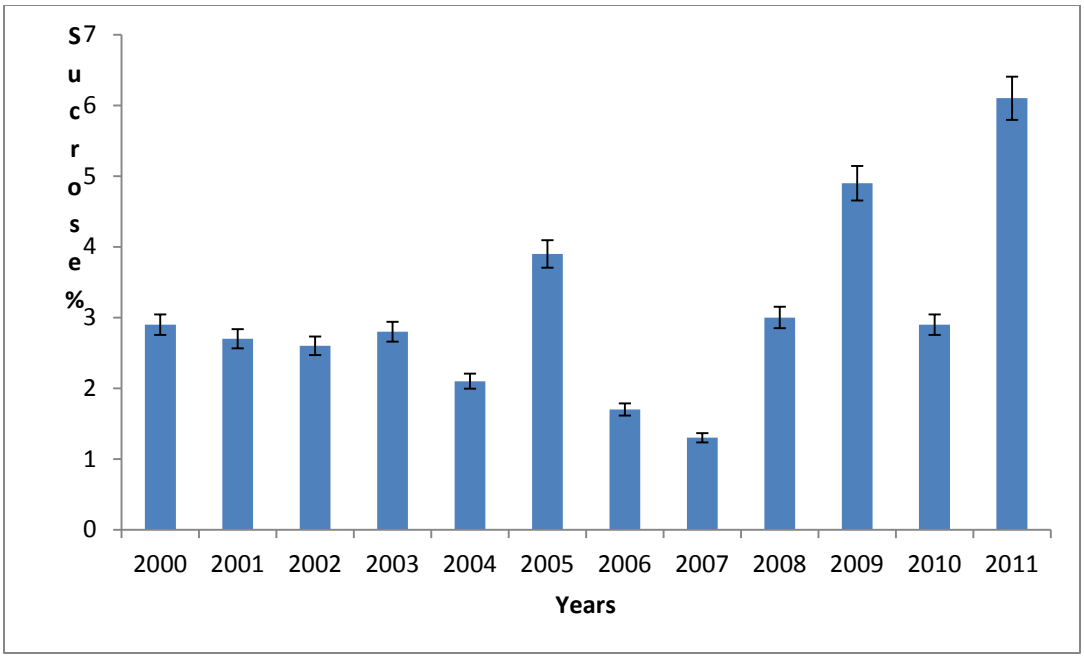
3.4.1 Histogram of TRS content in the honey samples analyzed between2000-2011

It ranged between 65-81 mg/kg. Standard error = 5% value.



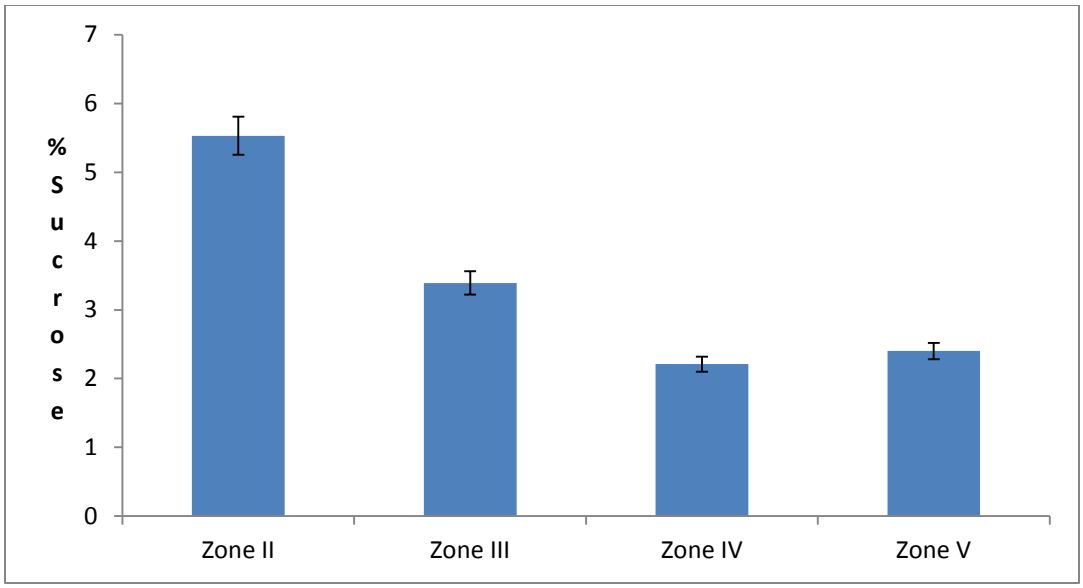
3.4.2 Histogram for TRS of honey from climatic zones II, III, IV and V

