CHARACTERISATION OF KENYAN HONEY AND A DESIGN MODEL FOR PROCESSING EQUIPMENT

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Declaration

This is my original work and has not been presented or submitted for the award of a degree in any other University

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We confirm that the work reported in this thesis was carried out by the candidate under our supervision and has been submitted for examination with our approval.

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Dedication

This work is dedicated to
My beloved wife - Josephine Ombui,
Our children - Felix Motari, Diana Kwamboka, and Cellin Michoki,
My mother - Bathseba Kwamboka,
and the loving memory of my late father – Nahashon Bichang'a.

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Abbreviations and Acronyms

FAO	Food and Agriculture Organisation of the United Nations
ASALS	Arid and Semi Arid Lands
KTBH	Kenya Top Bar Hive
IHC	International Honey Commission

NGO	Non Governmental Organisation
HMF	Hydroxymethyl furfural
DN	Diastase Number
KIRDI	Kenya Industrial Research and Development Institute
ASME	American Society of Mechanical Engineers
HPLC	High Performance Liquid Chromatography
AAS	Atomic Absorption Spectroscopy
AOAC	Association of Official Analytical Chemists International
ANOVA	Analysis of Variances
SPSS	Statistical Programme for Social Sciences

Abstract

Honey production potential in Kenya is estimated to be 100,000 metric tonnes which can earn the country between Ksh 15-20 billion in foreign exchange. This production potential is not met because of poor apiculture practices. Lack of appropriate honey extraction and processing equipment which is affordable and accessible has resulted into production of low level and poor quality honey. Honey produced in Kenya is from different regions and botanical sources and have different physicochemical and biochemical properties. There has been no study on these important properties in order to characterise and regulate the honey quality. The purpose of this study was to investigate the physicochemical and biochemical properties of Kenyan honey from different regions and design a model to fabricate and construct a processing equipment to improve the quality of local honey. Honey from the four regions of Kenya; Rift Valley, Central, Eastern and Coast was analysed for moisture content, electrical conductivity, ash content, mineral content, pH, HMF, water insoluble. The mean moisture content for the four regions was 19.48 ± 0.11% varying from 15.44-29.60%. Coast region had the highest mean moisture content (20.77 ± 0.46%) while Rift Valley had the minimum (18.84 ± 0.10%). The mean electrical conductivity for the four regions was 0.549 ± 0.029 mS ranging from 0.020-2.25 mS. Rift Valley honey had the lowest mean value (0.059 ± 0.015 mS) while Eastern had the highest. The mean viscosity for the four regions at 30 $^{\circ C}$ was 4342.98 ± 314.08 centipoises, varying from 1000-7700 centipoises. Rift Valley had the most viscous honey with a mean of 5607.75 ± 393 centipoises whereas Central had the least viscous with mean of 3335.00 ± 152.53 centipoises. The mean apparent reducing sugars for the four regions before and after hydrolysis were 69.41 ± 0.17 and 71.39 ± 0.17% respectively, ranging from 54.43-78.27% in the same order. Fructose was the dominant specific sugar in honey for the four regions followed by glucose, sucrose and maltose. The mean values of pH, HMF, density, diastase enzyme activity, and hygroscopicity for the four regions were 4.32 ± 0.02, 17.54 ± 1.46 mg/kg, 1.41 ± 0.00 g/cm^3, 15.04 ± 0.460 DN, and 8.67 ± 0.01% respectively. In the design of extractor warmer equipment, the overall mean of density and viscosity were used to determine the dimensions and heat transmission of the vessels. The pH was used for the selection of material for construction. Moisture content, HMF, hygroscopicity and diastase were used to set the processing and storage conditions. Kenyan honey was identified as floral (blossom), honeydew honey, compound or mixed honey with Newtonian behaviour. No thixotropic honey was found in these regions. The moisture content of Kenyan honey was found to be below the maximum permitted limit of (21%) and therefore stands no risk of fermenting. Most of the Kenyan honey had matured with acceptable levels of proline and diastase number. The physicochemical parameters of Kenyan honey were successfully used to design honey extraction and processing equipment which can be used to process honey in any part of the country.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Honey is a natural sweet substance produced by honey bees from the nectar of blossoms or from the secretion of living parts of plants or excretions of plant sucking insects on the living parts of plants, which honey bees collect, transform and combine with specific substances of their own, store and leave in the honey combs to ripen and mature (FAO, 2004; Codex Alimentarius Commission, 2001). It is the most important primary product of beekeeping both quantitatively and economically (FAO, 1996; Meda *et al.*, 2005). It is also the first bee product used by mankind in ancient times apart from wax and propolis (Cherbuliez and Domerego, 2003). The history of the use of honey is parallel to the history of man (Crane, 1975). The Egyptians kept bees and traded for honey along the East Africa Coast several thousands of years ago. Virtually in nearly every culture there is evidence that honey has been appreciated as a food source as well as a symbol employed in religious, magic and therapeutic ceremonies, a reverence it owes among other reasons to its unique position until very recently, as the only concentrated form of sugar available to man in most parts of the world (Jasim *et al.,* 2007; Meda *et al.,* 2005).

Kenya's production potential for honey is estimated to be 100,000 metric tonnes; though only 25 metric tonnes are produced annually (Wamwangi *et al.,* 1999; Ministry of Trade and Industry Documents, 2008; Ministry of Livestock Development and Fisheries, 2007). The estimated target is not met because of poor methods of harvesting, extraction, handling, storage, and marketing as well as limited honey data. Lack of appropriate, affordable and accessible honey extraction and processing equipment has resulted into poor quality and low level production of honey.

Kenya can earn up to a tune of Kshs 15-20 billion in foreign exchange if its full production potential is realized. Fulfilling this fundamental requirement in the beekeeping sector can also create employment, alleviate poverty, bring about improvement of incomes of people in rural areas and in particular Arid and Semi Arid Lands (ASALS) (Ministry of Livestock Development and Fisheries, 2008; Gatere *et al.*,1985; Mutungi *et al.*, 1999). The country's honey production capacity is low and its annual demand for natural honey stands at 70,000 kg making it a net importer of honey worth Kshs.13 million annually (Gatere *et al.,* 1985; Ministry of Trade and Industry, 2008; Central Bureau of Statistics, 2008).

Bees built their combs and produce honey in different types of beehives. Beekeeping in various parts of Kenya is dominated by the traditional log type of beehive. The modern Kenya Top Bar and Langstroth beehives take second place. Unlike the Kenya Top Bar and Langstroth beehives, the traditional log type is not well adapted for periodical honey comb inspection and subsequent removal for extraction when fully filled with honey. It is also more commonly exposed to honey predation by mites, moths and honey batchers. Both Kenya Top Bar and Langstroth hives avoid predators since in many cases they are hanged and suspended by strings and wires. These hives are designed for producing large quantities of honey since their honey frames when fully filled can be removed, honey extracted and the empty combs in the frames returned in the beehives for refilling. Though their honey production capacity is high, the modern beehives are expensive to small scale farmers. They cost between Kshs 5,000 to 8,000 per piece. Kenya's rural economy is not well endowed and therefore majority of the beekeepers can't afford the modern beehive (Personal Communication, 2008), hence they prefer the traditional log type and this has tremendously affected honey production in the country.

Beekeepers in rural areas practice poor methods of harvesting honey. Some completely destroy the beehive during harvesting by burning it, consequently killing a large number of bees. The surviving ones migrate to new sites to start afresh. This reduces bee population tremendously hence lowering honey production.

Extraction of honey harvested from Langstroth beehives is done by using centrifugal honey extractors. Centrifugal force is used to throw honey out of the comb cells onto the extractor vessel without destroying the honey combs, which are subsequently returned to the beehive for refilling. The extraction equipment however are imported and cost between Ksh 120,000 to 180,000.

Honey contains a wide range of sugars, depending on the nectar source and small amounts of other substances such as minerals, vitamins, proteins and some organic acids (Sato and Mayata, 2000; Jasim *et al.*, 2007). Essentially, glucose and fructose are its major constituents (Jeff, 2002; Nagai *et al.*, 2002). The physicochemical and biochemical properties of honey from different localities and regions are used to classify, identify, characterize and determine its processing, packaging and storage conditions (Pridal, 2002). In the designing of honey extraction and processing equipment, these properties play a major role. Many countries in the world such as Britain, Australia, New Zealand, Germany, Brazil, USA, Nepal and India have carried out extensive research on their honey regarding these parameters and as a result have managed to design and fabricate extraction and processing equipment as well as setting favourable conditions for its use (Crane, 1979; Ricciardelli D'Albore, 1998; Terrab *et al.*, 2004).

Bodies involved in the regulation of international honey trade such as the International Honey

Commission (IHC), the Codex Alimentarius Commission and the European Community Council, have set stringent conditions with regard to honey quality standards for both export and local consumption (IHC, 2002; Codex Alimentarius Commission, 2001). These standards are mainly dependent on both physicochemical and biochemical properties of honey as well as extraction and processing methods (International Regulatory Revised Codex Standard, 2001). There is no available documented information or data on these important physicochemical and biochemical properties of Kenyan honey for purposes of classification, identification, processing, and storage as well as quality determination. In this regard, Kenya has not put in place its standards and regulations and therefore majority of Kenyan beekeepers and processors lack access to international markets because the quality of honey is questionable (Kroll, 2004).

In the design of honey processing equipment, the parameters considered and utilized are thermal conductivity, viscosity, specific gravity, heat capacity, pH, moisture content, enzymes and HMF. The rate of honey extraction, flow, heat transfer and settling during processing also depend on these parameters (FAO, 2004; Jasim *et al.,* 2007; White, 1979).

1.2 Honey Production in Kenya and its Economics

Honeybee keeping is referred to as apiculture which is the management of bee colonies for the production of honey and other bee products such as wax, pollen, propolis and royal jelly (Gatere *et al.* 1985). Apiculture is practiced not only in Kenya but the whole world and it's perhaps the least cost livestock investment. It does not require much land, as beehives may be placed on almost all surfaces including river banks, houses and trees (Mutungi *et al.,* 1999; Crane, 1984). It requires less labour and attention as compared to other livestock activities. In Kenya, apiculture is especially an attractive type of investment for women and other vulnerable groups. Honey production is literally practiced in all regions and districts of

Kenya though there are some regions with a tradition of better developed beekeeping practice than others. These regions include Taita Taveta (Coast), Baringo (Rift Valley) Mbeere, Katunga, Marimanti, and Mwingi (Eastern), Nanyuki and Mount Kenya Region (Central) (Gatere *et al.,* 1985).

Apiculture in Kenya is characterized by low productivity and low product quality. This sub-sector is fragmented and the data available is remotely limited (Ministry of Livestock documents, 2008; Daily Nation, 2004). Institutional support for promoting honey production as an economic activity and providing technical and financial services is weak and unstructured leading to fragmented honey collection, processing and marketing through middlemen.

1.3 Problem Statement

There has been very few reported studies on the physicochemical and biochemical properties of Kenyan honey for purposes of characterization and quality regulation and therefore, Kenyan honey producers, processors and packers cannot easily classify, identify and set processing and storage conditions to guarantee honey quality. The prospect of achieving competitive prices both locally and internationally for Kenyan honey is therefore difficult. Lack of this important documentation has led to most consumers casting serious doubt on the quality of honey they consume or purchase and this has a serious effect on its market potential. Development of codes of procedure and practice in production and handling of honey and legal requirements and policy have not been put in place by Kenya Bureau of Standards (KEBS) due to lack of proper documentation on the palynological and physicochemical parameters on Kenyan honey.

Majority of local honey producers use inappropriate means to extract and process honey.

This leads to incomplete extraction and low quality honey with insect parts, debris and wax, which may be contaminated. In rural areas, honey extracted by crushing and mashing of honey combs is heated by water bath in open sufurias for the purpose of settling any particles present, melt wax and reduce moisture content. Unfortunately, this method increases moisture content in honey when not carried out carefully. The HMF also increases since heating is not controlled. This results to the low quality honey processed in rural areas. Hence the need for the design of simple honey processing equipment adapted for rural area beekeepers.

In order to improve on honey harvesting, extraction and processing, the equipment is now purchased from outside the country, making it expensive. Many Non Governmental Organizations (NGOs), which are involved in poverty eradication programmes, have engaged the rural population in different parts of the country in honey production, but the quality of honey produced remains questionable. There is therefore the need to characterize the Kenyan honey and design affordable processing equipment.

1.4 Hypotheses

a) The physicochemical and biochemical properties of honey from different regions in Kenya are different and play a major role in designing processing equipment.

b) Design and fabrication of processing equipment for Kenyan honey can be done based on some properties.

1.5 Objectives of the Study

1.5.1 General Objective

The general objective of the study was to investigate the physicochemical and biochemical characteristics of Kenyan honey and develop a design model for fabricating honey processing equipment.

1.5.2 Specific Objectives

The specific objectives of the study were to: -

i. Determine the:

   (a) moisture content, electrical conductivity, ash content, mineral content, pH, free acidity, hygroscopicity, HMF, water insoluble, viscosity, proline content, refractive index, specific gravity, specific rotation, apparent reducing sugars, apparent sucrose content and specific sugars of honey from different regions of Kenya.

   (b) Diastase activity.

ii. Design honey extraction and processing model equipment, affordable and suitable for Kenyan honey using some of the investigated properties of honey.

iii. Fabricate and construct the designed equipment.

1.6 Justification of the Study

Characterization, identification, classification, conditions of processing and storing of honey depend on its physicochemical and biochemical properties. It is therefore necessary to investigate the physicochemical and biochemical properties of honey as per location, region or country of origin. The documentation of these physicochemical and biochemical parameters among others are necessary in identifying, classifying, characterizing and setting processing, handling, packaging and storage conditions. The documentation will result in putting in place codes of practice in honey production and policy which will lead to increased production and improved honey quality in the anticipation of realizing Kenya's production potential earning the country between Ksh 15–20 billion hence contributing immensely to national wealth, job creation and poverty alleviation as well as setting suitable National Quality Standards for Kenyan honey.

Some of the results of the physicochemical and biochemical properties such as density, viscosity, thermal conductivity, heat capacity, moisture content, HMF and enzymes obtained were ultimately used to design a model for fabricating processing equipment suitable and affordable to Kenyan honey producers, processors and packers, as well as setting processing and storage conditions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Apiculture

The management of bee colonies for honey production is believed to have originated in the Middle East (Patrick, 2004; Tarek, 2008). The area around North Africa is believed to contain the Cradle of beekeeping with pictorial records showing that beekeeping in Egypt existed from 2400 BC onwards (Crane, 1979). In 1851, one important landmark in the development of beekeeping was made by an American, Lorenzo Lorraine Langstroth, who developed a specially designed hive, which made it possible to manage the process of honey production, by the colonies of bees and harvest the honey without destroying the bees (Morse and Hooper, 1985). Before this date, traditional beehives (log type) were entirely used in beekeeping in many parts of Kenya.

The development of modern beekeeping practices in Kenya was initiated in 1960's and has progressively become an important component of the livestock sub sector particularly in the semi-arid and arid lands where other forms of agriculture cannot be sustained effectively. The invention of Kenya Top Bar Hive (KTBH) in 1965 was another important milestone reached in the development of apiculture in Kenya (Figure 2.3). This new beehive was extensively tested in Kenya before disseminating the technology to other countries.

`Today this hive technology is applied in many parts of the world especially in developing countries (Patrick, 2004; Kigatiira, 2004). Currently honey is produced and consumed in almost all the countries of the world. China, USA, Argentina, Ukraine and Mexico are the world's leading honey producing countries. The leading exporters are China and Mexico while the leading importers are; Germany, Japan and USA whose imports in recent years have exceeded exports. Currently, Ethiopia and Tanzania are the leading honey producing countries in Africa. Ethiopia produces 2.5% while Tanzania has 1.15% of the global honey production (Ministry of Trade and Industry documents, 2008). It is hoped Kenya will be one of the leading honey producing countries in Africa when its production potential is realised.

2.2 Honey Production in Kenya

Majority of the Kenyan beekeepers use traditional beehives for honey production, though modern beehives have of late gained preference because of their high rate production.

2.2.1 Traditional Beehives

Two types of beehives exist; the traditional Beehives and modern beehives.

Traditional beehives are merely enclosures for the bees without internal structure (Figure 2.1).

Figure 2. 1 : **The Kenya Traditional Beehives**

In a modern beehive, the bees choose and construct their combs in the space provided in the enclosure. In this fixture, when the comb is filled with honey, removing it will mean destroying it since it is attached in a fixed frame manner to the enclosure. In Egypt from the time of Pharaohs about 5000 years ago, the traditional beehives used were round mud hives made from clay but the Kenyan version of beehive is a rounded log and there are several types of these with different shapes and designs (Kigatiira, 2004; Tarek, 2008).

Honey extraction from the traditional beehive combs is usually done by crushing and compressing the honey combs. This produces more bee wax than honey. In some countries, the traditional methods are no longer in practice (Delaphine, 1993). They are banned because they affect the rate of honey production, and are unhygienic. The destroyed combs during extraction are never returned for refilling, and therefore affecting the rate of honey production.

2.2.2 Modern Beehives

The modern beehives are made of square or rectangular boxes that are well ventilated and not bounded by ceilings or floors. The frames on which honey combs are constructed are hung in parallel. The frame sizes and materials they are made of solely depend on the weather conditions. In cold regions large frame size and hives are recommended for proper storage of bee food while in temperate or warm areas, less of that is appropriate (Crane, 1986).

Two types of modern beehive do exist; Langstroth hives (Figure 2.2) and Kenya Top Bar hives (Figure 2.3). Langstroth beehives are basically characterized by their removable honey comb frames (Figure 2.2). These hives also give the beekeeper, the convenience to remove and split the bees into another colony for reproduction purposes. The rectangular honey comb frame structures are made with the wax already placed inside for the bees to start comb building (Personal communication). These frames are toughened by wires that make them stable during honey extraction without destroying the combs or killing the bees.

Figure 2. 2: The Langstroth hives indicating the removable honey comb frame

The Kenya Top Bar hives are made of bar frames hanging freely from the top. These frames are removable with ample spacing for the bees and the combs are constructed along the top bars provided (Figure 2.3).

Figure 2. 3: The Kenya Top Bar Hive with frames called top bar

As opposed to Langstroth the top bars do not have a foundation and therefore after each harvest, the combs are detached for honey extraction hence compelling the bees to rebuilt new combs for filling (Wildman, 1990).

This type of method yield more bee wax than honey since the destroyed combs are not returned for refilling but processed into wax (Kigatiira, 2004).

2.2 Sources and Classification of Honey

There are two main sources of honey: honey from nectarines of flowers and honey from the secretions of living parts of plants or excretions of plant sucking insects on the living parts of the plants (Ouchemoukh, 2007). The former is called blossom honey, nectar honey, floral honey while the latter is called honeydew honey (O'Todle and Raw, 1991). A mixture of the two is called compound honey. There are two types of floral honey; monofloral honey and multifloral honey. Monofloral honey is honey foraged from flowers of one particular plant vegetation while multifloral honey is honey foraged from different plants. Therefore, monofloral honey has pollen from one plant vegetation while multifloral honey has mixed pollen.

2.2 Honey and its Uses

From an economic point of view, honey is the most important product from bees as compared to wax, propolis and royal jelly (Gatere *et al.,* 1985). Apart from being employed in religious, magic and therapeutic ceremonies by many cultural traditions and communities the world over; honey is used as food, sweetener, medicine and in cosmetics, natural healthy products and brewing. It is also used in the preparation of herbal medicine and in the pharmaceutical industry (Zumla and Lulat, 1989; Cartland, 1970).

2.2.1 Honey as a Food

Honey is composed of simple sugars, mainly fructose, glucose, maltose and raffinose among others (Andrew *et al.,* 2004). These sugars provide immediately available calories when honey is consumed and therefore as a food, honey is a good source of energy. This forms the basis of when, how and why it should be used by both the healthy and the sick people. Honey is most commonly consumed in its unprocessed state like liquid, crystallized or while in the comb. In these forms, it is eaten as food or incorporated as an ingredient in various food recipes (Kuyil, 2002). In many home made recipes and cultural tradition, honey is largely used on small scale as well as at industrial level in baked products, confectionery, candies, jams, chocolates, spreads, cereals, beverages and dried fruits among many preserved products. But in particular in the relatively new industry of "natural" health and biological products, honey is used abundantly as a sweetener of first choice.

At the same time, the increasing appreciation of more natural products in many countries, honey has been "rediscovered" as a valuable food and confers as an ingredient, enhancing market value of the end product. The use of honey in baked products, dried cereals and fruits is due to its characteristic hygroscopicity and flavour. This helps in adjusting the softness and aroma of the products resulting to increased customer appeal (Johnson *et al.*, 1957). The nutritional value of honey when used in its pure form and as an ingredient in other food products, facilitates better physical performance, resists fatigue, promotes higher mental efficiency, promotes growth of new born infants, fixes calcium to the bones and cures anaemia (El Banby, 1987).

2.4.2 Honey as a Medicine

Honey is used as a medicine and does not require any special preparations during application. When it is not used in its natural states, it is mixed with other liquids such as hot milk, tea or other infusions such as wine and other alcoholic beverages. Many countries' pharmacopoeias, describe honey based preparations which can be used by pharmacist such as honey rose water, which is used for topical application in infected throats and ulcers of the mouth (Greenwood, 1993).

Honey is a fundamental ingredient in some medicines, such as medicinal wines and vinegars. In medicinal wines, herbs are crushed and immersed in wine, and alcohol added in order to improve the extraction of medicinal products and preservation. The liquid obtained is filtered, pasteurized and then honey added for quick absorption when administered (Farouk *et al.,* 1988).

The major properties and effects commonly attributed to honey are medicinal benefits to the digestive system, respiratory system, skin and wound healing, eye disorders, diabetes as well as Ayurvedic medicine (Gheldof and Engeseth, 2002). Honey treats chronic and infective intestinal problems such as constipation, duodenal ulcers and liver disturbances (Salem, 1981). When applied directly to the eye, honey treats and reduces eye cataracts, cures conjunctivitis and other afflictions of the cornea (Salem, 1981; Haffeejee and Moosa, 1985; Linnet, 1996; Osaulko, 1953).

In the respiratory system, honey treats colds and ulcers of the mouth as well as bronchial and throat irritation infections both in adults, children and infants. In skin healing honey is used as a moisturing agent in cosmetics while in wound healing it is used as a nourishing agent. But in pharmaceutical preparations, it is applied directly on the open wounds, sores, bedsores, ulcers and burns. In its pure and unprocessed form, honey promotes tissue growth, prevents infections hence reducing scarring (Hutton, 1966; Manjo, 1975; Armon, 1980; Dumronglert, 1983). When honey is applied immediately on burns, it reduces blistering and speeds up generation of new tissues. For example a cream prepared from equal portions of honey, rye flour and olive oil has had considerable success in the treatment of wounds, sores and even gangrenous wounds in horses (Manjo, 1975).

In the Ayurvedic medicine of India, honey has predominantly been used as a vehicle for fast absorption of various drugs such as herbal extracts. Honey has also been used for sterilizing both internal and external body operated wounds as well as drying them up when topically applied (Braniki, 1981). Generally the treatment, healing and sterilizing action of honey as well as its efficacy against infections is due to high concentration of sugar, high acidity and hydrogen peroxide (H_2O_2) presence (White, 1963; Adock, 1962; Bogdanov, 1983).

2.5 Honey Chemistry

Honey has both reducing and non reducing sugars. The reducing sugars include glucose, fructose, raffinose and maltose. Glucose and fructose are the major reducing sugars in honey. Maltose, raffinose and sucrose are some of the disaccharides found in honey and most of them, apart from sucrose are reducing sugars. Sucrose is non-reducing because of the involvement of anomeric carbon in the glucose-fructose bond of sucrose and therefore not free to form an aldehyde in solution to react with Fehling's solution. The structure showing the involvement of anomeric carbon 1 and 2 is shown in Figure 2.4.

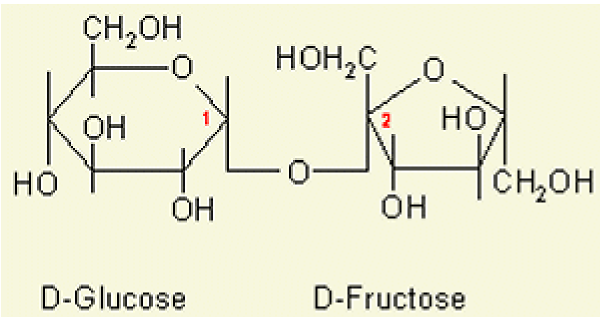


Figure 2. 4: Structure of sucrose: showing involved anomeric carbon

The reducing sugars in honey are tested and determined by using fehling's solution where a positive result is indicated by formation of red precipitate. Fehling's solution is composed of equal amounts of Fehling's solution A and B. Fehling's solution A is a solution of copper sulphate while Fehling's solution B is a solution of potassium sodium tartrate. Fehling's solution A is to provide the cupric ions (Cu^{2+}) while Fehling's solution B is to provide the alkaline medium (OH) as well as the tartaric acid to complex the cupric ion before oxidising the sugar as shown in Figure 2.5.