The range was between 70.3 -74.2. Standard error = 5% value



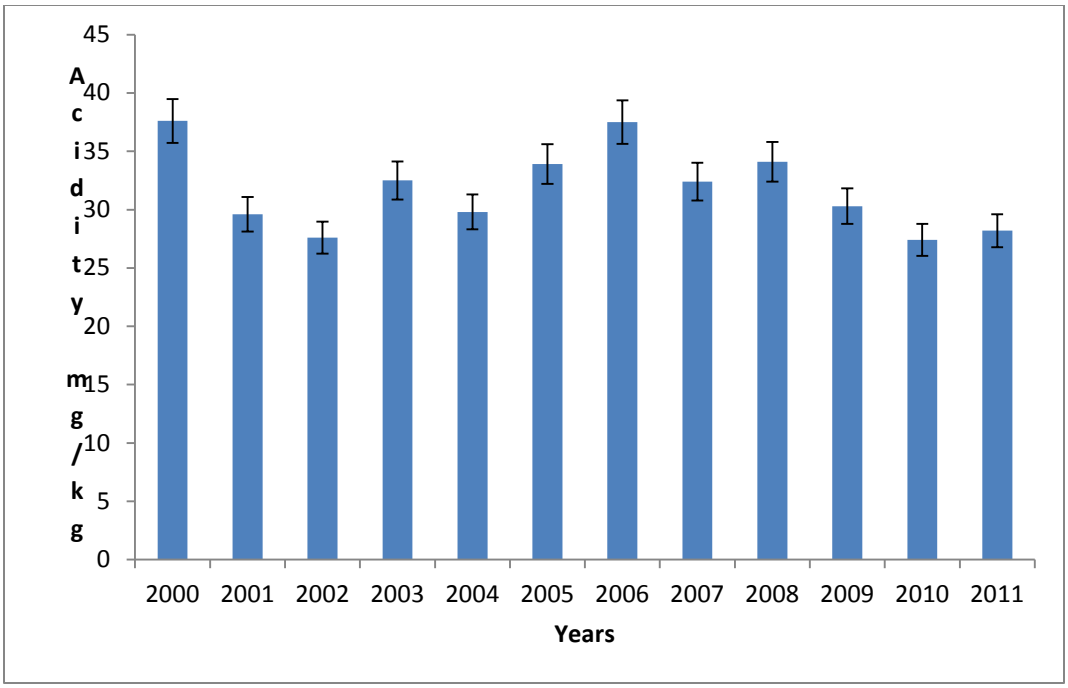
3.5.1 Histogram of sucrose content in the honey analyzed between 2000-2011.

It ranged between 1.3-6.1 mg/kg. Standard error = 5 % value



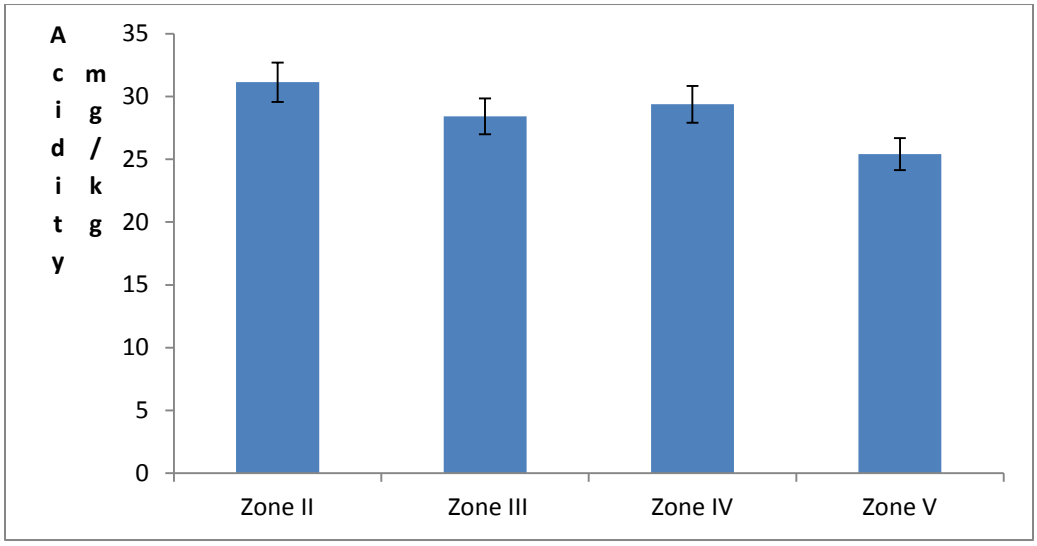
3.5.2 Histogram for sucrose 3.7.1 from climatic zones II, III, IV and V