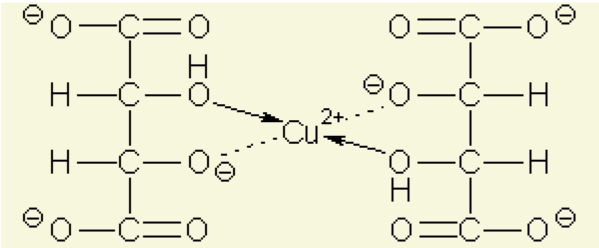
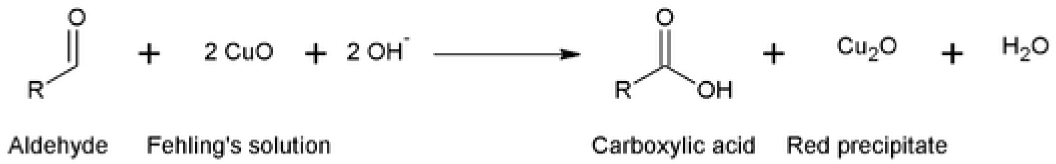


Figure 2. 5: Tartaric acid complexing cupric ions

In the determination of reducing sugar by Fehling's solution, a redox reaction is involved where the reducing sugar is oxidised to a carboxylic acid while the cupric ions complexed with the tartrate ion is reduced to cuprous oxide (red precipitate).

The reaction is as shown in equation 2.1



[2.1]

The mechanism of this reaction is given in Figure 2.6

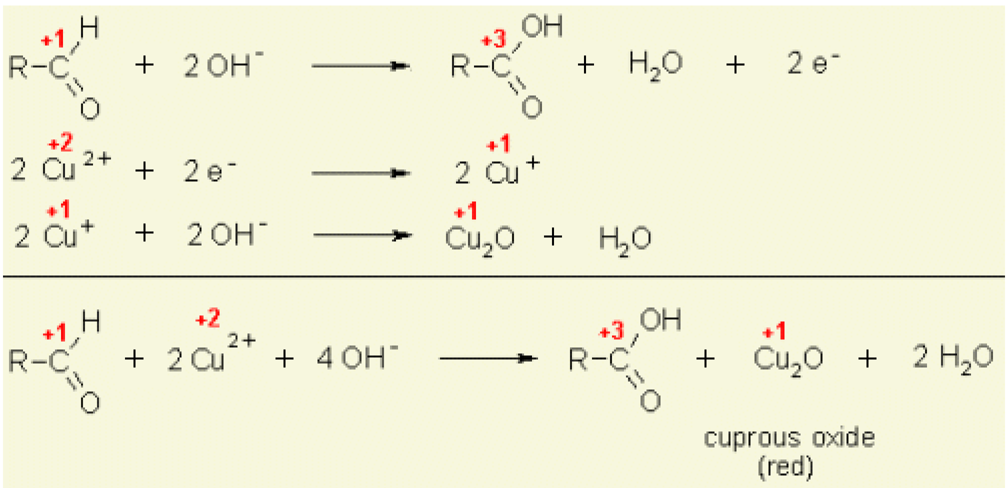


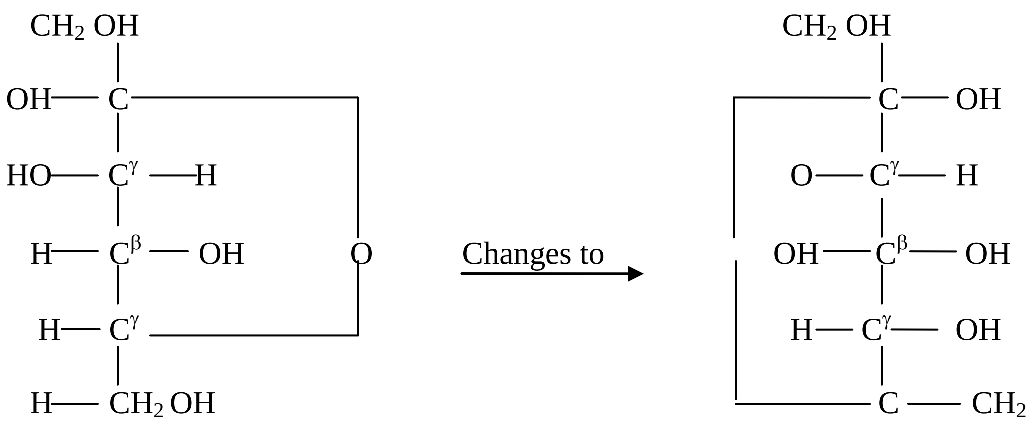
Figure 2. 6: Mechanism of reducing sugar by Fehling solution

The non-reducing sucrose in honey when hydrolysed with acids or enzymes gives D- glucose and D – fructose as shown in equation 2.2

$$C_{12}H_{22}O_{11} \xrightarrow{H_2O, H^+} C_6H_{12}O_6 + C_6H_{12}O_6 \qquad [2.2]$$

Invertase D- glucose D- fructose

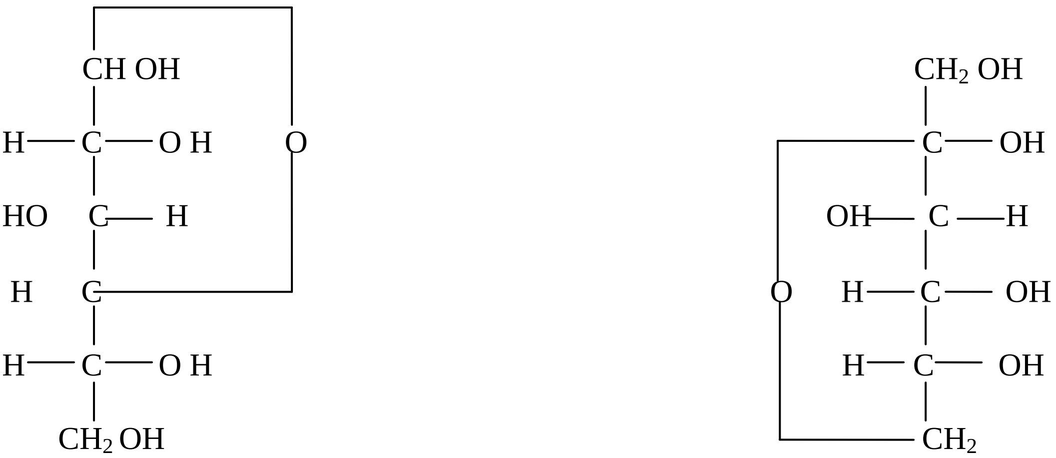
But in this hydrolysis, the sugars first formed are ∝ - D (+) glucopyranose and β - D (+) – fructofuranose. Since βD (+) fructofuranose is unstable, it changes immediately as shown in equation [2.3] to the stable form D (-) fructopyranose. This is as shown below.



[2.3]

β - D (+) fructofuranose D (-) fructopyranose (Fructose)

Sucrose is optically active with a specific rotation ([∝] D) of 66.5°. After hydrolysis, the glucose formed is dextrorotatory with specific rotation of =52.5° while fructose is laevorotatory with -92^0 specific rotation.



D (+) Glucose D (-) Fructose

Figure 2. 7: Structures of glucose and fructose showing dextro and laevo rotatory

The specific rotation of fructose is higher than that of glucose and therefore the mixture formed from the two will be laevorotatory with $[\propto]D = {}^{-}20^{0}$. The structure of fructose, glucose, sucrose and inert sugar is not the same. Their relative sweetness is as follows; fructose (173), glucose (74), inert (123) and sucrose (100). Fructose which is the dominant sugar in honey is the sweetest of all the sugars and that is why honey is sweeter than sucrose sugar.

When honey is heated, fructose undergoes thermal decomposition (deteriorates) forming Hydroxymethylfurfural (HMF) or 5-(hydroxymethyl) furfural. Aging and overstayed honey also decomposes to form HMF. The fructose decomposition reaction occurs in an acidic environment provided by honey. The HMF formed during decomposition is an aldehyde and a furan compound whose structure is shown in Figure 2.8.

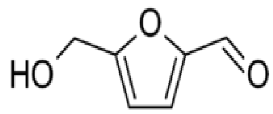


Figure 2. 8: **Furan**

During the decomposition reaction the amount of fructose in honey decreases due to deterioration and this lowers the quality of honey. The Figure 2.9 shows the decomposition reaction of fructose to HMF.

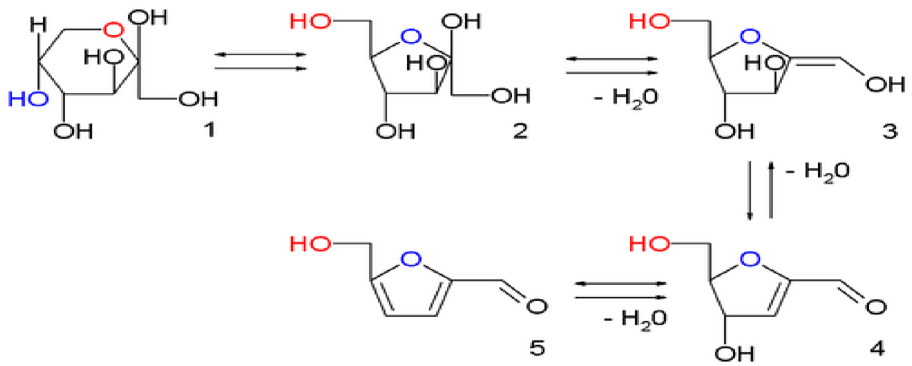


Figure 2. 9: **Mechanism of fructose decomposition HMF**

Honey clarification is the removal of suspended particles and other materials in honey by using carrez I ($K_4Fe(CN)_6$) and carrez II ($ZnSO_4$) solutions. During clarification, the solutions are added into the sample forming a precipitate $Zn_2(CN)_6$, as shown in equation 2.4

$$K_4Fe(CN)_6 + 2ZnSO_4 \longrightarrow K_4Fe(SO_4)_2 + \underset{\text{Precipitate}}{Zn_2(CN)_6} \quad [2.4]$$

The precipitate absorbs and retains the insoluble matter in honey which on filtration results into a clear honey solution.

2.6 Honey Characteristics

The characterization of honey is significant in understanding its properties and uses. The properties are important in its classification, identification, and quality control and design of processing equipment and uses. Honey has both physicochemical and biochemical properties. The physicochemical properties are colour, density or specific gravity, viscosity, hygroscopicity, surface tension, pH, moisture content, thermal conductivity, electrical conductivity, organic acids, HMF, minerals, sugars, amino acids and proteins (Ouchemoukh *et al.*, 2004). Biochemical properties include enzymes and microbes (Crane, 1979).

2.6.1 Physicochemical Properties of Honey

2.6.1.1 Colour

Colour in honey varies from clear and colourless like water to dark brown (Helena and Teresa, 1995). The colour of honey varies with the botanical origin, age and storage conditions. Honeydew honeys are mostly dark-brown where as floral honeys vary from clear, colourless to brown and may darken if stored for long even at 27 °C (White *et al.*, 1962). When honey is stored for long time in various conditions, the phenols in honey are oxidised by oxygen to dark materials resulting to honey colour change.

Honey colour is important for purposes of marketing and determination of its end use. Darker honeys are mostly for industrial use, while lighter honeys are marketed for direct consumption. In many countries with a larger honey market, consumer preferences are determined by the colour of honey as an indicator for a preferred flavour (Mathew, 2004). The lighter honeys are milder in flavour while the darker honeys are stronger in flavour and higher in minerals and proteins (Patricia, 1996).

2.6.1.2 Density

The density of honey is an important physical property that influences stratification in honey. Honey density is slightly greater than that of water although it depends on the water content of honey (Nanda *et al.,* 2003). Different types of honey may have different densities because of water content variation. Therefore, when honeys with different specific gravity are put together in storage tanks, they show distinct stratification. The less dense honey with high moisture content, settles above the denser drier honey. This prompts more thorough mixing during processing and packing to avoid such inconvenient separation. The extent of mixing and the ultimate moisture content of honey in the storage tanks will depend on the individual specific gravity of different types of honey (Moar, 1985).

2.6.1.3 Viscosity

Viscosity is the property of a fluid that resists the force tending to cause fluid flow. It is one of the most important physical and sensory characteristics of honey, which affects the quality of the product and the design of honey processing equipment. It is crucial in all process-engineering stages of production, starting from the extraction of honey from the combs, straining, mixing of different honey types, pumping, processing to packaging. Viscosity of many liquids, including honey is sensitive to temperature changes, decreasing when temperature increases. Liquids with this behaviour are referred to as Newtonian liquids. From the literature, many honey varieties exhibit Newtonian flow behaviour (Sopade *et al.,* 2003; Mossel *et al.*, 2000). When honey is freshly extracted from honey combs, it is a viscous liquid and its viscosity depends on a large variety of substances and therefore varies with its composition and particularly its water content (Chataway, 1932; Bhandari *et al.,* 1999). Viscosity is an important technical parameter during honey processing because it affects honey flow during extraction, pumping, settling, and filtration, mixing and boiling (White, 1975; Yanniotis *et al.*, 2006).

Honeys show quite different characteristics in regard to viscosity. Some honeys are thixotrophic, which means they are gel-like (extremely viscous), when standing still, turning liquid when agitated or stirred. Known examples of such honeys are "Heather" and "Manuka" honey from UK and New Zealand, respectively (Mossel *et al.,* 2000; Terrab *et al.,* 2002). Other honeys like Eucalyptus honeys and some Nigerian honeys show the opposite characteristics (Lazaridou *et al.,* 2004). The viscosity increases with agitation or stirring (dilatancy) and therefore during honey processing, this important property must be taken into considerations (FAO, 1996; Yanniotis *et al.,* 2006). Honey viscosity is determined by a rotator single cylinder viscometer at 30 rpm speed.

2.6.1.4 Hygroscopicity

Hygroscopicity, is the ability of a substance to absorb and hold moisture from the surrounding. Honey is a hygroscopic substance and its strong hygroscopic character is important both in processing and final use. The tendency of absorbing and holding moisture is a desired effect in end products containing honey such as pastry and bread. But during processing or storage, the same hygroscopicity can become problematic, causing difficulties in preservation and storage due to excessive water content. However, when equilibrium is attained, honey ceases to absorb moisture from its surrounding, but this is dictated by the relative humidity of the surrounding (Martin, 1958). Hygroscopicity is expressed as a percentage of moisture absorbed by honey.

2.6.1.5 The pH

The pH of honey is of great importance during the extraction and storage as it influences its texture, stability and shelf–life (Terrab *et al*., 2002). In the design of honey processing equipment, pH has a great influence in the selection of material for construction. The acidity of honey is as a result of the presence of gluconic acid, formic acid, oxalic acid and lactic acid (Nanda *et al*., 2003). The presence of these acids though minor constituents in honey, are beneficial for they act as acaricides in the control of mites.

The recommended pH value is usually 3.9 (IHC, 2002). Terrab *et al.*, (2004) reported pH values for some Spanish honey, ranging from 3.55 to 4.79 with a mean of 4.2. Nigerian Honey researched by Adebiyi (2004) showed significant variation in pH, which range from 4.31 to 6.02 with a mean of 4.75. The acids, in particular gluconic acid along with H_2O_2 give honey its antibacterial activity (Molan, 1998).

2.6.1.6 Sugars

In honey, sugars account for a 95 to 99% dry matter. The majority of these are the simple sugars, such as fructose, glucose, maltose and raffinose. Fructose and glucose represent 85 to 95% of the total sugars (Terrab *et al.,* 2001). Fructose is usually more abundant than glucose (Nagai *et al.,* 2002). The predominance of these simple sugars and in particular the high percentage of fructose is responsible for most of the physical and nutritional characteristics of honey (Persano Oddo, 2004). Small quantities of other sugars, such as sucrose, disaccharides, trisaccharides and oligosaccharides are also present. Though the quantity of these other sugars is of minimal importance, their presence in honey can provide information about honey adulteration and its botanical origin (Persano Oddo and Piro, 2004). Honeydew honeys contain less monosaccharides and more di, tri and oligosaccharides than blossom or floral honeys (Diez *et al*., 2004). Different types of sugars in honey are determined by using chromatographic techniques.

(a) Apparent Sugar Content

Apparent reducing sugars are simple sugars in honey such as fructose and glucose. In most blossom honeys, "apparent reducing sugars" represent the great majority of the honey sugars, but honeydew honeys contain more amounts of non-reducing sugars such as melezitose, maltotriose and raffinose than floral or blossom honeys (Diez *et al.,* 2004*).* The recommended limit for apparent sugars in blossom honey is put at 60 g/100 g minimum while that for honeydew honey is 45 g/100 g (International Honey Commission, 2002).

The measurement of reducing sugars helps to detect and differentiate between blossom and honeydew honey and also checking quality in terms of the permitted limits. Total reducing sugar are reducing sugar content after the hydrolysis(inversion) of honey and is usually higher than apparent reducing sugar before hydrolysis. Reducing sugars before hydrolysis and total reducing sugars for Algerian honey, studied by Ouchemoukh (2004), varied from 67.83 to 80.25 and from 71.25 to 84.25%, respectively.

(b) Specific Sugars

The specific sugars are identifiable sugars in honey such as fructose, glucose, sucrose, maltose, melezitose, maltotriose and raffinose. For blossom honeys, the sum of fructose and glucose should be within the minimum permitted limit of 60% (Codex Alimentarius Commission, 2001) while that for honeydew honey should be above 45% limit. For specific sucrose content, the maximum permitted limit is 5% for blossom honey while honeydew should have 15%.

The content of melezitose, maltotriose and raffinose in honey is a good indicator of identifying honeydew honey. Specific sugar spectrum yields information on honey authenticity and sugar adulteration (Bogdanov *et al.,* 2000). Specific sugar content in honey is conveniently determined by using HPLC (Prodolliet and Hischenhuber, 1997).

2.6.1.7 Moisture Content

Moisture content, (amount of water in 100 g honey) which is a parameter that is related to climatic conditions, season of the year and the degree of honey maturity (Terrab *et al.,* 2004; White, 1978) is quantitatively the second most abundant component of honey apart from sugars. Its content is quite critical, for it affects honey storage (Nanda *et al.*, 2003). Honey with high water content stands the risk of fermentation during storage. It is only honeys with less than 18% water that can be stored with little or no risk of fermentation. The final water content in honey depends on a number of environmental factors during production which includes, weather, humidity inside the hive, nectar conditions, the treatment of honey during extraction and storage (Helvey, 1954; Persano Oddo *et al.*, 2004).

According to Yanniotis (2006), moisture content of honey usually ranges between 14 to 18%, but must not exceed the permitted limit of 21% set by I.H.C. (2004) and Codex Alimentarius Commission (2001). Studies on some Nigerian honey showed that moisture content ranged from 16.38 to 30.82%, which was comparable to the values obtained from the USA honeys (Adebiyi *et al.*, 2004).

2.6.1.8 Mineral Salts (Metals)

Honey has small quantities of minerals present with Potassium being the most abundant. Other minerals present include sodium, magnesium, manganese, iron, copper, calcium and zinc (Saif-ur-Rehman, 2008). Dark honeys, particularly honeydew honeys are the richest in minerals (Adebiyi *et al.*, 2004; White, 1975). Detection and determination of these elements is important in the determination of the geographical origin or location of honey because different regions have different amounts of minerals in the soil (Salinas *et al.*, 1994). The elements in honey are detected and determined by atomic spectrophotometric method as well as flame photometry. Flame photometry method is particularly used for potassium and sodium measurement (Gurdeep *et al.,* 1991). Many researchers have studied the mineral composition of honey from different botanical and geological locations and found varied mineral elements. Twelve mineral elements were identified in honey samples from Italy (Pisani *et al.,* 2008). Recently, Fernandez-Torres (2005) studied the mineral composition of Spanish honeys of different botanical origins and found eleven minerals namely Zn, P, B, Mn, Mg, Cu, Ca, Ba, Sr, Na, and K.

2.6.1.9 Water Insoluble Solids Contents

Honey insoluble matter includes, pollen, honey comb debris, bee and filth particles. It is therefore a criterion of honey cleanness. The measurement of insoluble matter is important because it detects honey impurities that are higher than the permitted maximum of 0.1 g/100 g for honey extracted by centrifugation (Bogdanov *et al.,* 2000). The permitted levels for honey extracted by pressing the combs are 0.5 g/100 g (Codex Alimentarius, 2001). Most commercial honey in many countries is harvested by centrifugation, but in Kenya, honey is a large extent extracted by comb pressing and therefore, this parameter with two permitted levels, will continue to be used in checking honey cleanness and differentiating between centrifuged and pressed honey. Analysis of Andalusian honey by Serrano *et al.,* (2004) showed that water insolubles ranged between 0.000 to 0.240 g/100 g. In this, the maximum value is seen to be slightly above the permitted limit for centrifuged honey.

2.6.1.10 Electrical Conductivity

Electrical conductivity is a good criterion of determining the botanical origin of honey and is a routine honey quality control measurement (Krauze and Zolewski, 1991; Terrab *et al.,* 2002). Electrical conductivity is used for the discrimination between honeydew honey and blossom honey and also for the characterisation of unifloral honeys (Piazza *et al.,* 1991;

Bogdanov *et al.,* 1999). Honeydew honeys have higher electrical conductivity than blossom honeys (Diez *et al.,* 2004; Thrasyvoulous and Manikis, 1995).

Electrical conductivity depends on the ash and acid content, and the higher their content, the higher the resulting conductivity (Diez *et al.,* 2004). Electrical conductivity for blossom honey and mixtures of blossom honey and honeydew honey should be less than 0.8 mS/cm while that of honeydew honey is greater than 0.8 mS/cm (Codex Alimentarius, 2001; Ouchemoukh, 2007). Electrical conductivity for Algerian honeys as reported by Ouchemoukh (2007) was below 0.8 mS/cm permitted limit and it ranged between 0.6 mS/cm to 0.21 mS/cm with only one honeydew honey having 1.61 mS/cm outside the reported range. Electrical conductivity in honey is measured by using a conductivity meter.

2.6.1.11 Acidity

All honeys are acidic because of the presence of organic acids which contribute to honey flavour and stability against microbial spoilage (Nanda *et al.,* 2003). The main acid in honey is gluconic acid, found together with glucono-lactone in a variable equilibrium (Mateo *et al.,* 1997; Asif *et al.,* 2002).

Acidity is an important quality criterion used in checking honey fermentation which tends to increase acidity. However, the usual standard maximum value of 40 meq/kg has been increased to 50 meq/kg because there are some honeys which have a higher natural acidity (Echigo and Takenaka, 1974). The acidity of Pakistan honey studied by Asif *et al*. (2002), ranged from 6.733 to 22.937 meq/kg. Terrab *et al*. (2004) reported 17.6 to 39.8 meq/kg acidity range for Spanish honey. The acidity of honey is determined by fixed point titration method.

2.6.1.12 Ash Content

Ash content like electrical conductivity is a quality criterion used to determine the botanical origins of honey. Blossom honey has lower ash content than honeydew honeys (Anklam, 1998a; Ouchemoukh *et al.,* 2004; Rodriguez-Otero *et al.,* 1992). The maximum ash content value permitted by both Codex and EU standards is 0.6 g/100 g for blossom honey while that of honeydew honey and a mixture of honeydew and blossom honeys is 1.2 g/100 g (I.H.C, 2002; Krauze and Zalewski, 1991).

Ash content of Algerian honey as reported by Ouchemoukh *et al*. (2004) had values ranging from 0.006 to 0.54% while Northern Indian honey researched by Nanda *et al. (*2003) showed values ranging from 0.12 to 0.28%. Popek (2002) demonstrated that the ash content of honeydew honey is 0.56%. Honeydew and or mixed honeys have the highest ash content (Diez *et al*., 2004). However, the ash content parameter is slowly being replaced by the measurement of electrical conductivity (Bogdanov *et al.,* 1999).

2.6.1.13 Specific Rotation

Specific rotation is the angle of rotation of polarised light at the wavelength of the sodium D line at 20 °C of an aqueous solution of 1dm depth and containing 1 g/ml of the substance. The measurement of specific rotation is used to distinguish between blossom and honeydew honey (Persano Oddo, 1995). Different sugars in honey have the property of rotating the plane of polarised light and the overall optical rotation depends on the concentration of the various sugars in honey (Bogdanov, 1999; Kenjeric *et al.*, 2006). Fructose exhibits a negative rotation, while other sugars such as glucose show a positive rotation. The determination of specific rotation by means of a polarimeter is used in differentiating between honeydew honey which exhibits positive rotation (dextro-rotatory) and blossom honeys which exhibit negative rotation (laevo-rotatory) and in the classification of unifloral honeys (Piazza *et al.*, 1991; Persano Oddo and Piro, 2004).

Floral or blossom honeys show negative rotation as a result of the predominance of fructose in honey over glucose (Nanda *et al.*, 2003; Persano *et al.*, 1995). Research carried out on Algerian honey showed that there were two honeydew honeys with positive specific rotation +2.83 and +1.83 while the rest were blossom honey having negative specific rotation ranging from -1.00 to 7.29 (Ouchemoukh, 2004). In Kenya specific rotation has not been utilized in the identification of honey.

2.6.1.14 Hydroxylmethyl Furfuraldehyde (HMF)

Hydroxymethy furfuraldehyde (HMF) is a cyclic aldehyde that is formed by the degradation of sugars and is used to indicate the extent of heat treatment and storage changes in honey. It is a good indicator of deterioration in honey quality because of heating, aging or storage (honey freshness) (Andrew *et al.*, 2004). When honey is being processed, heat is applied to reduce its viscosity for easy flow, pasteurize or to liquefy it in case it is crystallized or prevent fermentation (Singh *et al.*, 1988).

Fresh natural honey has varying levels of HMF, which is normally below 1 mg/Kg (Zappala *et al.*, 2005). When ambient temperature is above 20 °C, levels of HMF start to rise. In countries where temperatures rise above 40 °C, beehive temperature also rises to 40 °C and HMF may rise to 10 mg/Kg for freshly extracted honey. Many countries impose their own maximum levels for HMF, but the codex levels is currently set at 80 mg/Kg from the earlier level of 40 mg/Kg, still being used by German, which is the largest importer of honey in the world (Codex Alimentarius, 2001).

The HMF is formed by the breakdown of fructose in the presence of an acid (Ramirez *et al.*, 2000). Heat increases the speed or rate of this reaction. The increase in rate or speed of formation of HMF is exponential with increase in heat applied (E.U. Council Directive, 2001;

Fallico *et al.,* 2004). At first HMF was used as an indicator of adulteration of honey with invert syrups (syrup of glucose and fructose) from cane sugar (sucrose) inverted by heating with a food acid where this process creates HMF. But it was quickly realized that heated natural honey had higher values of HMF which was not from the invert syrups. Therefore, the focus or interest shifted from being an indicator of adulteration to being an indicator of overheating and storage changes (E.U. Council Directive, 2001). However, high levels of HMF (greater than 100 mg/Kg) can still be an indicator of adulteration of honey with inverted sugar.

HMF is not harmful in levels found in food like 1000 mg/kg. Many sugar type products (molasses) have levels of HMF that are 10-100 times higher than that of honey. Many food products sweetened with high fructose corn syrups such as carbonated soft drinks can have levels of HMF between 100 and 1000 mg/Kg and are yet not harmful (Karabournioti, 2001). Analysis carried out on Pakistan honey showed HMF values ranging from 2.03 meq/kg to 42.896 meq/kg being quite below the upper permitted limits of 80 meq/kg (Asif *et al.,* 2002). HMF is determined by using a UV Spectrophotometer at a wavelength of 240 nm absorbance.

2.6.1.15 Proline

Proline is an amino acid found in pollen, nectar and saliva of honey bees and is the principal amino acid in floral honey, followed by lysine, glutanic and asparitic acids (Hermosin *et al.,* 2003; Ouchemoukh *et al.,* 2007). In honeydew honey, proline is a minor acid (Hill, 1959). Proline comes mainly from salivate of bees during the conversion of nectar into honey as it acts as an antioxidant and therefore, as ripening continues the bees inject more proline. For fully ripened honey, a minimum of 180 mg/kg is the acceptable permitted limit (Bogdanov *et al.,* 1999; Wu *et al.,* 2003).

Proline content therefore, is used as a criterion of honey ripeness and in some cases sugar adulteration when it falls below 180 mg/kg value. In Germany, honey with less than 180 mg/kg is considered either non-ripe or adulterated (Von der Ohe *et al.,* 1991). Burkina Fasan honey analysed by Meda *et al*. (2005) was said to be well ripened with proline content ranging from 437.82 to 2169.4 mg/kg and a mean of 989.5 mg/kg.

2.6.1.16 Free Acidity

Organic acids are the free acids in honey. They are the most important among the minor constituents. They include Gluconic acid, oxalic acid and lactic acid. Gluconic acid, which is a by-product of enzymatic digestion of glucose, predominates the other acids and contributes greatly to antibacterial activity of honey (Nanda *et al.*, 2003). The organic acids are responsible for the acidity of honey and contribute immensely on to its characteristic taste.
Analysis of organic acids of different types of honey could give an indication of the source of honey and their preservation capacity (Mateo *et al.*, 1997).

2.6.1 Biochemical Properties; Diastase Activity

Honey contains a number of enzymes, some of which are introduced into the honey by bees and have an important role in the formation of honey (Echigo *et al.*, 1974; White *et al.,* 1963). Although their presence in honey does not have any human nutritional value, their absence in honey serves as an indicator of aging honey. The reduction or complete absence of enzymes in honey indicates an adulterated, overheated or excessively stored honey (Raina *et al.*, 2000; White *et al.*, 1963). Enzymes are typically proteins of complex structure which catalyze specific chemical reactions. The main enzymes in honey are diastase (amylase), invertase (saccharase) and glucose oxidase (Echigo *et al.*, 1974; White *et al.*, 1963). Of all the enzymes in honey diastase and invertase have received the most attention and are most investigated. Both of them are introduced into the honey by honey bees.

Diastase is responsible for converting starch into dextrins and sugars. Diastase activity is an indicator of honey freshness and overheating of honey just like HMF (Thrasyvoulous and Manikis, 1995). Diastase activity decreases with the storage time.

This enzyme is measured using the Gothe scale, where the Codex standard has a minimum of 8DN on the Gothe scale (Codex Alimentarius, 2001; Persano *et al.,* 1990). Though there is natural variation of diastase activity, the present standard of minimum diastase number (DN) value has proven useful in accessing honey freshness (Oddo *et al.*, 1995).

Analysis of some Moroccan honey (Terrab *et al.*, 2002) showed that diastase activity ranged between 0.18 and 236 DN and only four samples had values below 8 DN limit as allowed by IHC (2002), and the European Community Regulations.

2.7 Equipment for Honey Extraction and Processing

The equipment used for extraction and processing of honey in Kenya include: Gravity clarifiers, settling, heating, cooling, filtering, bottling and storage vessels (tanks), strainers, pumps, capping buckets, capping tools, honey processors and honey extractors (Maxant, 2002). Gravity clarifiers: These are tanks which hold extracted honey for the settlement of any impurities such as wax particles, insect parts, air bubbles and other debris. Strainers are for removing visible impurities from extracted or dirty honey. Heating, filtering or cooling tanks are jacketed tanks which receive honey for melting, settling, mixing, heating and cooling. These tanks are provided with a heat exchange system (jacket) where hot water or cold water is circulated for purposes of heating or cooling honey.

The pumps are used for moving honey from one tank or machine to another. These pumps are adapted for both viscous and crystallized honey. Capping buckets are the buckets used for holding the pieces of wax cappings cut from the honey comb in preparation for extraction. But the cappings are accompanied with some amount of honey depending on the method of uncapping employed. The honey mixed with the wax cappings can be separated by gravity straining.

These are equipment commonly used for honey extraction. There were two main types of extractors found during our survey. These included honey press and centrifugal extractors. The sizes of the press extractors as observed were small, taking one honey comb at a time during extraction whereas centrifugal extractors were big, with many frame holders, taking up to 12 honey combs at a time.

2.7.1 Honey Presses (Extractors)

Honey presses extract honey from the combs by pressing. In this operation, the honey combs are mashed and then pressed to extract honey. This method leaves some honey with the crushed combs hence limiting honey extraction efficiency. Moreover, honey from this type of equipment has high levels of water insoluble solids content, usually 0.5 g/100 g of honey and above, much higher than the recommended limit of 0.1 g/100 g for centrifuged honey (Serrano *et al*., 2004).

2.7.1 Centrifugal Extractor

The principle of the centrifugal extractor is that the honey frame is mechanically rotated, effectively throwing the honey against the extractor wall, made of plastic or stainless steel. Centrifugal extractors are of two types; radical and tangential extractors.

(a) Tangential Extractor

In a tangential extractor, the frames lie almost against the barrel of the extractor wall. The outside of the frame is the one that empties the honey from combs when spinning. The machine is evenly loaded and spun until perhaps half the outside is extracted. The frames are then turned round so that the other face of the comb faces outwards, and the machine spun until this side is completely empty. The frame is turned for one last time and the last of the honey removed. This routine prevents, combs from breaking as the full inner side can burst through the empty outer side. Each frame has to be handled four times, load, turn, turn, unload and the machine has to be started and stopped four times. The amount of handling and time taken can be a disadvantage. But this is compensated because this machine affords a more thorough extraction than other machines. It is also the most compact extractor available and therefore cheaper.

(b) Radial Extractor

In a radial machine the frames sit in between rings, arranged like the spokes of a wheel. Honey is extracted from both sides simultaneously, so there is no need to juggle the frames once they have been loaded. Radial machines tend to be larger than tangential machines, in order to ensure that frames are far enough from the centre to extract properly. In both tangential and radical extractors, there is no significance in the direction for rotation. Two way rotation is not necessary, though some radial machines have a fast reverse phase to remove a little more of the honey in the base of the cells and dry the combs.

In general both centrifugal extractors (radial and tangential) give clean honey with less pollen grains, wax, and debris. These results to a low level of water insoluble solids content which is a measure of honey cleanliness and therefore honey quality.

During an earlier survey and honey sample collection in the Rift Valley region (Kerio Valley, Baringo, Sacho, Marigut and Loruk), Central region (Kirinyaga), Eastern Region (Kionyo, Chuka, Chogoria and Nkubu, Katunga, Marimanti, Mwingi) and Coast (Taita Taveta), individual beekeepers in these rural areas extract their honey by using *sufurias*, buckets and other plastic containers. The process of extraction involved mashing of honey combs in these containers and leaving them for few days to drain the honey out to the bottom while the combs float for removal. This process is unclean, slow and a lot of honey remains in the combs un-extracted.

In the same survey, a design of extractor cum processor was found at Marigut, which was one of the honey processing centres. The equipment contained slanting rectangular compartments with openings at opposite ends. The compartments were jacketed and supplied with hot water from the wood heated tank for the purpose of heating honey combs put in these compartments in order to release the honey from the cells. Honey released from the cells drain through various compartments, leaving wax, insect legs and other debris at subsequent chambers. In the process, moisture content in honey is reduced due to evaporation, and clean honey comes out of the last compartment which is then taken for settling and packaging. The disadvantage with this equipment is that of water temperature which could not be controlled. It can also not be used for the extraction of honey from Langstroth and KTB frames. This design arrangement is quite suitable for extracting and processing honey from the traditional beehives. These raises the need for the design of the equipment to be used for extraction of honey from both modern and traditional type of beehive honey combs.

2.8 Honey Processing in Kenya

Honey processing starts with uncapping of the honey combs which consists of the removal of the thin wax layer that seals the honey cells. The wax cappings are sliced off by a sharp long knife or special knives heated by steam or electricity or by capping scratchers (Jeff Rounce, 2002). After uncapping honey frames are arranged in the centrifugal extractor. The honey extracted by centrifugation above 60 rpm. Though complete and fast extraction of honey can be achieved at higher temperatures, the combs become softer and may break. Therefore, extraction temperature should not exceed 30 °C. Extracted honey is heated to 50 °C in a processor, left to settle and then filtered before packaging.

Some processing plants carry out honey pasteurization where heating is done very fast to 70-78 °C fine filtered and quickly cooled to avoid deterioration. The fine filtering is done by high pressure filters with diatomaceous earth (Codex Alimentarius, 2001). This removes all the fine materials, including pollen, in order to delay crystallization for as long as possible. Since this process pasteurizes and particularly removes some natural ingredients such as pollen, some consumers regard the honey as inferior, though preferred in supermarkets and other large marketing chains which want a product with a long shelf-life in a homogenous liquid state (EU Council, 2002).

2.9 Unit Operations

Unit operations are process operations without chemical reactions. In honey processing the unit operations that are taken into account and are considered in the development of the processing equipment include extraction, heat transfer, fluid transportation, filtering or screening, controlled crystallization and agitation (Warren *et al*., 2005).

Warming of honey is a heat transfer operation in which the warmer is provided with heat transfer arrangements, mostly a jacket or heating coils. Honey is heated to reduce its viscosity, moisture content and melt any crystals before filtration. Honey filtration as a unit operation process, is done by using a screen mesh. During heating, honey is agitated or stirred for uniform heat distribution in order to avoid local overheating. Heat is transferred into the honey through a heat transfer medium, which is usually heated water in a jacket or in a pan acting as a water bath. In a jacket, water is usually heated electrically using an element while the water bath is heated by wood or charcoal.

2.10 Theories and Principles of Processing Equipment Design

In the design of processing equipment, certain theories and principles are utilised and are important in determining the amount of energy required in the process, production capacity of the equipment, selection of material for construction, wall thickness of the vessels and covers. They include material balance, energy balance, design pressure, design temperature, design stress, corrosion allowance, and joint efficiency.

Honey processors are considered as pressure vessels. A pressure vessel is any closed vessel over 150 mm diameter which is subjected to a pressure difference of more than 1 bar in relation to atmospheric pressure. This definition is not strict on what constitutes a pressure vessel. For the purpose of design, two types of vessels are considered. Thin walled and thick walled pressure vessel. Thin walled are vessels with a wall thickness to diameter ratio of less than 1:10 while that of thick wall is above that ratio (ASME, 1998). Most of the food processing vessels, including honey processors are thin walled and when these vessels are subjected to pressure load, they experience significant circumferential and longitudinal stresses in comparison with the radial stress. This is because during design the radial stresses are ignored. In the thick walled vessels, radial stress is significant and the circumferential stress is spread along the wall. The majority of the vessels used in food manufacturing industries, experience these type of stresses and are significantly considered in their design (Douglas, 2005).

2.10.1 Material and Energy Balance

Energy balance in honey processing gives an estimate of the amount of energy to be utilized in processing a given quantity of honey. It assists in designing equipment that is cost effective in terms of fuel or electric power consumption. It also helps us to determine the rate of heat transfer from the heating medium to the honey in the designed vessels and ultimately the time taken for a given quantity of honey to attain target temperature. During honey processing heating is provided through a heating medium, usually water so as to avoid spot heating because of honey's viscosity. Heat or energy balance involves amount of heat transferred into the honey and that which is retained by the heating medium. The heat balance equation between honey and the heating medium is given by equation 2.5.

$$M_aC_a\Delta T_a = M_bC_b\Delta T_b \quad [2.5]$$

Where; $M_aC_a\Delta T_a$ represents the mount of heat transferred into the honey and $M_bC_b\Delta T_b$ heat transferred into the heating medium; M = Mass, C = Specific heat, ΔT =Temperature difference (Warren *et al*., 2005).

The total energy utilized in the process is given by equation 2.6.

$$(q) = M_aC_a\Delta T_a+M_bC_b\Delta T_b \quad [2.6]$$

2.10.2 Design Pressure

Design pressure is the maximum pressure a vessel can withstand in its operating conditions and is used to determine the vessel wall thickness during design (Browivell and Young, 1959). When the pressure vessel is exposed to internal pressure, the design pressure is the pressure at which the relief device is set and is10% above the normal working pressures in order to avoid spurious operations during minor process upsets. In determining the design pressure, hydrostatic pressure at the base of the column is added to the operating pressure

(Dippery and Srivastava, 2007). In the design of honey processing vessel, the design pressure is taken to be the hydraulic pressure of honey exerted on the vessel when full and is given by the relation in equqtion 2.7 (Joshi, 1991).

$$p = \rho\ (H - 0.3) \times 10^2 \qquad [2.7]$$

Where; p = pressure of honey in kg / cm^2, ρ = density of honey in kg/ cm^3, H = height of honey in the vessel in meters.

2.10.2 Design Temperature

The design temperature is the maximum working temperature of the material at which the designing stress is evaluated or determined. The strength of metals decreases with temperature increases and so the maximum allowable design stress will depend on material temperature (Harvey, 1991). Design stress evaluated from design temperature is used in determination of wall thickness during vessel design. The honey processing equipment to be designed in this study will be operating at temperatures ranging from 50 to 95 °C . Hence the design temperature for this vessel is 95 °C. It is within this limit that design stress is evaluated (Bickell and Ruiz, 1967).

2.10.3 Design Stress

Design stress is the maximum allowable stress that can be accepted in the material of construction. It is determined by applying a suitable stress factor (safety factor) to the maximum stress that the material will be expected to withstand without failure under the test conditions. The importance of stress factor in design is to allow for any uncertainty in the design methods, loading and the quality of the material and workmanship (Timoshenko and Woinowsky-Kreiger, 1968).

For materials subjected to higher temperatures, design stress is based on the yield stress of the material at the same temperature. Design stress is used to determine the wall thickness of the vessel, head covers and nozzles during design. Design stress, evaluated at the design temperature (95 °C) is 150 N/mm^2 for stainless steel which is to be used for the design of the equipment (Riegel, 1953).

2.10.4 Corrosion Allowance

Corrosion allowance in vessels is the additional thickness of metal added to allow for material lost by corrosion and erosion or scaling. During the design of the honey extractor and processor, this factor will be taken into consideration, depending on the material construction (Bednar, 1986). In this study, the material for construction is stainless steel, which is resistant to corrosion and therefore no corrosion allowance will be provided.

2.10.5 Material Selection for Construction

When selecting engineering materials, especially for food processing equipment and in particular honey processors, the overriding consideration for material selection is its ability to resist corrosion (Bednar, 1986). Since honey is an acidic food with a pH of 3.9, the material to be used for the construction of an extractor, processor, strainers (filters) and nozzles is stainless steel. This material is corrosion resistant with sufficient strength and is easy to work on during fabrication and construction. Though a little bit expensive, the material selected (stainless steel) satisfies both processing and mechanical requirements thus giving the lowest cost over the working life of the equipment while allowing for maintenance, replacement, as well as offering safety with no product contamination (Day, 1979).

2.10.6 Welded Joint-efficiency

Welding joint efficiency is an important consideration in the design of processing equipment that is joined by welding because it specifies clearly the strength of the joint (Joshi, 1991).

The joint strength and the safety of the equipment depend on the type of joint and the quality of welding which can be checked by visual inspection or the non destructive testing radiography (Maddox, 1998).

In design, the strength of a welded joint as can be compared with the virgin plate from which the vessel is constructed is calculated by multiplying the design stress of the material by the "welding joint factor" J. The joint factor values commonly used are 1.0, 0.85 and 0.7. And the value joint factor to be used depends on the type of joint and amount of radiography required. In our design work the joint factor to be used is 1.0 implying that the joint will equally be as strong as the virgin plate. This will be achieved by radio-graphing the complete weld length; cutting gout and remarking any defects to achieve factor 1.0. However, if lower joint factors are used in design, though saving costs on radiography, results in a thicker and heavier vessel (Weld, 1952).

2.10.7 Minimum Practical Wall Thickness

Minimum wall thickness is the plate thickness required to ensure that any vessel designed is sufficiently rigid enough to withstand its own weight and any incidental loads (ASME, 1998). In this study the vessel thickness will depend on the design pressure and the material selected for construction which ultimately determines corrosion allowance.

2.10.8 Equipment Fabrication Techniques

An economical and reliable fabrication technique is usually adopted to manufacture the various components of equipment such as food processing equipment. Selection of the material for construction and an appropriate choice of equipment fabrication method form an important aspect in influencing the design considerations of any equipment designed. Fabrication techniques are classified into two groups. The first group techniques are those that are adopted to give an approximate shape to the material. The methods involved in this type of fabrication are casting, forging, rolling, extrusion and drawing, stamping and welding.

In this study, drawing, rolling and welding will be used to give shape to the honey processing equipment. The second group are those techniques adopted to impart the final precise dimensions and ensure that the desired surface finish is attained. These methods include planning, shaping, turning and milling, drilling, boring, reaming, broaching, grinding, honing, polishing, electroplating and coating (Joshi, 1991). In honey extraction and processing equipment, shaping, turning, drilling, boring, reaming, grinding and polishing are the techniques to give the final procession finish.

2.11 Agitators

Certain processing operations, such as blending, dissolution, gas absorption, crystallization and uniform heat distribution need agitation of the liquids. In these operations, an agitator system is provided along with the basic equipment. The basic equipment can be a tank, a reaction vessel, a kettle, a crystallizer or a honey processor vessel. The selection of an efficient agitation system depends on the nature of liquid, operating conditions and the intensity of circulation. Agitators having small blade area which rotate at high speeds such as propellers, flat and curved blade turbines are used to mix liquids having low and medium viscosities, up to 1000 and 50000 cps respectively. But agitators having a large blade area which rotate at slow speeds, such as anchors, gates and helical screws are more effective for mixing high viscosity liquids (Hilland and Chapman, 1966).

Honey has medium viscosity and therefore will require a propeller agitator for mixing it. A propeller agitator is shaped with a tapering blade to minimize the effect of centrifugal force and produce a maximum axial flow. This type of agitator can be mounted centrally, off-centre or at an angle to the tank and is simple and portable. The design of this agitator requires that the diameter of the agitator be between 15 and 30% of the tank diameter and its peripheral speed should be between 300 and 500 metres per minute (Nagata, 1975). Therefore, this can be directly coupled to a standard electric motor. As the most economical unit for simple mixing, particularly in small tanks, this type of agitator is therefore suitably adopted for honey mixing. The power required to operate this agitator depends on several factors such as honey properties, height of the honey content, agitator type and size, vessel size as well as the agitation speed.

2.12 Design

Engineering design is the process of devising a system, component or process to meet the desired needs. It is a decision making process in which the basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective (ASME, 1998). Design can be classified into three groups which include either modification of existing device or selection of existing components while designing a system or creation of a totally new device. Most of the designs involve the modification of existing devices or equipment to make them more marketable (Suryanarayana, 2003). Design therefore encompasses the processes between the identification of the needed device to be created (or an existing one to be improved) and the beginning of fabrication or assembly of the components involved in producing it (ASME, 1998).

The origin of design is the requirements or needs of the people, business unit or an eyed opportunity to develop a modified, improved or new product. Product quality improvement, reduction of production cost, improving aesthetics, application of new technology or reduction of mass or volume of an existing unity are the driving forces leading to the modification of the design of an existing product (Boehm, 1987). In this work, the design originates from the desire to modify and develop a honey extraction and processing equipment to satisfy the needs of the small scale beekeepers and small businessmen in extracting and processing quality honey in order to satisfy the wants of the consumers and also meet legal, societal or personal monetary concerns (Ullman, 1992).

2.12.1 Steps Involved in Design Procedure

The design process starts with identifying preliminary specifications and conceptual outlines of the equipment to be designed. Several steps are involved between the conceptual outlines and the completion of the design.

The design procedures are not standardized, but the following steps are followed (Burmeister, 1998).

2.12.2 Project Definition

The first step is a brief description of the equipment to be designed, stating how it works, its components and draw backs. This is an important step because it makes the designer to recognize and understand the problem to be solved by employing a great deal of imagination, ingenuity and inventiveness. This step lays the foundation of the solution to the problem (Jones, 1970).

2.12.3 Preliminary Specification

This step involves the development of the preliminary specifications or requirements that the equipment should satisfy in order to solve the problem. The specifications developed reflect the requirements of the equipment end user (Rase and Barrow, 1964). The preliminary specifications which are stated in broad terms are expanded, resulting into the translation of every requirement to quantitative form. For example the specification that the equipment should be affordable is translated to monetary cost of the equipment. In expanding the specifications into quantitative form, simple calculations, such as arithmetic, algebra, differential or integral calculus are used (Berge, 1962).

2.12.4 Preliminary Design, Concepts and Concept Evaluation

This is the conceptualization step, which is one of the most important steps in the design process. During conceptualization, alternative design solutions are carefully considered by screening two or three different concepts, and the one which passes the feasibility study in regard to available information for similar equipments is chosen for detailed design.

After conceptualization, more detailed specifications, like dimensions, size and volume of equipment among others are developed (Stoecker, 1998).

2.12.4 Detailed Specifications

Detailed design involves the establishment and the quantitative determination of the requirements which the equipment should satisfy. The requirement may be constraints like equipment size, heat transfer, power consumption, and shell thickness of vessels, jacket capacity, and material selection (Bejan, 1996). After the determination of these requirements, the design for the chosen alternative is completed with the determination of the dimensions, volume and mass for each unit. Appropriate drawings of the designed equipment are then prepared for the fabrication of the prototype, followed by the development of the economic analysis or cost estimation (Johnson, 1973).

2.13 Analytical Techniques

2.13.1 Chromatographic Analysis of Specific Sugar

The chromatographic technique, introduced by Tsulett in the nineteenth century for separation of plant pigments, has become an indispensable analytical method for separation of specific sugars such as fructose, glucose, maltose, sucrose raffinose in honey. Initially the open-column chromatographic (OCC) methods were used but now a more efficient high performance liquid chromatography technique with reversed phase HPLC (RF-HPLC) stationary phase coupled with spectrophotometric and flourometric detection is used.

Chromatography can be defined as a physical method of separation in which the components to be separated are distributed between two phases, one held stationary (immobile) and the other phase mobile, moving in a definite direction (Britton, 1995; Din-Norm, 1992; Snyder *et al*., 1997; Meyer, 1994). As the mobile phase passes over and through the stationary phase, the components of the mixture equilibrate between the two phases resulting in different migration rates through the system. At any given time, an analyte molecule is either in the mobile phase moving along at its velocity or in the stationary phase and not moving at all in the downstream direction. The sorption-desorption process occurs many times as the molecule moves through the bed and the time required to do so depends mainly on its polarity or proportion of time it is absorbed and held immobile (Snyder *et al*., 1997). Separation is affected if the various components to be separated emerge from the bed at different times referred to as retention times.

There are different chromatographic techniques utilized in the separation of components. They are classified by naming the mobile phase followed by the stationary phase and thus gas-solid chromatography (GSC), gas-liquid chromatography (GLC), liquid-liquid chromatography (LLC), and liquid-gas chromatography (LSC), are some of the techniques. Recently supercritical fluids have been used as mobile phases and these techniques have been named supercritical chromatography (SFC) (Britton, 1995). The chromatographic separation techniques mostly used in honey sugars are GLC and HPLC.

The HPLC is chosen as a method of analysis due to its high speed, resolution, sensitivity, accuracy and automation systems. The HPLC identification of honey sugars is based on the retention times along with co-chromatography of the standards. The time taken by different sugars in the eluent to travel through the column from the time the sample was injected to the point at which the display shows maximum peak heights for sugars is not the same. Different sugars have different retention times. Therefore for proper identification of the specific sugars using retention times in relation to the standards, careful control of HPLC operating conditions was necessary.