It ranged between 2.2-5.5 mg/kg. Standard error = 5% value



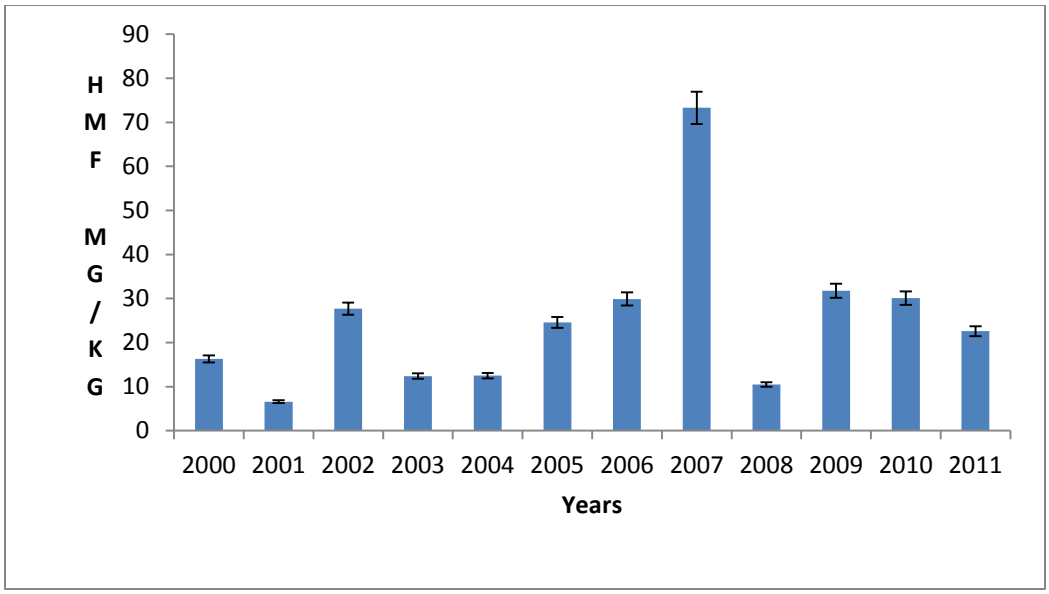
3.6.1 Histogram of acidity content found in honey analyzed between 2000-2011

Acidity ranged between 27-37 mg/kg/. Standard error = 5% value



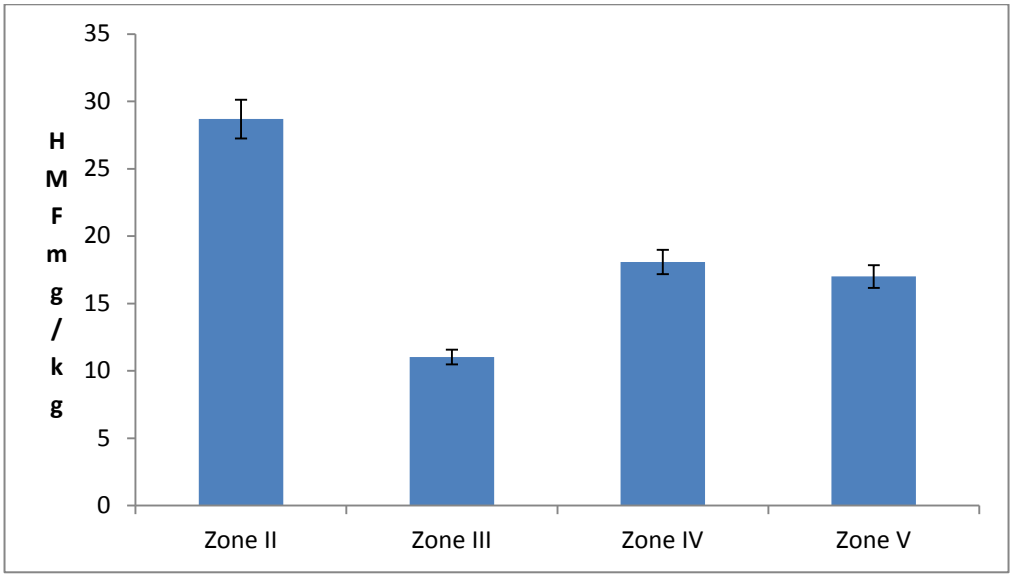
3.6.2 Histogram for acidity from climatic zones II, III , IV and V