Quantification is carried out by means of internal or external calibration for which the concentrations of the standards are also spectrophotometrically determined since they have varying purity (Britton, 1995; Rodriguez Amaya, 1999; Swallow, 1994). In the calibration procedure, standards of varying concentrations were prepared and injected into the column to obtain a linear curve preferably with a correlation coefficient greater than 0.9 (Khachik *et al*., 1992 ; Britton; 1995).

Gas chromatography can also be used to analyse honey sugars but thermal instability and limited volatility of sugars limits its use. Other techniques, such as supercritical fluid chromatography and HPLC coupled with mass spectroscopy (MS) may also be useful. The chromatographic procedure for analysis of the honey sugar follow the general procedure usually consisting of sampling and dissolving in the solvents, compatible with the mobile phase, filtering followed by the subsequent chromatographic separation, identification and finally quantification (Snyder *et al.,* 1997).

2.13.2 UV-Vis Spectrophotometric Analysis

This method is based on the absorbance of the collimated light when passed through the substance in a cell. In ultraviolet-visible (UV-Vis) spectrophotometry a beam of monochromatic radiation a beam is provided to illuminate a sample so as to measure the ratio of incident and transmitted radiation of a compound. When a beam of radiation strikes any object it can be absorbed, transmitted, scattered, reflected or it may excite fluorescence (Skoog *et al.,* 1990).

According to Beer-Lambert's Law, absorbance is proportional to concentration, thus a straight-line graph is expected on the calibration plotting absorbance versus concentration. That is true as long as the solutions prepared are dilute, but the Law breaks down for solutions of higher concentration and so a curve may result under these circumstances. The calibration curve method is quite convenient for the determination of the concentration of one or two samples of compounds. But when the samples involved are many, the use of a regression equation emanating from the graph becomes important in the calculation of the quantities to be determined.

The determination of hydroxymethyl furfural (HMF) and proline content in honey solutions obey the Beer-Lambert Law thus their absorbance is directly proportional to the concentration. Spectroscopic absorbance technique is used for the quantification of HMF and prolines in honey (Jeuring and Kuppers; 1980; White 1979; Kapitel *et al*., 1995; Figueiredo, 1991). Diastase activity in honey is also determined spectrophotometrically where Beer-Lambert's Law is utilized. A standard solution of starch, capable of developing with iodine a colour in a defined range of intensity (660 nm) is acted upon by the diastase enzyme in the honey sample under standard conditions. The diminution in the blue colour is measured by measuring absorbance at different intervals of time. A plot of absorbance against time or a regression equation is used to determine the time required to reach the specified absorbance, 0.235 from which the diastase activity is calculated (Schade *et al.,* (1958) and Din- Norm (1990).

2.13.3 Refractometry

Refractometry is based on the measurement of the angle of refraction of a collimated radiation in relation to the angle of incidence as it passes from one medium to another using a refractometer. A refractometer therefore measures the extent to which light is bent (refracted) when it moves from air into a sample and is typically used to determine the index of refraction (refractive index or η) of a liquid sample (Gurdeep, 1991), given in equation 2.16..

$$\text{Refractive index } (\eta) = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in substance}} = \eta \qquad [2.8]$$

In the Abbe refractometer (mostly used for determination of water content in honey) the liquid sample is sandwiched into a thin layer between an illuminating prism and a refracting prism (as shown in figure 2.12). The refracting prism is made of glass with a high refractive index (1.75) and the refractometer is designed to be used with samples having a refractive index smaller than that of the refracting prism.

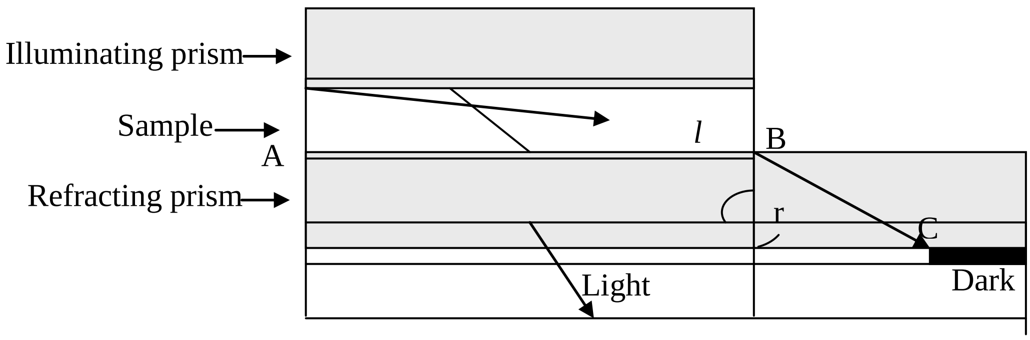


Figure 2:10 A cross-section of part of the optical path of an Abbe refractometer (The sample thickness has been exaggerated for clarity)

A light source is projected through the illuminating prism, the bottom surface of which is ground (roughened like a ground – glass joint), so that each point on this surface generates light rays travelling in all directions. Inspection of figure 2.12 will show that light travelling with largest angle of incidence (ι) will have largest possible angle of refraction (r) for that sample. All other rays of light entering the refractive prism will have smaller angles of refraction and hence lie to the left of point C. Thus a detector placed on the back side of the refracting prism would show a light region to the left and a dark region to the right (Dara, 1988). The most widely used wavelength of light for refractometry is the sodium D line at 589 nm (Gurdeep, 1991).

The refractive index method has been used to measure the water content of honey (Wedmore, 1955). Different honey samples have different refractive indexes since they do not have the same water content. The water content of these samples will be that value determined from the refractive index of the honey by reference to the standard table (Chataway, 1932; Wedmore, (1955); Codex Alimentarius standard for honey (1993).

2.13.4 Atomic Absorption Spectroscopic Analysis

This technique is used for the analysis of elements in liquids. Since its introduction, by Alan Walsh in the mid-1950, Atomic Absorption Spectroscopic (AAS) technique is the most powerful instrumental technique for the quantitative determination of trace metals in liquids. This method determines a total metal content and is almost independent of the molecular form of the metal in the liquid. This method has the advantage of determining any one element or metal in a liquid without necessarily separating it from the rest. Atomic absorption spectroscopy is not only restricted to aqueous solutions but also to non-aqueous. The principles of AAS involve the absorption of energy by ground state atoms in the gaseous state. When a digested solution of the sample containing metallic species is introduced into a flame, the vapour of metallic species absorbs energy and emits a characteristic radiation. But a large percentage of the metal atoms will remain in the non-emitting ground state. These ground state atoms of a particular element are receptive of light radiation of their own specific resonance wavelength. When a light of this particular wavelength is allowed to pass through a flame having atoms of the vapour metallic species, part of that light will be absorbed and the absorption will be proportional to the density of the atoms in the flame and therefore obeying Beer-Lamberts law. Hence AAS determines the amount of light absorbed which is proportional to the concentration of the absorbing metallic species. This technique is used to determine less sensitive atomic absorption elements such as Fe, Cu, Mg, Ca, Mn etc but not K and Na which are more sensitive.

2.13.5 Flame Photometry

Flame photometry is based on the measurement of intensity of the light emitted when a metal is introduced into the flame. Flame photometry is also called flame emission spectroscopy because of the use of flame to provide the energy of excitation to atoms produced in the flame. Flame photometry, which has high sensitivity and reliability for the determination of the elements in group I of the periodic table, will be used here. In this technique a solution containing a metallic salt is introduced into the flame where it is vaporized, leaving particles of the solid salt. This salt is subsequently converted into the gaseous state molecules that are progressively dissociated to give free neutral atoms or radicals. The neutral atoms are excited by the thermal energy of the flame and the unstable excited atoms quickly emit photons when returning to lower energy state. The radiation intensity is measured to give the concentration of metal in the sample.

2.13.6 Determination of Electrical Conductivity

Determination of electrical conductivity is based on the measurement of electrical conductance of a solution due to the presence and movement of ions when a force of electrical field is imposed. The magnitude of electrical conductance of the ions present is a reflection of the mineral content in honey. The technique has been used to determine the mineral content of honey (Piazza *et al*. 1991). Electrical conductivity measurement of honey is carried out by using a thermostated conductivity cell and a conductometer in a solution with 20% dry honey matter in 100 ml distilled water. The measured electrical conductivity is expressed in millisiemens per metre or millisiemens per centimetre (mS/cm) (Bogdanov *et* *al*., 1997).

2.13.7 Potentiometric Determination of pH

The potentiometric pH determination technique is the most accurate method of measuring the pH of a solution. Instead of hydrogen ions concentration, it is its activity that determines the e.m.f. of agalvanic cell which is used to measure pH. On this basis, pH is the negative logarithm of hydrogen ion activity, (Dara, 1988), given by equation 2.17.

$$pH = -\log a_{H+} \qquad [2.9]$$

pH meter employ the following galvanic cell to measure pH;

Glass electrode (GE) //H^+// standard calomel Electrode (SCE)

The cell voltage is given by equation 2.18:

$$E_{cell} = E_{SCE} + E_j - E_G - 0.059 \log [H^+] \qquad [2.10]$$

Where; E_j is the liquid junction potential and $E^0 = E_{SCE} + E_j - E_G$

Hence $E_{cell} = E^0 - 0.059 \log {}^aH^+$, which reduces to $E_{cell} = E^0 + 0.059$ pH

Where; E^0 is a constant for a given cell.

The pH meter measures e.m.f and converts this to pH. At zero e.m.f, the pH of the solution is 7 (Gurdeep, 1991).

2.13.8 Relative Density

Relative density is the density of a substance in relation to the density of water at a specified temperature. It is also known as specific gravity. Relative density is determined by using specific gravity bottle or pyknometer. The bottle is cleaned thoroughly dried and weighed. It is then filled to the mark with freshly boiled and cooled distilled water which is maintained at a specified temperature in the water bath and then weighed. The bottle is then emptied, dried, filled with the sample and weighed. Relative density is then calculated using equation 2.19.

$$\text{Relative density} = \frac{\text{Density of Sample}}{\text{Density of Water}} \qquad [2.11]$$

This technique has been utilized in the measurement of relative density of honey.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Areas

This study was carried out in Kenya's four regions which are popular in honey production, and have different climatic conditions, vegetation cover, as well as soil. The regions are Rift Valley (Baringo, Kerio Valley, Marigut and Luluk), Eastern (Mwingi, Marimanti, Matunga and Nkubu), Central (Kirinyaga, Nyahururu and Mt. Kenya) and Coast (Taita Taveta) provinces of Kenya. Rift Valley and Central regions have mainly volcanic soils but differ in their climatic conditions and vegetation cover. A larger part of Rift Valley is semi-arid and is covered with acacia vegetation while Central experiences two rain seasons in a year and is covered with mixed vegetation. Eastern region is also semi-arid having both alluvial and sedimentary soils, with acacia and shrubby vegetation. Coast region has a humid climate with sedimentary soils and mixed vegetation cover like mangrove and coconut. Because of their different climatic conditions, vegetation cover and soils, honey harvested from these regions may differ in their physicochemical parameters.

3.2 Research Design

This research was carried out in three phases: the first phase was the characterization of honey from different regions of Kenya which included Rift Valley, Central, Eastern and Coast provinces. The second phase was the designing of a model for processing equipment using some of the results obtained from the characterization of honey. While the third phase involved the fabrication, machining and construction of the designed model, from the developed design model for the extraction and processing of honey. The fabrication was done by rolling, bending, turning and welding, whereas machining was done by drilling, milling, boring using stainless steel sheets, rods and pipes.

3.3 Samples and Sampling Procedures

Honey sampling was done randomly from beekeepers, at the four regions of Rift Valley, Central, Eastern and Coast provinces. The honey samples were taken directly from the containers that the beekeepers use for honey storage after extraction by pressing or mashing. All samples were not pasteurised and were taken not more than two months after extraction. Plastic bottles of 500 cm^3 capacity with well stoppered lids were used for the sampling. About 350 gm honey was transferred into the plastic bottles and immediately stoppered. The samples were transferred to the lab and kept at ambient temperature.

Sample size collected from each region was twenty percent of the number of beekeepers. A total of 320 samples were collected, out of which Rift Valley and Central regions had 80 samples each, while Eastern and Coast had 120 and 40 samples respectively. Honey samples that were not well extracted from combs during sampling, were further extracted by pressing method. All samples were filtered through a 0.5 mm diameter mesh sieve.

3.4 Instruments and Chemicals

The instruments used in the analysis were HPLC, UV-Vis, AAS, Rotary Viscometer, Abbe Refractometer and a polarimeter. The HPLC system used for the analysis of specific sugars was Shimadzu (model) 10A with RID-6A model detector and C-R7A plus model recorder (Kyoto Japan). The column used was Shim-Pack CLC-NH_2 150 mm length and 4.6 mm diameter. The HPLC operated with a mobile phase of acetonitrile: water (80:20, v/v) flowing at the rate of 1.3 ml/min with a sample volume of 10 µml. The column and detector temperature was maintained at 30 °C.

The chemical reagents used for HPLC analysis were acetonitrile and methanol (HPLC grade) from Sigma Aldrich. The sugar standards used were fructose, glucose, sucrose, maltose and raffinose of 99.9% purity from BDH. The UV-Vis spectrophotometer was used for the analysis of proline HMF and diastase activity. The reagents used for the analysis of proline were Formic acid 98 -100% pure, ninhydrin, ethylene glycol monomethylether and 2-propanol, all analytical grades. The reagents used in the determination of diastase activity were sodium chloride, sodium acetate, glacial acetic acid, iodine and soluble starch.

HMF was determined at absorbance 550 using the following reagents; p-toluidine, 2-propanol, barbituric acid, Carrez I solution (potassium hexacynoferrate (II) $K_4Fe(CN)_6 \, 3H_2O$ in water), Carrez II solution (zinc acetate, $Zn(CH_3COO)_2 \, 2H_2O$ in water). All reagents were analytical grade.

3.5 Preparations of Working Solutions (IHC, 2002)

Carrez I solution was prepared by dissolving 10.6 g of potassium hexacyanoferrate (II), ($K_4Fe(CN)_6 \, 3H_2O$) in distilled water in a volumetric flask and diluted to 100 ml. Carrez II solution was prepared from 24.0 g of Zinc acetate ($Zn(CH_3COO)_2 \, H_2O$) dissolved in distilled water in a volumetric flask, 3.0 g of glacial acetic acid added and diluted to 100 ml. Starch solution was prepared from 2.0 g of anhydrous starch mixed with 90 ml distilled water in 250 ml conical flask and swirled. The suspension was rapidly brought to boil and gently boiled for three minutes. The hot solution was transferred to a 100 ml volumetric flask and rapidly cooled to room temperature by running water, filled to the mark and mixed thoroughly.

Iodine stock solution was prepared from 11.0 g of sublimated Iodine and 22.0 g of Potassium Iodide dissolved in 40ml water and diluted to 500 ml. This stock solution was kept in a stoppered dark bottle. Dilute Iodine solution was prepared by dissolving 20.0 g of potassium iodide in water to which 2 ml Iodine stock solution was added and diluted to 500 ml.

Stock of ninhydrin solution was prepared by dissolving 0.0400 g in 50 ml aqueous solution containing ethylene glycol monomethylether (methyl-cellosolve) 3% by volume. Ninhydrin dilute solution was made by diluting 1 ml of stock solution to 25 ml using 50% 2-propanol in water.

In the determination of apparent reducing sugars and apparent sucrose, Soxhlet's modification of Fehling's solution, standard invert sugar and methylene blue (indicator) were used. Soxhlet's modification of Fehling's solution is a combination of equal amounts of Fehling's solution A and B. Fehling's solution A was prepared from 69.28 g of copper sulphate pentahydrate $CuSO_45H_2O$ dissolved in water and volume adjusted to 1000 ml and kept for one day before titration. Fehling's Solution B was prepared from 346.0 g of sodium potassium tartrate ($C_4H_4NaO_54H_2O$) and 100.0 g of sodium hydroxide (NaOH) were dissolved in distilled water in 1000 ml volumetric flask and made to the mark and filtered.

Standard invert sugar solution was prepared from 9.5 g pure sucrose in 1000 ml volumetric flask mixed with, 5 ml hydrochloric acid (36.5% w/v pure HCl) and diluted to 100 ml. This solution was stored for three days at room temperature and then diluted further to 1000 ml.Methylene blue solution (Indicator) was prepared by dissolving 2.0 g of methylene blue in distilled water and diluting it to 1 litre.

The solutions used in the determination of HMF in honey were Para-toluidine solution, Barbituric acid solution, Carrez I and Carrez II solutions. They were prepared as follows:P-toluidine solution: 10.0 g of P-toluidine was dissolved in 50 ml 2-propanol by gently warming in water bath. After cooling to ambient temperature, the solution was filled to the mark with 2-propanol stored in the dark for at least 24 hrs before use. barbituric acid solution was prepared from 500.0 g barbturic acid taken into a 100 ml volumetric flask with 70ml water and dissolved by gently warming it in water bath. The solution was diluted to the mark after cooling to ambient temperature. The second Carrez I and Carrez II solutions used were prepared as follows; for Carrez solution I, 15.0 g of potassium hexacyanoferrate ($K_4F\ (CN)_6$ $3H_2O$) was dissolved in water in a volumetric flask and diluted to the mark and for Carrez II solution 30.0 g of zinc acetate, ($Zn\ (CH_3COO)_2\ 2H_2O$) was dissolved in water in 100 ml flask and diluted to the mark.

3.6 Preparation of Standards

3.6.1 Sugars

Standard sugar solutions were prepared by dissolving 2.0000 g fructose, 1.5000 g glucose, 0.2500 g sucrose, 0.1500 g maltose and 0.1500 g raffinose in 40 ml distilled water which was quantitatively transferred to 100 ml graduated flask onto which 25 ml methanol had been pipitted and the solution made to the mark. Using a syringe, with the premounted filter of pore size 0.45 µm, the solution was filtered into vials which were kept in the refrigerator at 4°C to maintain stability for a longer time waiting for analysis.

3.6.2 Minerals

The standard solutions of the metals for the analysis were made from their respective salts (NaCl, $Zn(NO_3)_2$, MnO_4, KCl, $CaCO_3$, $Mg(NO_3)_2$, $Cu(NO_3)_2$, Fe-metal and $Pb(NO_3)_2$) of Analar grade to give 1000 ppm stock solutions. An amount of the salt equivalent to 1 g of the metal was weighed and dissolved in 500 ml distilled water in 1000 ml volumetric flask and made to the mark giving 1000 ppm stock solution. Calibration standard solutions of 0, 2, 4, 6, 8, 10, 12, 14 ppm from which the absorbance or emission intensity was read, were made by serial dilution of the stock solutions.

Calibration graph of absorbance or emission intensity against concentration of the standards was drawn and a regression equation obtained used to calculate the sample concentration.

3.7 Experimental Procedure

3.7.1 Determination of Refractive Index and Moisture Content (Wedmore, 1955)

A 20.0 g honey sample was put in a 50 ml flask, closed tightly and then placed on water bath at 50 °C (± 0.2) for dissolution of any sugar crystals. It was cooled to ambient temperature and a small amount (two to three drops) was put on the refractometer prism (model RFM 330, England) at 20 °C, spread evenly and refractive index determined after two minutes in triplicate (AOAC, 1990). Using the refractive index determined, moisture content of honey was read from Wedmore Table of water content (Chataway, 1932). The temperature of the refractometer was kept at 20 °C by circulation of water whose temperature was maintained at 20 °C by using ice.

3.7.2 Determination of Electrical Conductivity (Vorwohl, 1964)

A 0.1M KCl solution was placed in a beaker and allowed to equilibrate to 20 °C. The electrical conductance of this solution was measured using the conductivity meter (model EC 215 Hanna Instruments - Romania) and the value obtained was used to determine the cell constant, which was then used in the determination of electrical conductivity of honey. The electrical conductivity of a solution of 20.0 g (dry matter) of honey in 100 ml-distilled water was measured. To prepare this solution, an amount of honey equivalent to 20 g anhydrous honey was weighed, dissolved in water in 100 ml volumetric flask and more water added to the mark. Forty millilitres of the sample solution was transferred into a beaker in a thermo stated water bath at 20 ^{o}C, allowed to equilibrate and its conductance taken. Two readings were taken for each honey sample to get an average value. The relation given in equation 3.1 was used to calculate the electrical conductivity (EC) of the honey solution and expressed to the nearest 0.01 mS cm $^{-1}$

$$EC = K.G \qquad [3.1]$$

Where; K = Cell constant in cm^{-1}, G = conductance in me

3.7.3 Determination of Ash Content (AOAC, 1990)

A 5.0 g portion of honey was placed in a crucible and calcined at 625 ºC in a furnace, cooled in desiccators and then weighed. This was repeated until constant weight was attained. The ash content was then determined as a percentage (AOAC, 1990).

3.7.4 Mineral Content

Honey sample (5.0 g) was digested by heating in a Kjeldah flask with concentrated nitric acid and sulphuric acid mixture for the oxidation of carbonaceous matter. Heating was done carefully so that no excess foaming took place. Concentrated nitric acid in small amounts was added until all the organic matter was oxidized. The solution was cooled and transferred to 100 ml volumetric flask and the volume made up to the mark with distilled water. Minerals in honey such as calcium, iron, zinc, magnesium, manganese and copper were then determined using atomic absorption spectrophotometer (Bulk Scientific Model 210VGP-USA). Potassium and sodium was determined using flame photometer (Model CFP400-UK) (Jacob, 1958).

3.7.5 Determination of pH (AOAC, 1990)

The pH of honey was determined by a pH meter, which had been calibrated using commercial buffer solutions of pH 4.0, 7.0 and 9.0. A 10 g of honey sample was taken and dissolved in 75 ml of carbon free distilled water in a 250 ml beaker, thoroughly stirred and its pH recorded at 20 ºC. Three readings were taken and averaged (AOAC, 1990).

3.7.6 Determination of Free Acidity of Honey

Ten grams honey sample was dissolved in 75 ml of carbon free distilled water on a magnetic stirrer. This was then titrated against 0.1 ml NaOH using phenolphthalein indicator. These measurements were taken in triplicates.

3.7.7 Determination of Hydroxymethyl Furfural (HMF) (Winkler, 1955)

Ten grams honey sample was weighed and dissolved in 20 ml distilled water and then transferred quantitatively to 50 ml volumetric flask. This was clarified with 1 ml of Carrez solution (I) and 1 ml of Carrez solution (II) respectively. The solution was made to the mark, mixed and filtered. Twenty millilitres of the filtered sample solution was pipetted to two separate test tubes and 5.0 ml of P-toluidine solution added to each tube. One millilitres of water was added to one tube (to give blank value) while 1.0 ml of barbituric acid solution was added to the other. The additions were carried out in 1 -2 minutes without delay and the absorbance of the sample against the blank was measured using a spectrophotometer as soon as the colour intensity had reached a maximum (3 – 4 minutes after adding the barbituric acid solution), using 1 cm cells at 550 nm. The same instrument (spectrophotometer) used here was utilized in the determination of proline content and diastase activity.

3.7.8 Determination of Insoluble Matter (Lord *et al.*, 1988)

Twenty grams of the honey sample was dissolved in about 200 ml water at about 80 $^{\circ}$C, filtered through a well dried sintered glass crucible of pore size 15 to 40 microns. The residue was then washed carefully and extensively with warm water until free from sugars. This was confirmed or checked by adding to some filtrate in a test tube, 1% phloroglucinol in ethanol, and mixed. To this mixture a few drops of concentrated sulphuric acid were run down the sides of the tube. If sugar were present, a colour could be produced at the interface, otherwise not.

The insoluble matter was dried at 135 $^{\circ}$C for an hour, cooled in the descator, weighed and dried continuously to constant weight (Lord *et al.*, 1988).

3.7.9 Determination of Viscosity

A 250 ml sample of honey placed in 400 ml capacity plastic bottles was incubated at different temperatures (25 $^{\circ}C$, 30 $^{\circ}C$, 35 $^{\circ}C$ and 40 $^{\circ}C$) and the viscosity measured at each temperature using a rotary single cylinder viscometer (model B, Japan). A suitable probe was fixed onto the scale of the viscometer, whose pointer (indicator) was made to read at zero. The honey sample at the incubated temperature was placed directly below the probe and the lever clamped as the probe is lowered and immersed in the honey up to the indicated mark.

The rotational speed of the probe was set at 30 rpm, the lever unclamped and the synchronous switch motor turned on. During the rotation, the indicator needle or pointer was allowed to stabilize after 35 seconds, the lever clamped and the motor turned off, ensuring that the scale of the rheometer (viscometer) remains in view. The torque M as indicated by the pointer on the scale was recorded. Duplicate readings were taken for each sample at each temperature. Viscosity was calculated by multiplying the average torque with 200 conversation factor given on top of the rheometer table (Muller, 1973)

$$\text{Viscosity} = M \times 200 \text{ (centipoises)}$$

3.7.10 Determination of Proline Content

A method by Ough (1969) was used in which 5 gm of the honey sample was dissolved in 50 ml water and quantitatively transferred to a 100 ml volumetric flask and made to the mark with distilled water. To five tubes, 0.5 ml of the sample, 0.5 ml of water (blank test) and three portions of 0.5 ml of proline standard solution was pipette to each tube. One millilitre of both formic acid and ninhdrin solution were separately added to each tube. The tubes were capped carefully, shaken vigorous for 15 minutes and immersed in a boiling water bath for another 15 minutes. The tubes were then transferred to a water bath at 70 $^{\circ}C$ for a further 10 minutes before 5 ml of the 2-propanol water solution was added to each tube, capped immediately and left to cool. Absorbance was then determined 45 minutes after removing from the 70 °C water bath at the maximum absorbance near 510 nm using 1cm cuvette.

3.7.11 Determination of Hygroscopicity

Three grams of honey were taken into previous weighed (M_o) plastic vials of the same size with uniform cross-sectional area and placed in an incubator set at 27 °C and 85% relative humidity. After 12 hours, the vials were removed dried in the air for 10 minutes and the weight taken as M. Duplicate readings were taken for each sample. Equations 3.2-3.4 were used in the calculation hygroscopic rate.

Amount of water absorbed (X g) = M - M_o + 3.0 g of honey [3.2]

$$\text{Percentage water absorbed} = \frac{X}{3} \times 100 \qquad [3.3]$$

$$\text{Hygroscopic rate} = \frac{X}{3} \times \frac{100}{12\text{hrs}} \qquad [3.4]$$

3.7.12 Determination of Diastase Activity (Schade *et al.*, 1958, Din-Norm 1990).

Calibration of starch solution was carried out to determine the amount of water that could be added to the reaction mixture so that the absorbance of the iodine starch solution is in the range of 0.745 to 0.770. Five millilitres of dilute iodine solution were pipetted into 6 test tubes of volumes 20, 21, 22, 23, 24 and 25 ml of water. Starting with the first test tube, 0.5 ml of the mixture containing 10ml of water and 5 ml starch solution were added, mixed well by Fagitating and immediately absorbance read at 660 nm against a water blank in a 1 cm cuvette. The same process was carried out with the other test tubes, until an absorbance in the range of 0.745 to 0.770 was obtained. The amount of water determined in this way was the standard dilution for every determination carried out with the starch solution.

Diastase activity was determined using a spectrophotometer set at 660 nm. Ten grams of honey was dissolved completely in approximately 15 ml of water and 5 ml of acetate buffer without heating. The solution was transferred quantitatively to a 50 ml volumetric flask containing 3 ml sodium chloride solution and then made to volume. This was the sample solution. A 10 ml sample of solution was pipetted into a 50 ml flask and placed in the 40 ^{o}C water bath together with a second flask containing 10 ml of starch solution.

After 15 minutes, 5 ml of this starch solution was pipetted into the honey solution, mixed and time started. At periodic intervals, for the first time after 5 minutes 0.5 ml aliquots were removed and 5 ml of diluted iodine solution added rapidly. The amount of water as determined in calibration of the starch solution was added, mixed well and absorbance of each separate solution read immediately at 660 nm against the distilled water as a blank (Schade *et al*., 1958).

3.7.13 Determination of Specific Rotation (Junk and Pancoast, 1973)

The specific rotation of honey was determined with a polarimeter, able to measure within 0.05 circular degrees and equipped with sodium lamb (Junk and PanCoast, 1973). A 12.0 g honey sample equivalent to 10 g dry matter (honey without moisture, obtained by subtracting moisture content) was dissolved in distilled water, to which 10 ml of Carrez solution (I) and Carrez solution (II) reagents were added consecutively with agitation and made up to volume with distilled water. The solution was filtered the next day and then filled to a clean rinsed 2-dm polarimeter tube, placed in the polarimeter and the angular rotation read. The measurements were taken at 20 °C temperature.

Specific rotation $[\propto]_D^{20}$ was calculated using the following equation:

Specific angular rotation = $$[\propto]_D^{20} = \propto \times \frac{100}{1 \times P}$$

Where $\propto$ = angular rotation found

l = Length in decimetres of the polarimeter tube

P = grams of dry matter taken

3.7.14 Determination of Specific Sugars by HPLC

Five grams of honey was dissolved in 40 ml distilled water. Twenty five millilitres of HPLC grade methanol was pipetted into 100 ml volumetric flask to which the honey solution was quantitatively transferred. The volume was adjusted to the mark and the solution filtered by a membrane filter with pore size 0.45 microns, collected in sample vials and then stored in the refrigerator at 4 °C . A 20 microlitres aliquot of the sample and standards were analysed by HPLC using acetonitrile: water (80:20 v/v) mobile phase. Retention times were used for the identification of the specific sugars in the sample whereas the areas were used for the determination of their amounts.

3.7.15 Determination of Apparent Reducing Sugar Content (Lane and Cynon, 1932)

Fehling's reduction titration method was used in the determination of apparent reducing sugars. First Fehling's solution A (copper sulphate pentahydrate – $CuSO_{4.}5H_2O$) was standardized so that exactly 5 ml pipetted, when mixed with approximately 5 ml of Fehling's solution B (sodium Potassium tartrate – $C_4H_4NaO_54H_2O$) would react completely with 0.050 g invert sugar added as 25 ml dilute invert sugar solution (2 g/l) (Lane and Eynon, 1932). A 2.0 g homogenized honey was dissolved in distilled water and then diluted to 200 ml in a volumetric flask. Fifty millilitres of this solution was further diluted to 100 ml with distilled water. The reagents prepared were first titrated against the honey solution so that the total volume of the added reactants at the end of reduction titration could be 35 ml.

a) **Preliminary Titration**

The 35 ml total volume of the added reactants at the completion of the reduction titration was made up by the addition of a suitable volume of water to the reactant before the titration commenced (IHC, 2002). Since the compositional criteria of the honey standard specify that there should be more than 60 percent reducing sugars (calculated as invert), a preliminary titration was necessary to establish, the volume of water to be added to a given sample to ensure the reduction was carried out at constant volume. This volume of water added was calculated by subtracting the volume of diluted honey solution consumed in the preliminary titration (x ml) from 25 ml. five millilitres of Fehling's solution A was pipetted into a 250 ml Erlenmeyer flask to which 5 ml of Fehling's solution B and 7 ml distilled water were added. The mixture was heated to boiling over wire gauze and maintained at moderate ebullition for 2 minutes, by repeated small additions of diluted honey solution until the indicator was decolourized. The total volume of diluted honey solution consumed was noted as x ml. The amount of water necessary to bring the total volume of the reactants at the completion of the titration to 35 ml was calculated by subtracting the preliminary titration (x ml) from 25 ml.

b) Determination Reducing Sugar

Five millilitres Fehling's solution A was pipetted into a 250 ml Erlenmeyer flask and approximately 5 ml Fehling's solution B added. To this mixture, (25 – x) ml distilled water, a little powdered pumice or other suitable anti-bumping agent and from a burette all but 1.5 ml of the diluted honey solution volume determined in the preliminary titration were added. The cold mixture was heated to boiling over wire gauze and maintained at moderate ebullition for 2 minutes 1 ml methylene blue solution was added whilst still boiling and the titration was completed within a boiling total time of 3 minutes by repeated small additions of diluted honey solution until the indicator was decolourized. The total volume of the diluted honey solution consumed was noted as (y ml). Titrations were done in duplicates.

3.7.16 Determination of Apparent Sucrose

Two grams of the homogenized honey sample was dissolved in distilled water and diluted to 200 ml in a calibration flask. Fifty millilitres of the honey solution was placed in 100 ml flask together with 25 ml distilled water and heated to 65 $^{\circ}$C over boiling water bath. The flask was then removed from the water bath, 10 ml of 6.3 4 M hydrochloric acid added and the solution was allowed to cool naturally for 15 minutes and then brought to 20 °C and neutralized with 5 M sodium hydroxide, using litmus paper as indicator. It was again cooled and the volume adjusted to 100 ml. The method used for the determination of the reducing sugars was adapted. Percent invert sugar was calculated (g invert sugar per 100 gm honey) after inversion using the same formula as for percent invert sugar before inversion. Apparent sucrose content = (invert sugar after inversion minus invert sugar content before inversion) x 0.95. The result was expressed as gm apparent sucrose per 100 g honey.

3.1.3 Data Analysis

The SPSS program was used to analyze the data obtained after a descriptive analysis of the variables was carried out and the normality of the data was verified by means of Kolmogorov test. Secondly, analysis of variance (ANOVA one way) was done to detect if the region or geographical location was significant in various characteristics. The bi-variant correlation between the variables of some parameters was done to detect their interdependence.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Physicochemical parameters

Honey sampled from four different regions of Kenya, Central, Eastern, Coast and Rift Valley was analysed for the physicochemical parameters. The parameters included moisture content, electrical conductivity, specific rotation, viscosity, sugars, pH, free acidity, HMF, specific rotation, relative density, mineral salts, ash content, water insoluble matter content and proline. The results obtained for each parameter were presented in tables and charts and analysed using Statistical Program for Social Sciences (SPSS) for relations.

4.1.1 Refractive Index and Moisture Content

The refractive index of honey samples from different regions in Kenya measured and the values obtained used to determined moisture content using Wedmore Table of refractive index (appendix B). Wedmore Table uses the relationship given in equation 4.1(Wedmore, 1955) of moisture content and refractive index.

$$\textbf{Moisture content} = \frac{1.7390 - \log(n_{20} - 1)}{0}.0002243 \qquad [4.1]$$

The results of the refractive index of honey from the four regions are shown in Table 4.1.

Table 4. 1: Mean Refractive Index and Range of Honey from Different Regions in Kenya

	Refractive Index	
Region	**Mean ± SE**	**Range**
Rift Valley(n=80)	1.4894 ± 0.00025	1.4808 - 1.4952
Coast(n=40)	1.4846 ± 0.00116	1.4679 - 1.4903
Central(n=80)	1.4890 ± 0.00170	1.4817 - 1.6199
Eastern(n=117)	1.4882 ± 0.00048	1.4625 - 1.4979
Total(n=317)	**1.4882 ± 0.00049**	**1.4625 - 1.6199**

n= number of sample analysed, SE= Standard error

The mean and range of the determined moisture content are given in Table 4.2

Table 4. 2: The Percentage Mean and Range of Moisture Content of Honey from Different Regions in Kenya

Region	Moisture Content %	
	Mean ± SE	**Range**
Rift Valley (n=80)	18.84 ± 0.10	16.52 - 22.29
Coast (n=40)	20.77 ± 0.46	18.47 - 27.43
Central (n=80)	19.70 ± 0.15	17.67 - 21.92
Eastern (n=117)	19.32 ± 0.19	15.44 - 29.60
Total (n=317)	**19.48 ± 0.11**	**15.44 - 29.60**

From Table 4.2, the moisture content of honey from Rift Valley region varied from 16.52 – 22.29%, with mean value of 18.84 ± 0.10**.** Out of 80 samples analyzed, only one R12 (appendix 1A) had moisture content of 22.29% which was above the permitted limits of 21% as set by Codex Alimentarius Commission (2001) and the International Honey Commission (2002). The moisture content of Coast honey ranged from 18.46 – 27.42% with mean value of 20.77 ± 0.46%. Six samples out of the 40 analysed, had moisture content of 27%, which was well above the permitted levels of 21%. Honey samples from Central region had moisture content which varied from 17.67 – 21.92%, with a mean value of 19.23%. A total of 80 honey samples were analysed where 16 samples were found to have 21% moisture content, the maximum limit permitted. The rest of the honey had moisture content below this value.

The moisture content for Eastern region honey varied from 15.44 – 29.60%. Out of the 117 samples analysed only four samples had moisture content above the 21% permitted limit. The mean value for these honeys was 19.32% ± 0.19. The honey from Rift Valley had the lowest moisture content on average with that from the Coast region having the highest. The difference in moisture content is attributed to the climatic conditions, season of the year and the degree of honey maturity (White, 1975). Honey samples which showed lowest moisture content were from Arid and Semi Arid Lands (ASAL). These are dry regions and therefore with low moisture content. However, the mean values from all the four regions were well below the permitted maximum limit of 21% moisture content (Codex Alimentarius Commission, 2001; European Commission and International Honey Commission, 2002). The mean values for Rift Valley, Eastern, Coast and Central obtained, 18.84%, 19.32%, 20.77% and 19.77% respectively though close to one another were significantly different ($P < 0.05$). This was attributed to different climatic conditions, season of honey harvesting, degree of maturity and storage conditions. Therefore moisture content can be used to identify or discriminate the geographical origin of the honey. However, some samples from the same region were found to have significantly different moisture values.

As expected, honey from Coast region had higher moisture content because of being more humid than Eastern, Central and Rift Valley regions and therefore, nectaries foraged there have higher level of water content, resulting to high moisture content in the honey. In terms of individual sample moisture content, Eastern region had a sample with the lowest (15%) moisture content, followed by Rift Valley (16%) while a sample with the highest moisture content (27%) came from Coast followed by Rift Valley (22%). This again was attributed to different climatic conditions and stage of honey maturity.

The moisture content of honey from different botanical and geographical origin is in the range of 13 – 29% (Lazaridou *et al*., 2004*).* The moisture level of the Kenyan honey represented by the four regions lies within this range and was consistent with Indian honey, which had 18.7 – 21.8% (Singh and Bath, 1997) and Moroccan honey, with 16.8 – 20.3%. But in contrast, Saudi honeys; Alkhalifa and Al-Arify (1999) had lower moisture content which ranged between 14.0 – 16.9% (Terrab *et al*., 2002) while Chinese honeys had higher moisture content in the range of 19.8 - 29.0% (Junzheng and Changying, 1998).

4.1.2 Specific Rotation

Specific rotation is increasingly becoming an important parameter in differentiating between honeydew honey and floral honey. Honeydew honey has positive specific rotation values whereas floral honey has negative values. Honeys having higher fructose content than glucose and other sugars are Laevo-rotatory, hence giving negative specific rotations. Those with high glucose content are dextro-rotatory, giving positive specific rotation values. Table 4.3 shows the specific rotation of honey from different regions in Kenya.

Table 4. 3: The Mean and Range of Specific Rotation for Honey from Different Regions in Kenya

Region	**Specific rotation**	
	Mean ± SE	**Min - max**
RIFT VALLEY (n=80)	-12.93 ± 0.59	-25.50 - $^{+}$15.50
COAST (n=40)	-9.18 ± 0.68	-19.00 - $^{+}$5.25
CENTRAL (n=80)	-9.62 ± 0.72	-24.00 - $^{+}$2.00
EASTERN (n=117)	-12.18 ± 0.44	-17.50 - $^{+}$1.75
Total (n=317)	**-11.34 ± 0.31**	**-25.50 - $^{+}$15.50**

It can be seen from Table 4.3 that the maximum specific rotation for Rift Valley samples was +15.50 while the minimum was -25.50. Coast had +5.25 as the maximum and -19.00 minimum specific rotations. The values for Central region varied from -24.00 to +2.00 while Eastern region had -17.82 as minimum and +1.75 as maximum values. The mean specific rotations (Figure 4.1) for Rift Valley, Coast, Central and Eastern regions are -12.93 ± 0.59, -9.18 ± 0.68, -9.62 ± 0.72 and -12.18 ± 0.44, respectively. These means show that Rift Valley honey has the highest fructose content followed by Eastern, Central and lastly Coast region.

This study shows that the specific rotation values from all the four regions of Kenya had both negative and positive values. Positive values were indicative of honeydew honeys while negative values indicated floral honeys (Piro *et al*., 2002). However, a good number of samples from the four regions showed negative values between -1 to -7. These samples were actually a mixture of blossom (floral) and honeydew honeys, in which the concentration of fructose is a little bit higher than glucose and other sugars. Some samples did not turn the plane of polarized light to either side. They had zero specific rotation, indicating that they have equal amounts of floral (blossom) and honeydew honey. These samples were R9 from Rift Valley and MT 16 and MT20 from Central region (Appendix 1A and 1B).

Honeydew honey samples with positive specific rotation (Figure 4.1) were R56 (Appendix 1A) with +15 specific rotations, MT21 (Appendix 1A and 1B) with +2.0 specific rotations, MW14 (Appendix 1 Table 3) with 1.75 specific rotations and C12, C16 (Appendix 1D) from Coast with +5.25 and +2.00 specific rotation respectively. All these honeys were honeydew honeys with varying glucose content. Those with bigger positive values, have similarly higher relative glucose content. Therefore sample R56 with +15 specific rotations had the highest percentage of glucose content. The majority of the honey from Eastern region, particularly from Mwingi and Central region were a mixture of honeydew honey and blossom honey (compound honey). Most of their specific rotation values lied between -1 and -7. Analysis of specific rotation clearly shows its usefulness in differentiating between honeydew honey, blossom honey and mixed or compound honey (Persano and Piro, 2004; Piazza *et al*., 1991). Apart from the specific rotation identification, honeydew honeys can also be identified from their very dark colour, strong flavour and being heavily bodied (Crane, 1979).

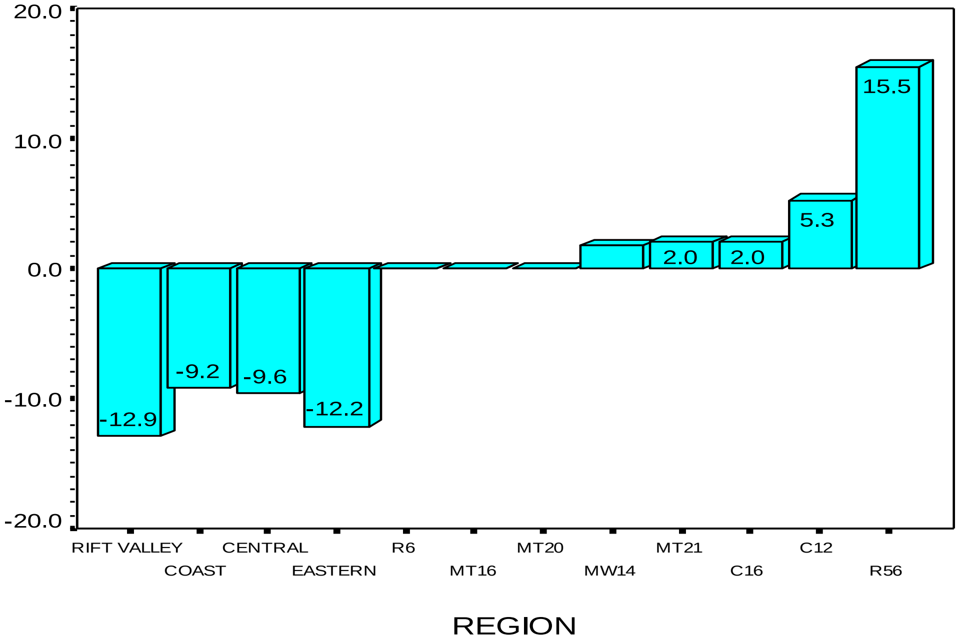


Figure 4. 1: The Mean Specific Rotation of Honey and honey with positive specific rotation from Different Regions

3.1.3 Electrical Conductivity

Electrical conductivity, along with other parameters such as ash content, acidity, pollen grains and specific rotation are used to identify honey origin (Crane and Walker, 1986). Honeydew honey has higher electrical conductivity values than floral honey (Perez *et al*., 1994). The electrical conductivity of Kenyan honey from the different regions was analysed and results are given in Table 4.4

Table 4. 4: The Mean and Range of Electrical Conductivity of Honey from Different Regions in Kenya

Region	Electrical conductivity mS/cm	
	Mean ± SE	**Min – Max**
Rift Valley (N=80)	0.059 ± 0.015	0.020 - 0.927
Coast (N=40)	0.332 ± 0.017	0.122 - 0.714
Central (N=80)	0.378 ± 0.012	0.251 - 0.792
Eastern (N=117)	1.076 ± 0.044	0.398 - 2.253
Total (n=117)	**0.549 ± 0.029**	**0.020 - 2.253**

The honey from Rift Valley region had electrical conductivity varying from 0.020 to 0.927 mS/cm, with a mean value of 0.059 ± 0.015 mS/cm. The mean value is within the permitted limits of not more than 0.6mS/cm for floral honeys (International Honey Commission, Codex Alimenterius Rome, 2001). Honeydew honeys have more than 0.6 mS/cm as the permitted limits (International Honey Commission, 2002; Codex Alimenterius Rome, 2001). The mean of (0.059 ± 0.015 mS/cm) reveals that most of the honey from Rift Valley was floral honeys.

However, a few samples such as R9 and R56 (Appendix 1A) which had 0.8 mS/cm and 0.9 mS/cm were either mixed compound honey or honeydew honey. These values are well above the accepted limits for floral honey and therefore were honeydew honey, a position more reaffirmed by their specific rotation values which were found to be: 0.00 for R9 and +15 for R56. These values are typical honeydew honey values. Electrical conductivity for Coast honey varied between 0.122 mS/cm and 0.714 mS/cm, with 0.332±0.017 mS/cm as the mean. The mean shows that majority of the honey in this region are floral honeys, though two honeydew samples C12 & C16 (Appendix 1A) with 0.7 mS/cm and 0.67 mS/cm respectively were noticed. When their corresponding specific rotation was determined, they were found to be +5 for C12 sample and +2 for C16. From the specific rotation point of view these values are typical of honeydew honey. Their ash content was also found to be high.

Central region honey (Mt. Kenya) had electrical conductivity values ranging from 0.25 to 0.88 mS/cm with 0.35 mS/cm as the mean. The mean value is well below the maximum and the minimum permitted limits for floral and honeydew honeys respectively. This value (mean) indicated that most of the honey from Central is floral honey. Three exceptions of honeydew honeys noted were MT16, MT20 and MT21 (Appendix 1A) which had means of 0.77 mS/cm, 0.65 mS/cm and 0.79 mS/cm respectively. These values were above 0.6 mS/cm, the minimum permitted limit and therefore characteristic of honeydew honey. Their corresponding ash content and specific rotations were found to be MT16-0.77%, MT20-0.657% and MT21-0.79% and 0.00, 0.00 and 2.00, respectively. Both of these values, ash content and specific rotation are characteristic of honeydew honeys as revealed by electrical conductivity values.

Electrical conductivity for Eastern region varied from 0.398 mS/cm to 2.253mS/cm, with a mean value of 0.52±0.044 mS/cm. The mean value is almost approaching the maximum permitted value for floral honey, which is 0.6 mS/cm. Honey from this region therefore seems to be a mixture of floral and honeydew honey. It is noted that honey samples MW14 and MW1 (Appendix 1A) are honeydew honeys since they have 0.668 mS/cm and 0.605 mS/cm electrical conductivity values respectively. These values are slightly above the permitted maximum limit for floral honey (0.6 mS/cm) which also happens to be the minimum limit for honeydew honey (International Honey Commission, 2002; Codex Alimentarium, 2001).

4.1.4 Viscosity

The viscosity of honey from different regions of Kenya was determined at different temperatures (25 °C, 30 °C, 35 °C, and 40 °C) and their statistical results are given in Tables 4.5 and 4.6.

Table 4. 5: The Mean and Range of Viscosity of Honey from Different Regions in Kenya at 25 °C and 30 °C

Region	**Viscosity (centipoises) at 25 °C**		**Viscosity (centpoise) at 30 °C**	
	Mean ± SE	**Min – Max**	**Mean ± SE**	**Min – Max**
Rift valley (n=80)	8951.50±569.69	1200.00-20000.00	5607.75±393.46	1100.00-9600.00
Coast (n=40)	6572.50±326.38	2100.00-11000.00	3512.50± 11.50	1600.00 -6400.00
Central (n=80)	3953.75±178.42	1900.00-8800.00	3335.00±152.53	1300.00 - 8800.00
Eastern (n=117)	5697.26±335.40	1300.00-19600.00	4451.32±788.95	1000.00-7700.00
Total (n=317)	**6188.96±223.18**	**1200.00-20000.00**	**4342.98±314.08**	**1000.00-67700.00**

Table 4. 6: The Mean and Range of Viscosity of Honey from Different Regions in Kenya at 35 °C and 40 °C

Region	**Viscosity (centipoises) at 35 °C**		**Viscosity (centipoises) at 40 °C**	
	Mean ± SE	**Min – max**	**Mean± SE**	**Min – max**
Rift valley (n=80)	3864.25±253.51	1040.00 -13880.00	2306.25±95.53	1000.00 - 5000.00
Coast (n=40)	2605.00±158.72	1200.00-4800.00	1835.00±96.51	700.00 -3300.00
Central (n=80)	2241.25±109.41	800.00-6300.00	1430.00±71.09	600.00 -4700.00
Eastern (n=117)	2462.74±90.95	600.00-5100.00	1774.02±60.73	500.00 -4000.00
Total (n=317)	**2778.49±87.31**	**600.00-13880.00**	**1829.21±43.04**	**500.00 -5000.00**

The mean viscosity of Rift Valley honey at 25 °C was 8951.50±569.69 centipoises with a range of 1200.00-20000.00 centipoises. With increase in temperature, (from 25-30 °C and then to 35 °C) the mean viscosity and range decreased progressively. At 40 °C, the decrease of mean viscosity had reached 2306.25±95.53 centipoises with a range of 1000.00-5000.00 centipoises. This indicates that all the Rift Valley honey samples showed Newtonian behaviour in which viscosity decreases with increase in temperature (Abu-Jdayil *et al*., 2002 and Lazaridou *et al*., 2004; Junzheng and Changying, 1998). The same trend and behaviour was observed for Coast, Central and Eastern region honeys. In all these regions, no honey was found to show thixotropic behaviour as Karvi honey of India or Manuka honey of New Zealand (Bhandari *et al*., 1999).

The effect of temperature on viscosity seems to be more pronounced up to 30 °C. The effect is much less at temperatures 35-40 °C. This can be attributed to the presence of honey crystals and colloids at lower temperatures. But as temperature increases, crystal particles size decrease as they melt hence effecting less viscosity.