The range was 25-32 mg/kg. Standard error = 5% value



3.7.1 Histogram of H.M.F content found in honey samples analyzed between 2000-2011.

It ranged between 7-73 mg/kg. Standard error = 5% value



3.7.2 Histogram for HMF in honey analyzed from climatic zones II, III, IV and V

The range was between 11-28 mg/kg. Standard error = 5% value

Year	Moisture	TRS	Sucrose	Acidity	HMF
	%	%	%	Mg/kg	Mg/kg
2000	17.6	81.7	2.9	37.6	16.3
2001	18.1	72.4	2.7	29.6	6.6
2002	19.1	74	2.6	27.6	27.7
2003	17.8	71.8	2.8	32.5	12.4
2004	17.5	73.6	2.1	29.8	12.5
2005	18.7	68.7	3.9	33.9	24.6
2006	18.3	71.7	1.7	37.5	29.9
2008	20.4	65.6	3	34.1	10.5
2009	17.9	74.2	4.9	30.3	31.8
2010	17.5	72.7	2.9	27.4	30.1
2011	17.6	69.3	6.1	28.2	22.6
Means	18.2	72.1	3.1	31.7	24.9

Table 1: Summary of figures for quality of honey analyzed from 2000-2011

	Moisture	TRS	Sucrose	Acidity	HMF
Zone II	17.66	70.58	5.53	31.13	28.69
Zone III	17.98	71.06	3.39	28.42	11.03
Zone IV	18.06	74.45	2.21	29.37	18.08
Zone V	17.9	73.7	2.4	25.4	17

Table 2: Mean figures for honey analysis from sources in climatic zones II, III, IV and V

4.0 Discussion

4.1 Quality of honey analyzed from 2000-2011

Most of the honey analyzed at the station originated from zone III, 900-1800m above sea level with annual rainfall of between 800-1200 mm , map 1 and map 2. The area is significant for agriculture and is resettled by humans. This include: parts of Nyanza, Western and Central provinces, Central Rift Valley and small strips of Coast province.

4.2 The color of honey has no bearing on quality. The most common colors are: light amber, though amber to dark amber, Fig.1. This characterizes some crops/fruit trees, such as Mango. Other colors like gold, dark brown, water white can occasionally be observed. White honey, sourced from sisal plants is bitter and therefore not harvested for consumption. White honey too can be found in some *Acacia spp* and other plants. Eucalyptus honey is very light in color. Yellow color is noted but rare. The minerals such as potassium, chlorine, sulfur, iron, manganese, magnesium, and sodium have been found to be much higher in darker honeys. This is, however not an indicator of honey quality.

4.3 The average moisture content was 18.2%, which is within the recommended limit. In the year 2008, it exceeded 20%, 3.3.1 and 3.3.2. This accelerates fermentation, especially during warm weather. In Kenya, fermented honey is known as mead, due to high alcohol level.

From May 1997 to February 1998, Kenya experienced extra-ordinary heavy rainfall, due to the 'El-Nino' weather phenomenon. Mid-December to late March is usually a hot and dry season in Kenya. During this season, it turned out to be the wettest, with the heaviest precipitation ever recorded in the country in the past several decades. 'El-Nino' is an abnormal warming of surface ocean waters in the Eastern Pacific called Southern Oscillation. The Southern Oscillation is the see-saw pattern of reversing surface air pressure between the Eastern and Western Tropical Pacific.

4.4 The Total Reducing Sugars (TRS), sucrose and acidity for honey in 3.4.1 shows an average of 72.1 mg/kg, which was above the minimal limit of 65%. The average sucrose level in 2011 was 3.1 but shot to 6.1 mg/kg in 3. 5. 1 , thus exceeding the 5mg/kg limit, in the year 2005, 2009 and 2011. This could have been as a result of adulteration. Other parameters measured in the same year were normal. The average Acidity was 31.7 in 3.6.1. The ensuring fluctuation could have been as a result of climatic variation.