At 30 °C of temperature, the viscosity of honey from the four regions behaved differently. The mean, minimum and maximum viscosity for coast honey was almost reduced to half. That for Central did not change much at this temperature. The maximum viscosity value 8800 centipoises remained the same as the one at 25 °C. The mean (3953) reduced slight to 3335 at this temperature. Eastern honey showed viscosity change at this temperature. The changes were slightly higher than for Central honey. The viscosity behaviour shown by Central honey at 30 °C was attributed to the presence of increased number of crystals in the honey samples, which had not melted hence the effect of temperature on viscosity was minimal. The appreciable reduction of viscosity for Coast honey was attributed to its high moisture content as well as composition crystal and colloidal. The slight reduction of viscosity for Eastern honey was due to less moisture content as well as crystal nucleation.

At 35 °C, viscosity responded substantially to this change in temperature. The mean values for coast honey reduced from 3535 to 2241 centipoises, while Eastern showed reduction from 4451 to 2462.72 centipoises. At this temperature, it is observed that viscosity of honey from all regions decreased. This can be explained by the fact that crystals melting had already been initiated in the honey samples that had crystallized, leading to viscosity reduction. However, the effect of temperature of 35 °C is less pronounced than at 30 °C (Abu-Jdayil *et al.,* 2002).

At 40 °C, the minimum, maximum and mean viscosity of honey from all the regions decreased further. The maximum mean viscosity at this temperature was 2306 centipoisess for Rift Valley honey and the minimum (3335 centipoises) was from Central region. This indicates that the most viscous and less viscous honey was from Rift Valley and Central regions respectively. This is attributed to less moisture content in Rift Valley honey compared with that from Central region.

When the mean viscosities of honey from different regions were statistically analysed using ANOVA, the p values for viscosity at 25 °C , 35 °C and 40 °C were 0.000, less than p = 0.5 hence statistically significant. It shows that there were significant differences between the mean viscosities of the regions at these temperatures. This can be attributed to differences in moisture content as well as honey composition. Honeys with different moisture content have different viscosities and since different regions have honey with different moisture content, their viscosities are bound to differ greatly, resulting to their differences in the means. At 30 °C, (where p-values is greater than p = 0.05 level), there was no significant difference in the regional viscosity means. This is due to the fact that the effect of the temperature on honey viscosity is more pronounced up to 30 °C and therefore the difference is not great at this temperature.

4.1.5 Sugar Content

The sugar content is an approximation of the amount of both reducing and non-reducing sugars in honey. The apparent reducing sugars and apparent sucrose were determined before hydrolysis or inversion for all the honey from the four regions. The apparent reducing sugars corresponded to the sum of the main individual sugars; fructose and glucose and the minor reducing disaccharides, mainly maltose. Table 4.7 shows apparent reducing sugars' concentration as a percentage before and after inversion. The apparent reducing sugars were determined by Fehling's titration reduction method.

Table 4. 7: Percentage Mean and Range of Invert Sugar in Honey from Different Regions before and after Inversion

Region	Invert sugar per 100 g honey before inversion		Invert sugar per 100 g honey after Inversion	
	Mean ± SE	Min- max	Mean ± SE	Min – Max
Rift Valley (n = 80)	71.60 ± 0.22	66.98 – 76.50	72.98 ± 0.19	68.79 - 77.40
Central (n = 80)	68.67 ± 0.27	64.24 – 74.30	70.18 ± 0.32	65.04 - 77.33
Eastern (n = 117)	68.78 ± 0.29	54.10 – 76.07	71.76 ± 0.30	63.04 - 78.27
Coast (n = 40)	68.37 ± 0.50	53.38 – 73.14	69.59 ± 0.53	54.43 - 73.14
Total (n – 317)	**69.41 ± 0.17**	**53.38 – 76.50**	**71.39 ± 0.17**	**54.43 - 78.27**

The average composition of apparent reducing sugars before inversion from the Rift Valley region was the highest (71.60 ± 0.22%) with Coast showing the minimum (68.37 ± 0.50%). All the apparent reducing sugar mean values for the four regions were found to be well above the 65% recommended limit (Codex Alimentarius Commission, 2001). This shows that honey from these regions is mostly from the nectaries of plants (floral honey).

Coast region had the lowest range of apparent reducing sugars (53.38 – 74.14%) before inversion or hydrolysis while Rift Valley had the highest range (66.98 – 76.50%). The minimum apparent reducing sugars for both Eastern (54.10%) and Coast (53.38%) are below the recommended limits. This shows that the samples with these values were either compound honey or honeydew honey which usually has less than 65% reducing sugars. The mean apparent reducing sugars for the four regions is 69.41 ± 0.17% and is well above the minimum permitted limit. This indicates that Kenyan honey is mostly floral honey. However, there were significant differences ($p < 0.05$) in the mean apparent reducing sugars of honey from different regions before inversion (hydrolysis). This was attributed to different stages of honey ripeness as well as different nectar sources in different geographical locations.

After hydrolysis of honey from the four regions using hydrochloric acid, their apparent reducing sugar means and ranges for all the regions increased from their previous values (before inversion). Rift Valley region honey which had the highest mean of 71.60 ± 0.22% with a range of 66.98 to 76.50% increased to 72.98 ± 0.19% with increased range of 68.79 to 77.40%. Coast region which had the least mean of 68.37 ± 0.50% with the range of 53.38 to 73.14% increased to 69.59 ± 0.53% with an increased range of 54.43 to 73.16%. However, it was noted that honey from Eastern region with the minimum apparent reducing sugar of 54.10% had the highest increment after inversion to a value of 63.04%. The increase in apparent reducing sugars after hydrolysis for all the regions was due to the conversion of apparent sucrose content found in honey into invert or reducing sugar, which subsequently increases the total amount of reducing sugars.

The apparent sucrose content was calculated from the difference in apparent reducing sugar, before and after hydrolysis. The apparent sucrose content and ranges obtained are given in Table 4.8.

Table 4. 8: Percentage Mean of Apparent Sucrose Content

Region	Mean ± SE	Range
Rift Valley (n = 80)	1.3127 ± 0.137	0.020 - 5.40
Coast (n = 40)	1.1571 ± 0.035	0.610- 1.31
Central (n = 80)	1.4376 ± 0.047	0.500 - 2.25
Eastern (n = 117)	2.8304 ± 0.180	0.124 -15.29
Total (n = 317)	**1.641 ± 0.090**	**0.000 - 15.29**

From Table 4.8 Eastern region honey had the highest mean apparent sucrose content of 2.8304 ± 0.18% with a range of 0.124 to 15.29% whereas Coast had the lowest mean of 1.1571 ± 0.035% with the range of 0.610 to 1.31%. The recommended sucrose content maximum limit for floral honey is 10% (Codex Alimentarius Commission, 2001). All the means for the four regions reported are far below this limit. The minimum and maximum sucrose content ranges are also below this permitted limit except for the maximum sucrose value (15.29%) from Eastern region shown in Table 4.8.

Apparent sucrose, the most important sugar from legislative point of view in many countries (The council of the European Union, 2002) had low average and range values and this could be explained by the fact that most of the honeys were in the advanced state of ripening, and therefore much of the sucrose had been converted by diastase and invertase enzymes to glucose and fructose.

The sugar spectrum of honey depends upon different types of sugars such as glucose, fructose, maltose and sucrose present in the nectar as well as the enzymes present in the bee and nectar (Maurizio, 1979). Therefore, the feature of high sucrose content generally found in some honeys may be a plant characteristic and not in any way indicative of sugar feeding to the bees. Sugars fed honeys are usually low in water content and pH along with high sucrose content (Abu-Tarboush *et al*., 1993), because bees sucked sugars without water and not nectar. There were significant differences ($p<0.05$) in sucrose contents between the regions. This is attributed to different ripening stages in honey as well as different botanical origins of honey.

4.1.6 Specific Sugars

The specific sugars that were analysed by HPLC were fructose, glucose, maltose and sucrose. The monosaccharides, fructose and glucose were present in all samples as the main sugars (Table 4.9). Fructose was always the highest quantitatively, followed by glucose. These findings were in agreement with those of Terrab *et al*., (2001). Specific sugars of honey from different regions in Kenya were analysed using the HPLC. The heights of the sugar standards' peaks (Figures 4.3 and 4.4) along with those of the honey samples obtained were used in the determination of the specific sugars utilising the formula given in equation 4.4:

$$\textbf{Specific Sugar (W)} = \frac{A_1 \times V_1 \times M_1 \times 100}{A_2 \times V_2 \times M_o} \qquad [4.4]$$

Where; A_1 = Peak height of sugar compound in sample

A_2 = Peak height of sugar compound in standard

V_1 = Total volume sample solution in ml (100 ml)

V_2 = Total volume of standard solution in ml (100 ml)

M_1 = Mass amount of standard taken

M_o = Mass amount of sample taken

The peaks showing the retention times of the sugar standards used are shown below. Fructose (denoted by F) eluted first at 11.685 minutes followed by glucose (G) at 13.474 minutes, sucrose (S) at 19.865 minutes and lastly maltose (M) at 23.621 minutes. Sample calculations of four Rift Valley honey samples R10, R16, R23, R29 and R39 with the following peaks are shown in Appendix 6.

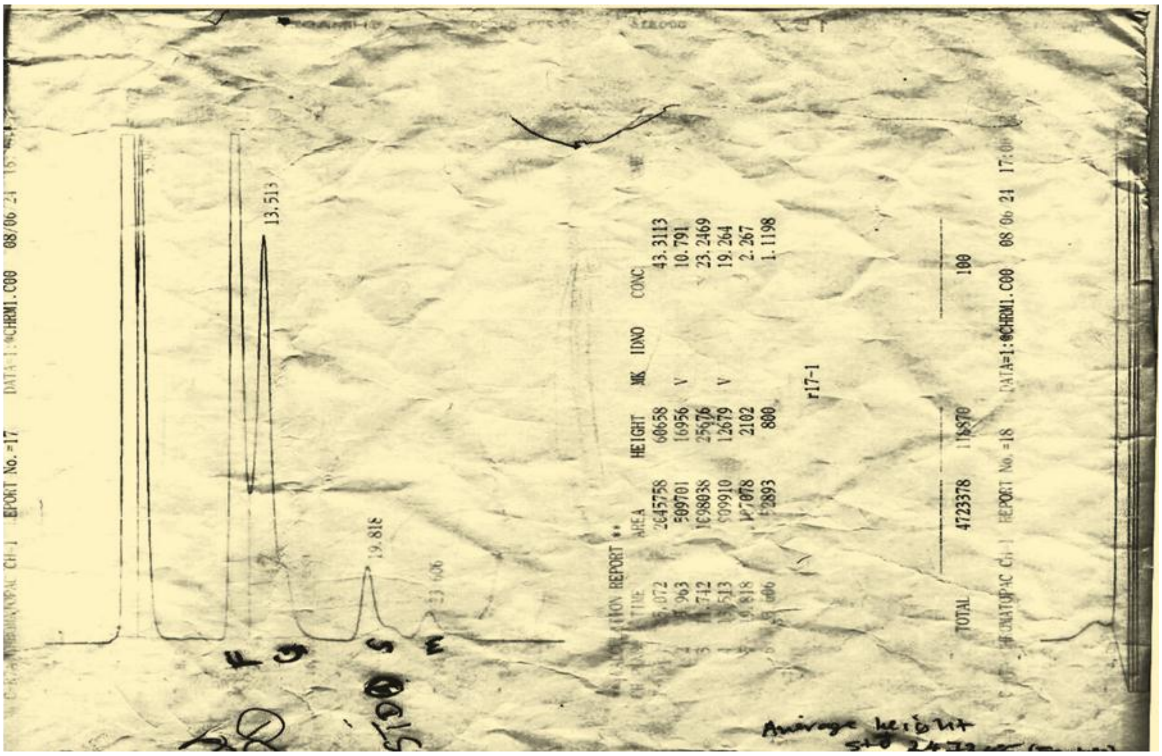


Figure 4. 2: The HPLC Chromatogram of Standard Sugars

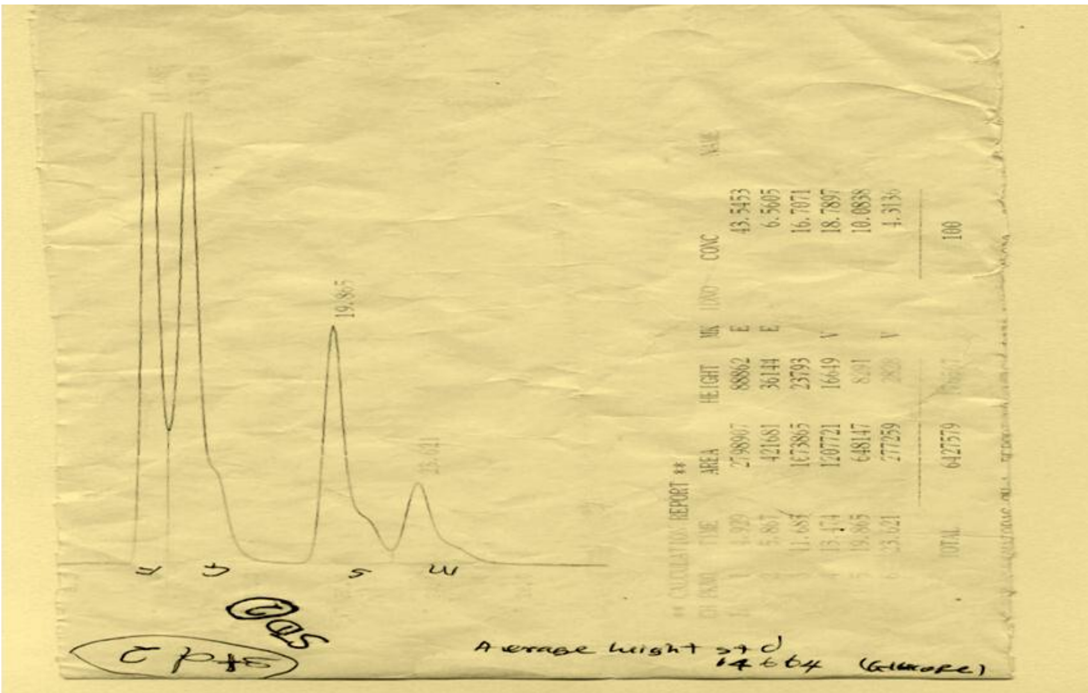


Figure 4. 3: Second Run HPLC Peaks of Sugar Standards Showing Different Retention Times and Peak Heights

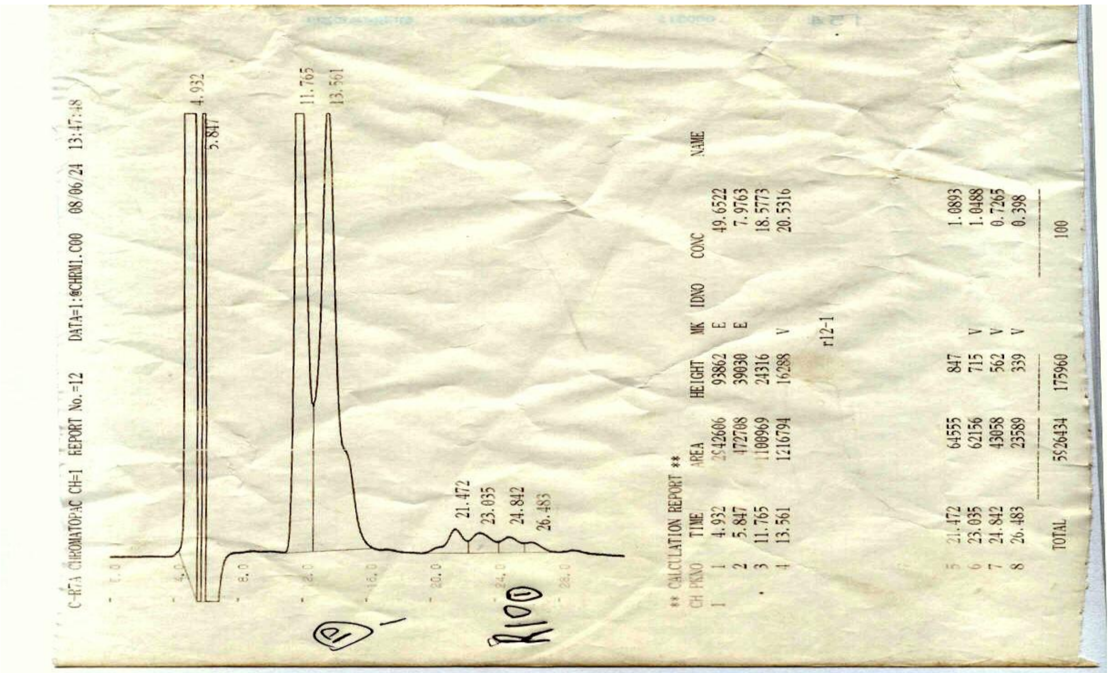


Figure 4. 4: The HPLC Peaks of R10 Honey Sample from Rift Valley

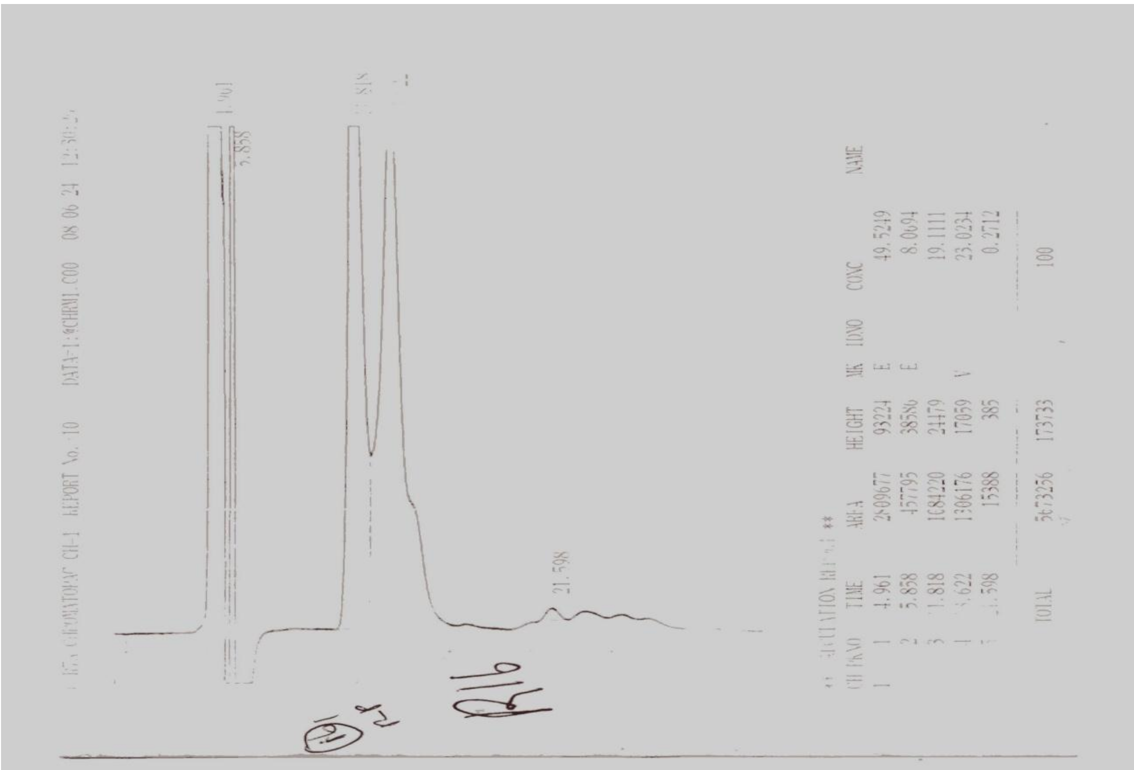


Figure 4. 5: The HPLC Peaks of R16 Honey Sample from Rift Valley

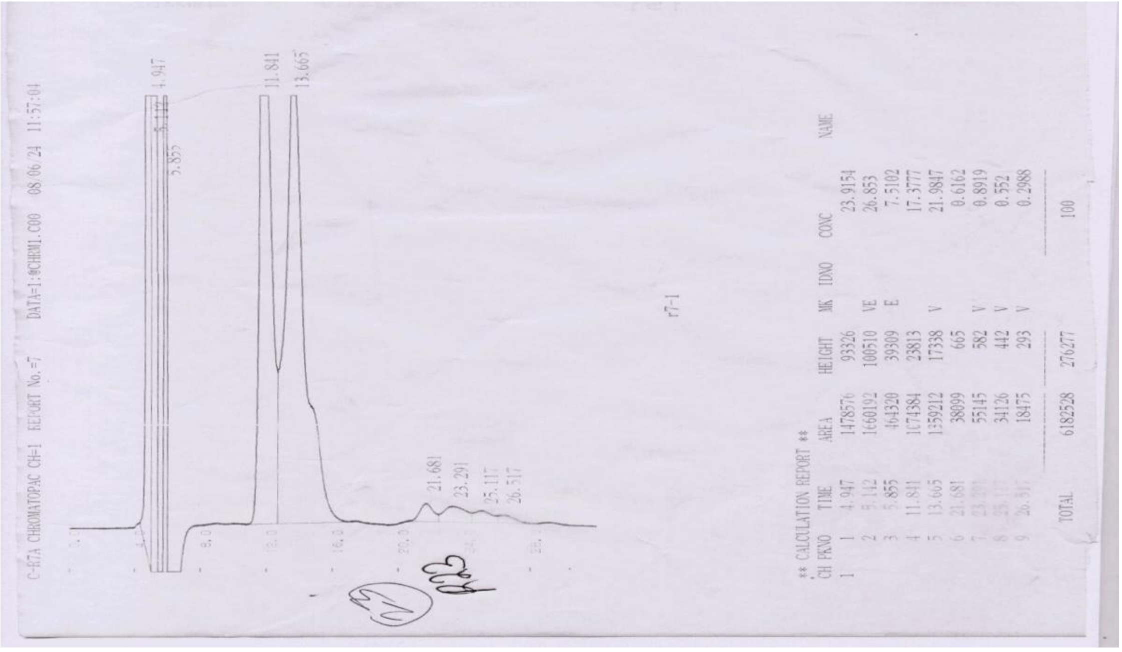


Figure 4. 6: The HPLC Peaks of R23 Honey Sample from Rift Valley

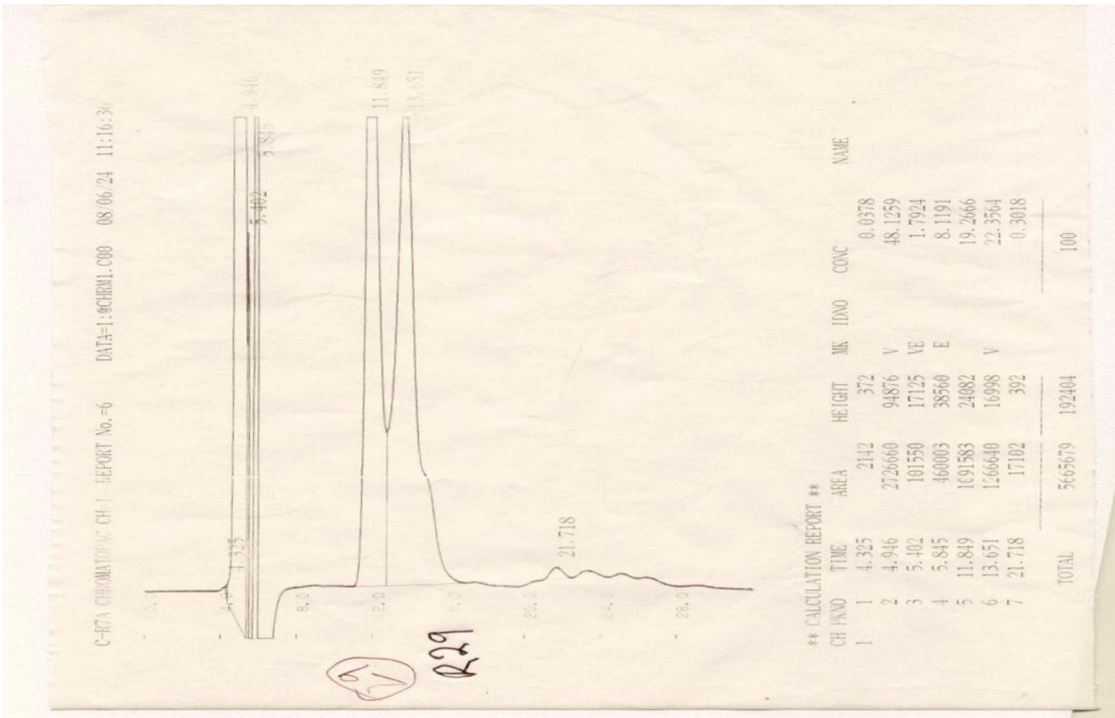


Figure 4. 7: The HPLC Peaks of R29 Honey Sample from Rift Valley

The results of the specific sugars obtained for some of the Rift Valley honey samples shown in the peaks above are given in the table 4.9.

Table 4. 9: Percentage of the HPLC Identified Specific Sugars for some Rift Valley Samples

Sample	Specific Sugar Content (%)			
	Fructose	Glucose	Sucrose	Maltose
R 10	39.32	33.32	0.82	1.17
R 16	39.58	34.90	0.40	_
R 23	38.5	35.5	0.40	0.96
R 29	38.9	34.77	0.30	_
R 39	40.44	37.86	0.50	_

Similar determinations were carried out with other analysed samples and the results obtained were statistically analysed and are represented in Table 4.10.

Table 4. 10: Percentage Mean and Range of Specific Sugars in Honey from the Rift Valley Region (N = 39)

Specific Sugars	Rift Valley (n = 39)		Central (n = 36)		Eastern (n = 32)	
	Mean ± SE	**Min - max**	**Mean ± SE**	**Min – max**	**Mean ± SE**	**Min - max**
Fructose	38.74±0.44	32.00-44.48	38.75 ± 0.42	33.00-43.25	35.78 ± 1.70	35.50-41.40
Glucose	32.88±0.48	27.00-38.97	30.99 ± 0.56	23.00-39.30	30.00 ± 1.45	29.50-35.00
Sucrose	1.01 ± 0.12	0.00 - 3.00	1.69 ± 0.23	0.00 - 4.82	2.67 ± 0.20	0.90 - 4.60
Maltose	0.98 ± 0.21	0.00 - 5.44	1.25 ± 0.30	0.00 - 6.40	1.65 ± 0.19	0.00 - 4.40

From Table 4.10, the highest mean fructose content of 38.75 ± 0.45% with a range of 33.00-43.25% was found in Central region honey while Eastern had the lowest of 35.78 ± 1.70%

with a range of 35.50-41.40%. Both the mean fructose content and the ranges for all the regions analysed were within the minimum permitted limits of 30% for floral honey (IHC, 2002). In terms of glucose content, Rift Valley had the highest mean of 32.88 ± 0.48% with a variation of 27.00-38.97%. Eastern had the lowest mean of 30.00 ± 1.45% with a variation of 29.50-35.00%. All the glucose means for the regions analysed were within the minimum glucose content permitted limit of 25% for floral honey (Codex Alimentarius Commission, 2001, IHC, 2002). The minimum and maximum glucose content range values for all the regions except Central region were within this permitted limit.

The sum of the specific sugars (glucose and fructose) should be approximately equally to apparent reducing sugars that were found before sucrose hydrolysis during the determination of apparent reducing sugars. Therefore, for each region analysed, the specific sugars (glucose and fructose) should be equal or in close agreement with the mean apparent reducing sugars content obtained earlier.

For Rift Valley region, the total specific sugar content of fructose, 38.78% + glucose 32.88% = 71.62%. The mean value that was obtained for apparent reducing sugars before hydrolysis for Rift Valley honey was 71.60%, (table 4.7). This value is in good agreement with the total of the dominant specific sugars analysed by HPLC. The average specific sucrose content (1.01%) as analysed by HPLC for this region was closely in agreement with apparent sucrose content (1.31%) as analyzed by Fehling's titration method. This confirms further that Rift Valley is floral honey which was at its advanced stage of ripening. For Central region honey the summation of the reducing specific sugars (fructose 38.75% + glucose 30.99% = 69.74%) is in close agreement with the average apparent reducing sugars (68.78%) obtained for same region (table 4.7). The reason for the small difference observed might be due to inaccuracy in the experimental stage during apparent reducing sugar analysis using Fehling's reduction titration method as compared with the more accurate HPLC chromatographic technique used for specific sugar analysis.

The summation of mean glucose and fructose content for Eastern region honey was (35.78% + 30.00 %) was 65.78%, which is slightly above the minimum 65% recommended limit for floral honey. This indicates that honey from Eastern region contain some compound honeys which have low sugar content. However, the obtained value of 65.78% is above the recommended limit indicating a slight dominance of floral honeys in this region.

In terms of sucrose content, Eastern region had the highest (2.7%), while Rift Valley had the lowest (1.0%). These values are well below the maximum recommended limit of 10%, indicating that honey from all these regions as analysed by HPLC was at the advanced stage of ripeness. The sucrose content values in the HPLC analysis, though slightly different are in good agreement with those of the apparent sucrose that were analysed by Fehling's reduction titration method. The variation of mean specific sucrose content in honey for the investigated regions is clearly shown in the Figure 4.9.

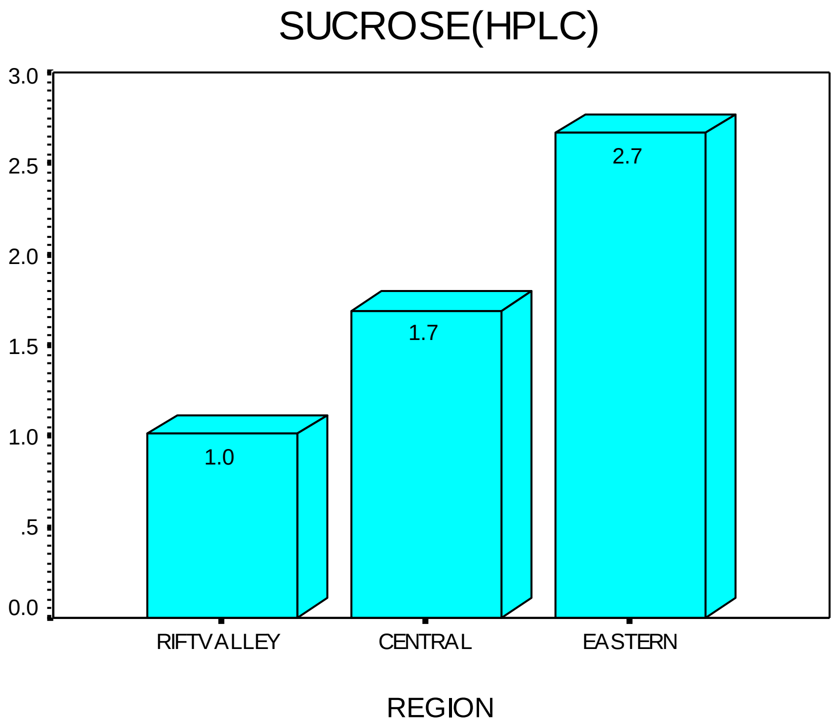


Figure 4. 8: Percentage Average Sucrose Content in Honey from Different Regions Analysed by HPLC

The mean sucrose content of honey between regions investigated were found to be significantly different ($p<0.05$). This was attributed to different honey maturity levels in different regions. The amount of sucrose in honey is an indication of the level of honey maturity with higher amounts indicating less matured honey where much of the glucose has not been converted to glucose and fructose. Therefore, since honey from different regions were foraged and harvested at different times, the levels of sucrose tended to differ resulting to variation in the regional mean values.

Considering the four regions studied Rift Valley, Eastern, Central and Coast, the quantitative importance of apparent reducing sugars descended in that order. Their average compositions in the order given were 71.60, 68.78, 68.60 and 68.37% respectively. Both the average apparent reducing sugars and those of the specific sugars are above the accepted limits, indicating that most of Kenyan honey is floral honey. There was no significant difference ($p<0.05$) in the mean specific sugars between the regions. This was attributed to the same botanical source (mainly floral) from which nectar honey was foraged. Therefore, this parameter (specific sugars) cannot be used to discriminate honey geographically.

4.1.7 The pH

The pH values of honey are of great importance during extraction and storage of honey as they influence the texture, stability and shelf life. The pH value of honey from different regions in Kenya was determined and the results are presented in Table 4.11.

Table 4. 11: Mean ± SE and range of pH of honey from different regions in Kenya

Region	**pH**	
	Mean ± SE	**Min- Max**
Rift Valley (n=80)	3.95 ± 0.03	3.16 - 4.64
Coast (n=40)	4.57 ± 0.02	4.25 - 4.75
Central (n=80)	4.32 ± 0.01	4.20 - 4.57
Eastern (n=117)	4.48 ± 0.02	4.04 - 5.07
Total (n=317)	**4.32 ± 0.02**	**3.16 - 5.07**

Coast region honey had the highest mean pH m value of 4.57 ± 0.02 with the range of 4.25 – 4.75. The least mean pH of 3.95 ± 0.03 was found in Central region honey with a range of 4.20 - 4.57. The permitted honey pH value limit is 5 (European Union, 2002; International Honey Commission, 2004; Codex Alimentarius Commission, 2001). The mean pH values for the investigated regions shown in the table above are all within the permitted pH limit.

The pH values of most honey lie between 3.5 to 5.5 where floral honeys are characterized by low pH values whereas honeydew honey have high pH values. Most of the Kenyan honey have low pH values as indicated in table 4.11 and therefore are floral honeys. However, amongst samples analysed one sample from Rift Valley R56 and two samples from Coast region C12 and C16 had a pH of 4.6, 4.25 and 4.51 respectively. Most of the pH values of Coast honey which ranged between 4.25 and 4.75 were consistent with some Algerian honey which had a range of 3.80 – 4.88 as investigated by Ouchemoukh *et al.* (2007). The mean pH values of the different regions investigated are clearly shown in Figure 4.10.

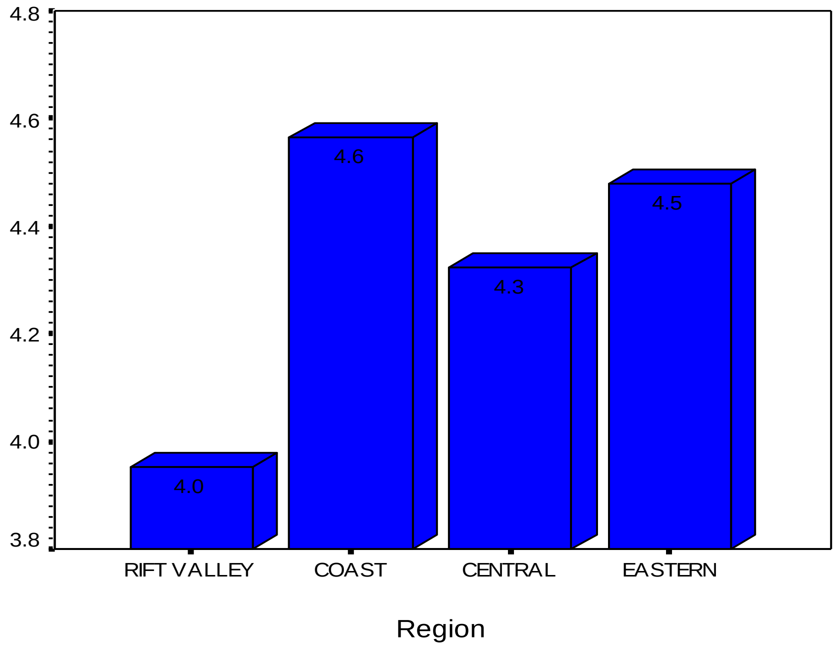


Figure 4. 9: Mean pH values of honey for the regions

Considering the mean pH values of honey from the four regions, Rift Valley honeys were more acidic with mean pH value of 3.95, followed by Central honey with the mean pH value 4.32, Eastern followed Central with pH 4.5 and lastly Coast with 4.56 pH mean value. Honey from the four regions investigated, were acidic and their pH values were within the accepted limits. The acidic nature of the honey is attributed to the presence of organic acids such as gluconic acid, oxalic acid, lactic acid and glucono lactone and their variation affects pH values (Nanda *et al*., 2003).

The pH results of the four regions investigated were consistent with the results for some Indian honey, whose pH range was 3.8–5.0 (Jasim *et al*., 2007). There were significant differences ($p < 0.05$) in the mean pH values of honey for the different regions investigated. This could be attributed to the different geographical locations of the regions under study. Different geographical regions have different vegetation cover with different floral nectaries characteristics. Therefore honey foraged from different regional vegetation with different organic acids could have different pH values, resulting to the differences in the mean values between these regions. Therefore the significant difference in the mean pH values can be attributed to botanical origin of the honey.

The pH values alone are not enough for the discrimination of honey from different geographical regions. However, free acidity and pH values when used together have some classification power for the differentiation between unifloral honeys and therefore quite useful for the determination of the botanical origin (Persano and Piro, 2004; Persano *et al*., 1986).

4.1.8 Free Acidity

Free acidity of honey which is due to the presence of organic acids, particularly the gluconic acid, in equilibrium with their lactones or esters and inorganic ions such as phosphates and chlorides (Nanda *et al*., 2003), was analysed for all the samples from the four regions and the values obtained given in Table 4.12. Most of these results were found to be within the prescribed limits of 40 meq kg-1 (Codex Alimentarius Commission, 1998).

Table 4. 12: Mean ± SE and range of free acidity in honey from different regions

Region	Free Acidity	
	Mean ± SE	**Min- max**
Rift Valley (n=80)	14.48±0.53	7.50-30.50
Coast (n=40)	27.25±0.78	20.00-36.00
Central (n=80)	27.05 ±0.66	21.00-39.00
Eastern (n=117)	37.38±1.12	20.00-86.33
Total (n=317)	**27.72±0.69**	**7.50-86.33**

From Table 4.12 the highest mean free acidity of 37.38 ± 1.12 meq/kg was from Eastern region honey which had a variation of 20.00 – 86.33 meq/kg whereas the lowest mean of 14.48 ± 0.53 meq/kg with the range of 7.50 – 30.50 meq/kg was found in the Rift Valley region honey. The mean free acidity of Kenyan honey in all regions as shown in Table 4.12 is well below the permitted limit of 40 meq/kg and is favourably comparable with that obtained by Terrab (2004) for Spanish honey, which ranged from 17.6–39.8 meq/kg with a mean of 34.5 meq/kg. However, some Pakistani honey had lower values which ranged from 6.733–22.937 meq/kg and a mean of 22.03 meq/kg (Asif *et al*., (2002).

There was a significant difference ($p < 0.05$) in the free acidity means for the regions investigated. This is attributed to both climatic conditions as well as regional vegetation (botanical origin of honey). Different regional plants have varying amounts of organic acids in their nectaries which include gluconic acid, which contribute greatly to free acidity in honey, hence resulting to variation in the mean values for the different regions.

4.1.9 Hydroxymethyl Furfural (HMF)

The HMF is a very important parameter used in honey quality determination. It is an indicator of the extent of honey deterioration as a result of heating or rise in temperature (Samko *et al.*, 1992). It is also a measure of honey adulteration by invert syrups (Ramirez *et al*., 2000). Analysis done on the honey samples from the four regions showed distinct variations in their HMF value, (Table 4.13).

Table 4. 13: Mean ± SE and range of HMF content in honey from different Regions in Kenya

Region	**HMF content mg/kg**	
	Mean ± SE	**Min – max**
Rift Valley (n=80)	6.94 ± 0.28	0.67 - 12.67
Coast (n=40)	16.21 ± 2.67	0.00 - 54.59
Central (n=80)	13.39 ± 1.19	1.53 - 64.16
Eastern (n=117)	28.09 ± 3.54	0.81 - 96.13
Total (n=317)	**17.54 ± 1.46**	**0.00 - 96.13**

From the table above, the highest mean HMF content of 28.09 ± 3.54 with a variation of 0.81 – 96.13 mg/kg was found in Eastern region honey. Rift Valley honey had the lowest mean HMF of 6.94 ± 0.28 mg/kg with a variation of 0.67 – 12.67 mg/kg. This indicates that all the mean HMF content were well within the permitted limits of 40 mg/kg by Codex Alimentarius Commission, (1998) and 80 mg/kg (I.H.C, 2002). The total mean HMF (overall mean, 17.54 ± 1.46 mg/kg) was also within the accepted limits. However, Coast, Central and Eastern regions had a maximum value range samples of 54.59, 64.165 and 96.23 mg/kg respectively, that were above the 40 mg/kg and 80 mg/kg permitted limits. Comparatively Pakistan honey had lower HMF range values (from 2.03 – 42.896 mg/kg) than Kenyan honey (Asif *et al*., 2002).

Honeys exposed to high temperature accumulate HMF, resulting in high levels (Rodgers, 1979). The variation or differences of HMF observed in honey samples from the regions may be due to climatic conditions and methods of harvesting, extraction and storage conditions practiced by the farmers. The regions with higher temperatures such as Eastern and Coast showed high levels of HMF as compared to Rift Valley and Central regions which usually experience relatively low temperatures. However, fresh honey samples have less than 15 mg/kg-1 HMF and therefore HMF cannot be used as a criterion for the botanical classification of honey. The mean HMF values for different regions were significantly different ($P < 0.05$) because of the different climatic conditions and aging of honey.

In terms of quality with regard to HMF accumulation, Rift Valley region honey was the best (with the lowest HMF), followed by Central, Coast and Eastern regions. Generally, Kenyan honey from all regions investigated was of good quality since all the HMF means as shown in table 4.13 were below the accepted limits. HMF is an important factor used in the honey processing design considerations as well as setting its processing and storage conditions to avoid honey quality deterioration.

4.1.10 Ash Content

Ash content is a parameter used for the determination of botanical origin of honey with high values of ash content being typical of mixed and honeydew honeys, (White, 1978). Ash content was analysed in the honey from the different regions under study and the results are presented in Table 4.14.

Table 4. 14: Mean± SE and range of percentage ash content in honey from different regions

Region	**Percentage Ash content**	
	Mean ± SE	**Min – max**
Rift Valley (n=80)	0.36 ± 0.18	0.01 -14.25
Coast (n=40)	0.83 ± 0.18	0.00 -5.06
Central (n=80)	1.51 ± 0.27	0.00 -10.59
Eastern (n=117)	0.64 ± 0.02	0.15 -1.62
Total (n=317)	**0.81 ± 0.09**	**0.00 -14.25**

Honey from Central region had the highest mean ash content of 1.51 ± 0.27% with a range of 0.00 – 10.59%. The lowest mean ash content of 0.36 ± 0.18% was from Rift valley honey with a range of 0.01 – 14.25%. The mean ash contents for all the regions investigated are represented in figure 4.12, giving a clear indication that Central region had higher ash content (1.51%) followed by Coast (0.83%), Eastern (0.64%) and lastly Rift Valley (0.52%).

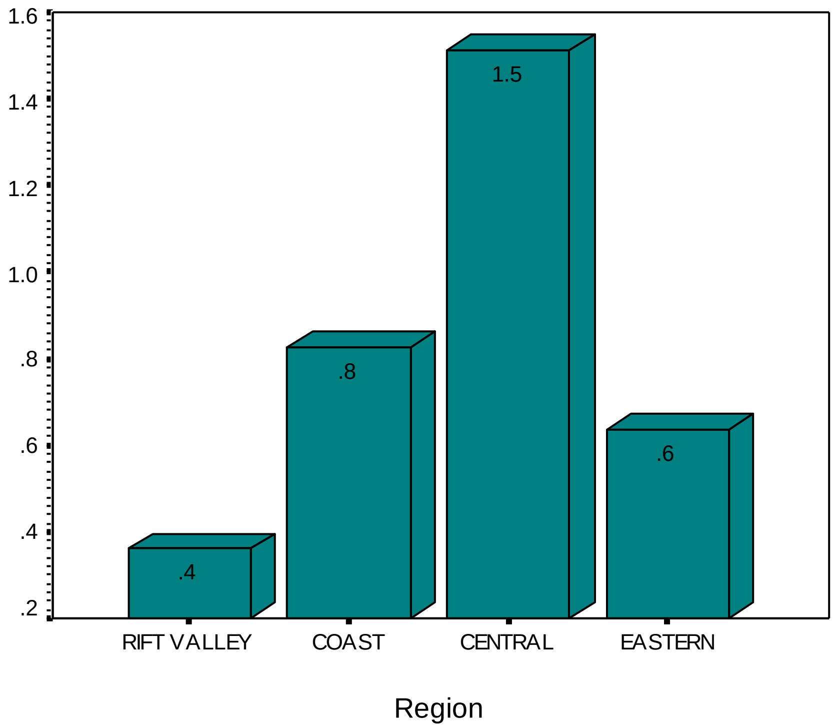


Figure 4. 10: Mean percentage Ash content in honey from different regions

The mean values for Rift Valley and Eastern were well within the permitted limits of 0.69/100 g honey. But Central and Coast honeys had higher values of ash content than the permitted limits, an indication that the honey samples from these regions had more honeydew honey or were mixed honeys than those from Eastern and Rift Valley. Northern India honey as reported by Nanda *et al*. (2003) had lower ash content than Kenyan honey, ranging from 0.12 to 0.28%. Some Nigerian honey as reported by Adebiyi *et al*. (2004) had also lower ash content than Kenyan honey ranging from 0.095% to 0.518%, with 0.30% as the mean.

The honeys from the regions were significantly different in terms of ash content. These differences are attributed to different geographical locations of the regions studied in terms of soils that have different amounts of mineral salts and therefore the nectar producing plants having different mineral content (Anklam, 1998b). Honeydew honey and mixed honeys usually show higher values of ash content (Ouchemoukh *et al*., 2007). Samples R9 and R56, from the Rift Valley region were noted to be honeydew honeys since their specific rotation were 00 and +15 respectively and their ash content (14% and 10%) respectively, were observed to be much higher than those for floral and mixed honeys. This confirms that this parameter is a useful tool for the identification of honey with regard to its botanical origin either as honeydew honey, mixed or floral (Kirkwood *et al*., 1960; White, 1975).

4.1.11 Density

Density of honey is a parameter which depends on the moisture content such that honey with low density tends to have higher moisture content. Density was analysed in honey from different regions in Kenya and the results presented in Table 4.15.

Table 4. 15: Mean and range of density in honey from different regions

Region	**Density**	
	Mean ± SE	**Min - Max**
Rift Valley (n=80)	1.41 ± 0.00	1.33 - 1.42
Coast (n=40)	1.41 ± 0.00	1.4 - 1.42
Central (n=80)	1.41 ± 0.00	1.38 - 1.42
Eastern (n=34)	1.41 ± 0.00	1.40 - 1.42
Total (n=234)	**1.41 ± 0.00**	**1.33 - 1.42**

Density investigated was the same in all the regions except for the ranges. Rift Valley region had the widest density range of 1.33 to 1.42 g/cm^3 while Eastern and Coast had the narrowest range of 1.40 – 1.42 g/cm^3.

The average density for honey from all the four regions was within the permitted limits of 1.43 g/cm^3 as set by the International Honey Commission, (2002) and Codex Alimenterius Standards (2001). There was no significant difference in the density means between the regions. Therefore, when honey from these regions are mixed together and stored, there is minimal risk of stratification. The time required for agitation to attain uniformity in such honey is also very much shortened. Although mean density cannot be used to identify the botanical or geographical origin, density ranges can be used to discriminate honey with regard to climatic conditions. Honey from humid regions has a higher minimum density than those from dry regions. Density of Kenyan honey is comparable to that of Pakistan honey which ranged between 1.4172-1.4228 g/cm^3 (Asif *et al*., 2002). This indicates that the amounts of honey sugars mainly fructose, glucose and maltose did not vary much.

4.1.12 Mineral Content

Honey has low quantities of mineral content which include potassium, sodium, magnesium, iron, copper, calcium and zinc and all these minerals were identified in Kenyan honey. Honey from different regions in Kenya was analysed for minerals and the results obtained are presented in Table 4.16.

Table 4. 16: Mean and range of minerals from different regions in Kenya

Element		Concentration (ppm)			Total (n=297)
		Rift Valley	Central	Eastern	
Potassium	Mean ± SE	739.39 ± 2.49	873.63 ± 1.40	939.50 ± 3.72	**850.84 ± 2.54**
	Min - max	540.60 - 860.46	647.55 - 895.58	780.60 - 989.56	**540.60 - 989.56**
Sodium	Mean ± SE	175.21 ± 0.13	252.60 ± 0.05	350.55 ± 0.19	**259.45 ± 0.12**
	Min - max	125.55 - 320.87	240.50 - 315.46	285.80 - 458.70	**259.45 ± 0.12**
Calcium	Mean ± SE	44.43 ± 0.22	158.84 ± 0.44	178.88 ± 1.21	**127.8 ± 0.62**
	Min - max	78.18 - 107.73	119.9 - 208.73	135.64 - 225.27	**78.18 - 225.27**
Magnesium	Mean ± SE	26.9 ± 0.11	47.72 ± 0.21	60.47 ± 0.29	**45.03 ± 0.2**
	Min - max	0.001 - 43.0	28.10 - 65.57	45.23 - 88.32	**0.001 - 88.32**

a) Potassium

Potassium was found to be the most abundant mineral in honey from all the regions analysed. Eastern region honey had the highest concentration of potassium with a mean of 939.50 ±

3.72 ppm and a range of 780.46 989.56 ppm while the lowest concentration of 739.38 ± 2.49 ppm mean with a range of 540.60 – 860.46 ppm was from Rift Valley region. This shows that honey from Eastern region is richer in potassium than that from both Rift Valley and Central regions. Therefore the element can be used to discriminate honey as per the geographical region. All the potassium mean concentrations between the regions studied were found to be significantly different at $p < 0.05$ due to their different geographical locations which have soils with different mineral concentrations.