4.5 The average HMF was 24.9 mg/kg but in the year 2007, there was clear indication of overheating, 73.3 in 3.7.1. This was observed in a few other samples from very hot localities, which produced infinite results. A sample from (West Pokot recorded 130.6, Kitui 115 and other samples, 192 and 63.4 from Keiyo), Fig. 18 , 2007. Such overheated honey smells and tastes like burnt sugar. Temperatures in the mentioned regions can be very high since it is in the arid or semi arid regions. Honey storage at high temperatures produces similar results, with high HMF level.

4.6 Honey quality and region of origin

The histogram shows moisture content with little variation across the zones, noticeable only in zone IV, 18%. The honey is however, safe from fermentation. The TRS histogram shows similar results for zones II and III, 70% and IV and V, 74%. These zones are arid and semi-arid, with little or no precipitation at all. The sugar content is much higher due to water scarcity and increased evaporation. The histogram shows a decline in sucrose content from zones II to V. The presence of rain in the zones II and III affect the concentration of sucrose in honey as observed in zones IV and V, which appears constant. The TRS, however, indicate a higher percentage in this zone. Acidity in the honey across zones II, III and IV were within the range of 25 and 30mg/Kg. Zone V has the lowest acidity level, at less than 24. There is need for more study in this area.

Zone II is around the forested areas or water towers of Kenya and any negative deviation from the expected results would imply heavy deforestation, calling for targeted afforestation programmes to reverse the trend.

4.7 Honey quality and climate change

Due to varying ecological zones, honey characteristics may vary with seasons. Agro-climatic zones 0-lll are originally of forest zones with natural vegetation, Map1. The burning of forest and grass lands kills re-growth of trees and ecologically valuable bushes. Since weather patterns have changed, there is eminent overgrazing in many parts with re-occurring droughts. It is, however recognized that nutrients are recycled through grazing animals and without them the soils are starved of nutrients. Livestock population has therefore, effect on vegetation and so does the growing human population. Re-seeding of plots is recommended. With the rains come floods, loss and destruction, as an indicator of degradation. Prompt collaborative action must be undertaken by line Government Ministries, to curb further loss. This will speed up cooperation with other stake holders in a Private Public Partnership, to contain the climate change situation.

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Bees will naturally collect nectar from plants and store good quality honey. The results showed that all measured parameters were within the required limits, irrespective of hive technology used, except for HMF, where the range was wide, with indication of honey overheating, either due to devastating temperatures or uninformed processing. Various shades of amber pre-dominated the honey color, indicating the rich multi-flora in most of the areas of honey sample origin.

5.2 Recommendation

It is recommended that beekeepers be trained on the relevant honey handling and processing skills, with focus on possible points of honey contamination/adulteration, along the value chain, in order to minimize on the incidence, if any, and maintain the required honey quality within the hive and across market establishments.

REFERENCES

David M J. C Fletcher (1978). The African bee, *Apis mellifera adansonii*, in Africa. Ann.Rev. Entomo, 2 3:151-71

Kagio, S.M, Musembi, D.K and Asiko, G.A (2012). Impact of climate change on the development of honeybees, melliferous plants and honey production. Animal production society of Kenya, biennial symposium. Green hills Hotel-Nyeri

Kasolia, David J (1991). Effects of processing conditions and storage on honey quality. Msc. thesis, University of Nairobi

Kenya National Bureau of Statistics (2010). 2009 Population and housing census highlights brochure

Kigatiira I.K (1986). Ecology and behaviour of the African honey bee. PhD thesis, Cambridge University, U.K.

Mbaya J. K. S (1983). Races of Honeybees in Kenya and Some Aspects of their Behaviour, Msc. thesis. University of Nairobi, Nairobi, Kenya

Raina S.K. and Kimbu D.M (2005). Variations in races of the honeybee *Apis mellifera* (Hymenoptera: Apidae) in Kenya. International Centre of Insect Physiology and Ecology

Ruttner, F (1975). African Races of Honeybees, pp. 325-44. *Proc. XXVth lnt. Apic. Congr. Apimonida*, Grenoble

Ruttner, F (1977). The Present Knowledge on the Taxonomy of African Races of Bees

.