Generally, Eastern region honey was found to be richer in potassium followed by Central and lastly Rift Valley. In the characterisation of Moroccan honey Terrab *et al*. (2002) found potassium to be the most abundant mineral with an average of 203 ppm. Nanda *et al*. (2003) reported the mean values of potassium for Indian honey to be from 489.52 – 932.15 mg/kg. Rodriguez-Otero *et al*. (1994) reported potassium as the most abundant element in Galicia honey with a mean of 1500 mg/kg. Kenyan honey with overall mean (total mean) of 850.84 ± 2.54 ppm is more richer in potassium than Moroccan and Indian honey but less richer than Galicia honey.

b) Sodium

Sodium was the second most abundant mineral in honey from the regions analysed with a total mean of 259.45 ± 0.12 ppm. The highest concentration of sodium with a mean of 350.55 ± 0.19 ppm and a range of 285.80 – 458.70 was found in Eastern region. Rift Valley region had the lowest mean concentration 175.21 ± 0.13 ppm with a range of 125.55 – 320.87 ppm. The different sodium mean concentrations found in this investigation, shows that honey from Eastern region is richer in sodium than Rift Valley and Central and therefore can be a discriminant factor in identifying honey as per geographical region. Rodriguez-Otero *et al*. (1994) reported sodium mean of 102 mg/kg in Galicia honey. This value is lower than the minimum average value for Kenyan honey (175 mg/kg) which is from Rift Valley and therefore Kenyan honey is of better quality than Galicia honey in terms of sodium mineral content. The means of sodium in the regions investigated were significantly different at $p < 0.05$ due to their different geographical locations having different sodium mineral concentrations in the soil.

c) Calcium

Calcium was the third most abundant mineral in honey from different regions in Kenyan honey with a total mean of 127.80 ± 0.62. Rift Valley region honey had the lowest concentration of calcium with a mean of 44.43 ± 0.22 and a range of 78.18 – 107.73 ppm. The highest mean concentration of 178.88 ± 1.21 ppm with a range of 135.64 – 225.27 was from Eastern region. This indicates that honey from this region is comparatively richer in calcium than the other regions studied. There were significant differences at $p < 0.05$ in the mean concentrations between the regions and this was attributed to different geographical locations.

d) Magnesium, Iron, Copper and Manganese

Magnesium is quantitatively the fourth mineral in honey from all the regions investigated with a total mean of 45.03 ± 0.2 ppm. The mean values obtained in this study were more than that obtained in Moroccan honey (36.19 ppm) (Diez *et al*., 2004). Honey from Eastern region has the highest concentration of magnesium followed by Central and lastly Rift Valley. The lowest concentration (26.9 ± 0.11) of magnesium was found in Rift Valley honey while the maximum concentration (60.47 ± 0.29 ppm) was registered from Eastern region. The means of magnesium obtained in the regions investigated were significantly different at $p < 0.05$ due to geographical location and therefore magnesium in honey can be used to discriminate honey region wise. Other levels of metals such as iron, manganese and copper were determined and their means were in traces.

Generally Kenyan honey is rich in minerals especially K, Na, Ca, Mg, with Eastern region honey being the richest in all the minerals investigated, followed by Central and then Rift Valley. In all these regions, the mineral content were found to be significantly different due to different geographical locations, implying that mineral content can be used to identify and discriminate Kenyan honey region wise.

4.1.13 Water Insoluble Matter Content

Water insoluble matter is an important parameter in determining the method used to extract honey from combs and was determined in honey from different regions in Kenya and the results presented in Table 4.17.

Table 4. 17: Mean and range of water insoluble matter contents in honey from different regions

	Insoluble matter (%)	
Region	**Mean ± SE**	**Min – Max**
Rift Valley (n=80)	0.78 ± 0.13	0.00 - 5.23
Coast (n=40)	1.05 ± 0.17	0.12 - 6.26
Central (n=80)	0.86 ± 0.06	0.10 - 2.01
Eastern (n=117)	0.14 ± 0.03	0.07 - 3.10
Total (n=317)	**0.60 ± 0.05**	**0.00 - 6.26**

From the above table, Coast region honey had the highest mean water insoluble matter of 1.05 ± 0.17% with a range of 0.12 – 6.25%. The lowest mean of 0.14 ± 0.03% water insoluble matter with a range of 0.07 – 3.10% was from Eastern region honey. Figure 4.17 shows clearly the variation of the mean percentage water insoluble matter of honey from the four different regions of Kenya investigated.

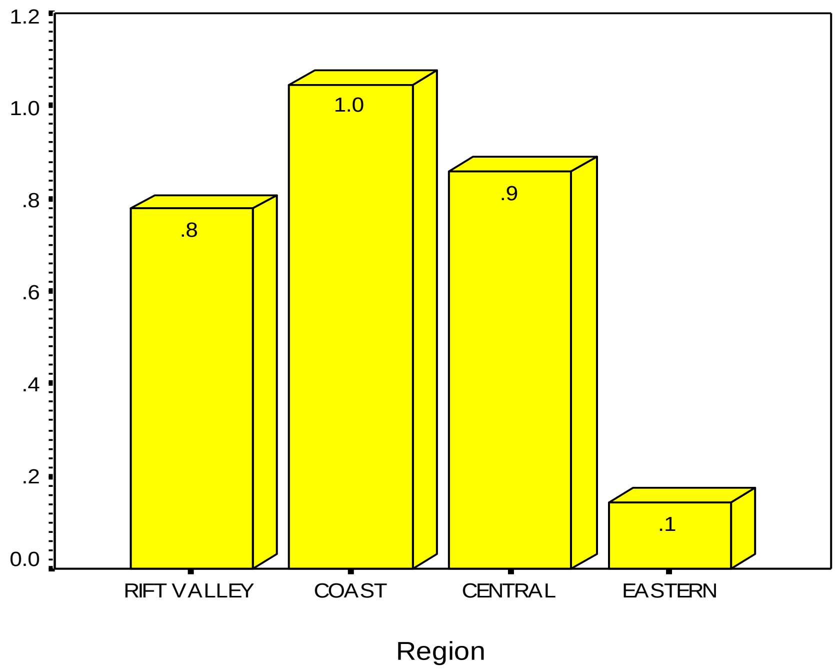


Figure 4. 11: Mean of water insoluble matter per region

The permitted limit of water insoluble matter for honey extracted by centrifugation is 0.1 g/100 g and 0.5 g /100 g for honey extracted by pressing (Codex Alimenterius, 2001; International Honey Commission, 2002). The mean water insoluble matter from Rift Valley, Coast and Central regions (as shown in Table 4.17) exceed the permitted limit of honey extracted by centrifugation. This observation indicates that honey from these regions was extracted by pressing. However, Eastern region honey had a mean value of water insoluble matter that was within the permitted limit, an indication that honey extraction might have been done by centrifugation rather than pressing.

There were significant differences in the mean values of water insolubles in the four regions investigated ($p < 0.05$). This was because of the different methods used for honey extraction in different regions resulting to different amounts of water insolubles in honey. Honey extracted by pressing has high water insolubles compared to the one extracted from the centrifugal extractor.

4.1.14 Hygroscopicity

Hygroscopicity of honey is the ability of honey to absorb water and is an important parameter that determines storage and the packaging conditions of honey in order to avoid fermentation. Hygroscopicity of honey from different regions in Kenya was determined and the results expressed as water percentage are presented in Table 4.18.

Table 4. 18: The mean and range of hygroscopicity of honey from different regions

Region	**Hygroscopicity (%)**	
	Mean ± SE	**Min – Max**
Rift Valley (n=80)	8.33 ± 0.01	3.00 - 17.00
Coast (n=40)	7.67 ± 0.01	4.67 - 9.67
Central (n=80)	9.67 ± 0.03	0.67 - 43.67
Eastern (n=117)	8.67 ± 0.01	4.00 - 26.33
Total (n=317)	**8.67 ± 0.01**	**0.67 - 43.67**

From the Table above, Central region honey had the highest hygroscopic percentage mean of 9.67 ± 0.303%, with the widest hygroscopic range of 0.67 – 43.67%. Coast region had the least hygroscopic mean of 7.67 ± 0.01% and the narrowest range of 4.67 – 9.67%. This indicates that Central region honey had the strongest hygroscopic character followed by Eastern, Rift Valley and lastly Coast. The variation in hygroscopic character between the regions is due to different honey moisture content and composition. For example Coast honey had the least hygroscopic character because it has the highest moisture content on average (Table 4.2) and therefore the rate of moisture absorption is relatively reduced.

The variations of mean hygroscopic percentage of honey from different regions investigated in Kenya are clearly shown in Figure 4.14.

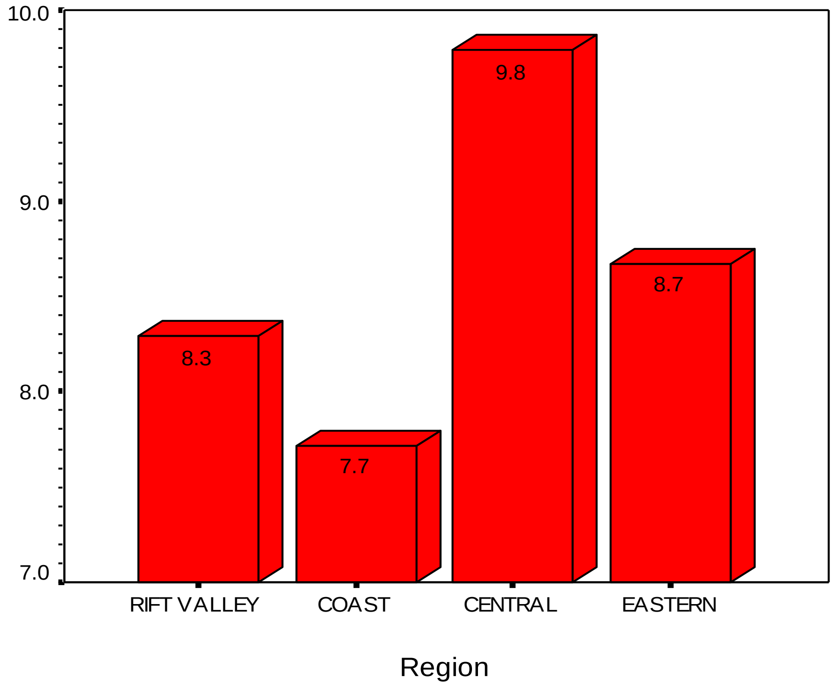


Figure 4. 12: Mean percentage hygroscopic values of honey from different regions

Central region honey with the highest hygroscopic character as shown in the Figure 4.14 could stand the risk of fermenting much faster if exposed to a more humid environment as compared to the other regions honey. This is because in addition to its normal moisture content, 9.67% will be absorbed from the surrounding in a more humid environment, resulting in an increased moisture content exceeding the 21% permitted limit, below which honey fermentation is limited.

Coast region honey which is the least hygroscopic stands a lower risk of fermenting. Therefore in the design of honey processing equipment as well as determining honey packaging and storage conditions, the hygroscopic character of honey is a major factor to be considered. There were significant differences between hygroscopic means of honeys from different regions because of different moisture content and sugar composition ($p < 0.05$). Honey with higher moisture content was observed to be less hygroscopic as compared to that with low moisture content. Generally Kenyan honey has a strong hygroscopic character and therefore food processing, packaging and storage conditions are a requirement.

4.1.15 Proline Content

Proline content was determined in honey from all regions of Kenya and study and the mean and the range results are presented in Table 4.19.

Table 4. 19: Mean and range of proline content in honey from different regions

Region	**Concentration (mg/Kg)**	
	Mean ± SE	**Range**
Rift valley (n = 80)	33.56±2.69	5.68 -103.47
Coast (n = 40)	372.26±10.49	246.25 -510.52
Central (n = 80)	444.14±13.61	258.71 -815.84
Eastern (n = 117)	520.41±17.18	128.17 -842.40
Total (n = 317)	359.60±13.22	5.68 -842.40

From Table 4.19, Rift Valley region had the lowest proline content of 33.55mg/kg with a range 5.68 to 103.47 mg/kg. The proline contents for Coast, Central and Eastern regions were well above the minimum permited limit of 180 mg/kg (Bogdanov *et al*., 1999). Eastern region had the highest mean of 520.41 mg/kg with a range of 128.17 to 842.40 mg/kg. The high proline content for Coast, Central and Eastern regions can be attributed to the early maturity of honey in which proline content was increasingly added by honey bees as honey matured (Bergner and Hahn, 1972). However, authors such as Hermosin *et al*, (2003) reported that high values of proline are typical of honey dew honeys. Others such as Louveaux (1978) think that the majority of proline content come from the salivate secretion of Apis mellifera. The mean proline content between the regions were significantly different probably due different honey maturity times.

4.2 Biochemical Parameters; Diastase Activity

Honey from Central, Eastern, Coast and Rift Valley was analysed for the biochemical parameter, diastase activity. Diastase activity is a quality factor influenced by storage and heating, therefore, an indicator of honey freshness and overheating. Diastase activity for honey from different regions in Kenya was determined and the results are given in Table 4.20.

Table 4. 20: Mean and range of diastase activity in honey from different regions of Kenya

	Diastase activity(DN)	
Region	**Mean ± SE**	**Min- max**
Rift Valley (n=80)	17.82 ± 1.45	1.14 - 76.73
Coast (n=40)	9.85 ± 0.48	3.07 - 17.20
Central (n=80)	13.97 ± 0.79	3.48 - 33.75
Eastern (n=117)	15.64 ± 0.39	5.27 - 27.56
Total (n=317)	**15.04 ± 0.46**	**1.14 - 76.73**

From Table 4.20, Coast region honey had the lowest mean diastase activity of 9.85 ± 0.48 DN with a variation of 3.07 – 17.20 DN. The highest mean diastase activity of 17.82 ± 1.45 DN with a variation of 1.14 – 76.73 DN was from Rift Valley region honey. The permitted mean minimum diastase activity limit for multifloral honeys is 8 DN (I.H.C, 2002). All the mean diastase activity shown in the table for all the regions investigated are above this limit, suggesting that most of the honey was fresh and multifloral. However, in all the regions, the minimum diastase activity for individual honey samples was found to be below the permitted limit.

The low diastase activity is indicative of maturity of the honey in which diastase enzyme had completed its work early enough, hence, showing low enzymatic concentration in the honey samples. This parameter is therefore more supportive of honey over storage than overheating. The low diastase activity, particularly shown by Coast honey, may be indicative of the contribution of unifloral honeys in which diastase activity is usually low. Since this parameter is time and heat dependent, it cannot be used to discriminate honey on the basis of their geographical or botanical origin. The variation in diastase activity for the four regions is shown in Figure 4.15.

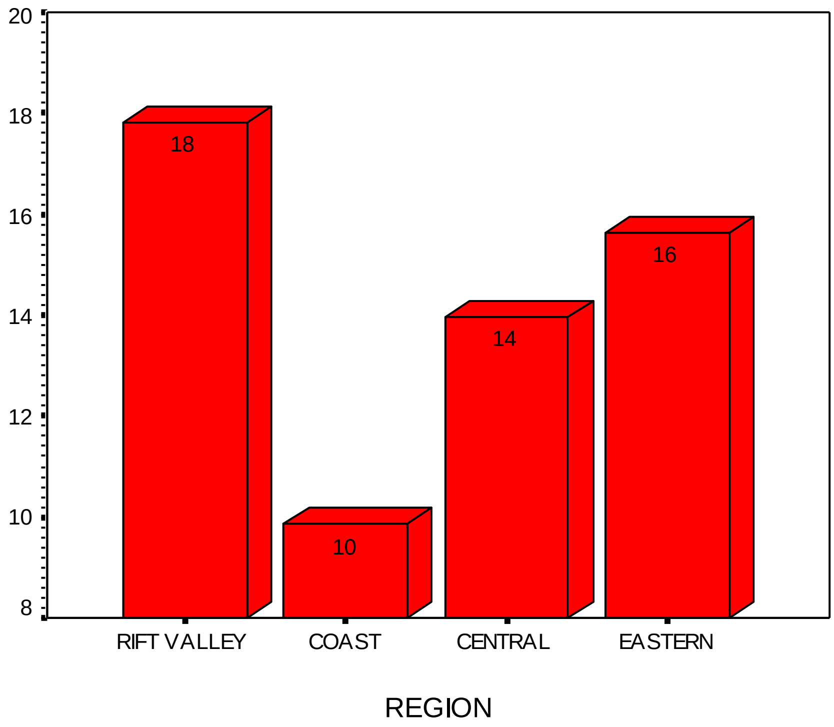


Figure 4. 13: Mean Diastase Activity for Each Region

From Figure 4.15, it is observed that Rift Valley region honey has the highest diastase number followed by Eastern, Central and lastly Coast region. This shows that honey from the Rift Valley was fresh as compared to the rest. However, honey from Coast region seems to have overstayed hence had less diastase enzyme concentration which gave low diastase number. P-value for diastase activity between the regions was 0.000. This is less than p = 0.05 level, showing that there is a significant difference in diastase activity between the regions under study, due to the maturity levels of the honey. Diastase activity is an enzymatic activity whose concentration decreases with the honey maturity. Therefore honey from different regions, with different maturity levels had varying diastase activity. This resulted to significant differences ($P<0.05$) between the mean values for different regions, indicating that most of the honey in Kenya is harvested in different seasons, when it is mature and is usually not heated after the harvest.

CHAPTER FIVE

5.0 EQUIPMENT DESIGN

5.1 Design Procedure

In the design of honey extraction and processing equipment, the design procedure followed involved the following steps: (Suryanarayana, O. 2003)

- **i.** Project definition
- **ii.** Preliminary design specification
- **iii.** Preliminary design, concepts and concept evaluation
- **iv.** Detailed design

5.1.1 Project Definition

This step involved a brief description of the honey processing equipment, stating how it works, its components and draw backs.

5.1.2 Preliminary Design Specifications

The specifications or the requirements which the designed equipment was to satisfy were stated. The specifications reflected the needs of the beekeeper and other honey processors. The preliminary specifications which were stated in broad terms were expanded to a quantitative form such as dimensions and cost. For example, the specification that the equipment should be affordable was translated to monetary cost of the equipment.

5.1.3 Development of Detailed Specifications, Concepts and Concepts Evaluation

The broad terms in the preliminary specifications were expanded and translated into measurable quantities such as volume, size, and dimensions (Max S. and Claus D. 1980, and

Suryanarayana, O. 2003) . The dimensions of both radial and tangential extractor vessels were determined by using the standard dimensions of the deep super frames. The manipulation of frame width, breadth and length gave the diameter and length of the extractor vessel. The dimensions of the honey processor, holding and settling tanks were determined by using the following formula:

$$\pi r^{2} h = m \times \frac{100\mathbf{o}}{\rho} \qquad [5.1]$$

Where; r = radius of vessel in cm, m = amount of honey in kg, ρ = density of honey in kg/cm^3, h = height of vessel in cm.

Based on the developed equipment dimensions, size and volume, three conceptual equipment and process designs were carried out. The three conceptual designs consisted of extractor, processor, holding and settling tank. During the conceptualization process, careful screening of the three conceptual designs was carried out and that which satisfied most of the preliminary requirements (specifications) was selected for detailed design.

5.1.4 Detailed Design

This step involved the establishment and determination of the broad requirements (specifications) that the selected process equipment should satisfy (Suryanarayana, O. 2003). These requirements included the determination of material and energy balance, honey processor capacity, heat transfer coefficient, heat transfer surface area, amount of heating medium requirement, time required for heating honey to target temperature, processor wall thickness and jacket cylinder wall thickness using theories and principles of pressure vessels design (Coulson, J. and Richardson J. 1983). The design of head covers, nozzles for both honey processor and jacket cylinder was also carried out in this step.

5.1.4.1 Material and Energy Balance

Material balance involving the amount of honey extracted and processed per day was carried out using the law of mass balance. Energy balance, which involved amount of heat required to raise a given amount of honey to target temperature was determined by the formula: (Suryanarayana, O.2003, Holman, J 1997).

$$q = MC\Delta T \qquad [5.2]$$

Where; M = mass of batch or honey, C = heat capacity of honey, ΔT = temperature difference.

5.1.4.2 Processor Capacity

The capacity or volume of the honey processor was determined by employing the amount of honey to be processed per day and honey density. Equation [5.1] was utilized for this purpose.

5.1.4.3 Amount of Heating Medium Required

The quantity of heating medium required to supply a given amount of heat was determined by employing the energy used (calculated as $MC\Delta T$) to heat honey to target temperature using the relation; (Warren, *et al.,* 2005)

$$MC\Delta T = M_1C_1\Delta T_3 \qquad [5.3]$$

Where; M_1 = amount of heating medium required (kg), C_1 = heat capacity of heating medium (kJ), ΔT_3 = temperature difference of heating medium.

5.1.4.4 Determination of Heat Transfer Coefficient

Heat transfer coefficient to be used in the calculation of heat transfer surface area and time required for heating honey was determined by utilizing the density, thermal conductivity, viscosity and heat capacity of honey, in the relation; (Nicholas, P. 2004).

$$\frac{UDi}{k} = a\left[\frac{L^2N\rho}{\mu}\right]^{\frac{2}{3}}\left[\frac{C\mu}{k}\right]^{\frac{1}{3}}\left[\frac{\mu b}{\mu w}\right]^{0.14} \quad [5.4]$$

Where; $U =$ The heat transfer coefficient , Di = diameter of vessel designed (m), L = diameter of agitator (m), N = speed of agitator in revolutions per hour, ρ = Density of fluid (honey) (kg/M^3), μ = Viscosity of honey in centpoise, C = Specific heat of honey (kJ/kg ºC), μb = Viscosity at bulk fluid temperature, μw = Viscosity at surface temperature

5.1.4.5 Determination of Heat Transfer Surface Area

The jacket surface area required to transfer a given amount of heat from the heating medium to the honey inside the vessel was determined by utilizing heat transfer coefficient, amount of heat to be transferred and the logarithmic mean temperature difference using the relation: (Max, S. and Klaus, D. 1980).

$$Q = U A \Delta TL \quad [5.5]$$

Where; Q = the amount of heat to be transferred, U = heat transfer coefficient, ΔTL = logarithmic mean temperature difference, A = heat transfer surface area.

Where ΔTL is given by: (Holman, J. 1997).

$$\Delta TL = \frac{\Delta T_2 - \Delta T_1}{\ln \frac{\Delta T_2}{\Delta T_1}} \quad [5.6]$$

Where; $\Delta T_1 = Tc_2 - Tc_1$ = lowest temperature of heating medium (Tc_2)- lowest temperature of honey (Tc_1), ΔT_2 = highest temperature of heating medium (Th_2) - highest temperature of honey (Th_1).

5.1.4.6 Determination of Heating Time Required

The time required for heating a given amount of honey to target temperature was determined by utilizing the predetermined heat transfer coefficient, heat transfer surface area and amount of heating medium using the relation :(Nicholas, P. 2004).

$$In\left(\frac{T^1 - t_1}{T_1 - t_2}\right) = \frac{W_h C_h}{Mc}\left(\frac{k_1 - 1}{k_1}\right)\theta \qquad [5.7]$$

Where; $k_1 = \ell^{uA/W_h C_h}$, T_1 = heating medium temperature t_1 = initial batch temperature, t_2 = final batch temperature, W_h = heating medium flow rate (kg/h), C_h = heating medium specific heat (kJ), A = heat transfer surface area (m^2), M = weight of honey, θ = time.

5.1.4.7 Determination of Processor Vessel and Jacket Wall Thickness

The minimum wall thickness required to resist the hydrostatic pressure of the honey in the vessel was determined by first obtaining the internal pressure of the vessel when full, using equation [2.5]. Utilizing the obtained internal pressure (p), minimum wall thickness (t) for the processor and jacket vessels were determined using the following equation: (Coulson, J. and Richardson, J. 1983).

$$\mathbf{t} = \frac{\mathbf{p \times D_i \times 10^3}}{\mathbf{2fj - p}} \qquad [5.8]$$

Where; t = wall thickness (mm), P = internal design pressure (N/mm^2), Di = internal diameter, J = joint efficiency, F = permissible design dress at operating temperature (N/mm^2).

5.1.4.8 Determination of External Critical Pressure

The processor designed is jacketed and therefore subjected to external pressure. The critical external pressure exerted on the vessel is determined using the wall thickness (t) of the vessel and its outside diameter (D^o) using equation [2.10] (Coulson, J. and Richardson, J. 1983).

$$\mathbf{Pc = \frac{2E}{1 - V^2}\left[\frac{t}{D^0}\right]^3}$$

Where; E = Young‘s modulus of elasticity, V^2 = poison’s ratio, t = wall thickness of vessel D^0 = outside diameter of vessel. The Pc obtained was used to calculate or determine the most appropriate processor wall thickness to avoid buckling.

5.1.4.9 Design of Head Cover

Three types of head covers designed were Flat, Ellipsoidal and Torispherical heads. The most appropriate cover in terms of cost and formation was fabricated for both the processor and jacket cylinder.

5.1.4.10 Design of Flat Head

The plate thickness of the flat cover to withstand the internal pressure of the vessel was obtained by analyzing the stresses in the flat plate that depends on the degree of constraint at the plate periphery. The internal design pressure, design stress and internal vessel diameter were used to determine plate thickness (t) using relation:

$$t = C_p D_e \sqrt{\frac{pi}{f}} \quad [5.9]$$

Where; C = a design constant, dependent on the edge or peripheral constraint

D_ℓ = nominal plate diameter, f = Design stress, p_i = internal design pressure. The design constant or peripheral constrains (C) for flat cover that is welded to the vessel shell was taken as 0.55 but those with flanged end utilize a constant of 0.45.

5.1.4.10.1 Design of Ellipsoidal cover

The minimum plate thickness for ellipsoidal head with a major and a minor axis ratio of 2:1 was determined by using relation:

$$t = \frac{piDi}{2fj - 0.2pi} \quad [5.10]$$

5.1.4.10.2 Design of Torispherical cover

The Torispherical end covers have two junctions, one between the cylindrical section and the head and the other between the crown and the knuckle radii. The differential dilation causing shear stress at these joints was determined by relation:

$$C_s = \frac{1}{3}\left[3 + \sqrt{\frac{R_c}{R_k}}\right] \quad [5.11]$$

Where; R_c = crown radius, R_k = knuckle radius, C_S = stress concentration factor.

The plate thickness of the torispherical cover was then determined by utilizing C_S in relation:

$$t = \frac{piR_cC_s}{2fj + pi}(C_s - 0.2) \quad [5.12]$$

5.1.4.11 Nozzle design and Reinforcement

Nozzles were welded around the holes made on the vessel walls. The stress concentration created near the holes was reduced by welding nozzle reinforcing material around the nozzle (holes). The minimum nozzle thickness required was determined by using the equation [2.16]:

$$t_n = \frac{p_i D_n}{2f_j - p_i} \quad [5.13]$$

Where; t_n = nozzle thickness (mm), P_i = internal design pressure of vessel (N/mm^2), D_n = diameter of nozzle (mm), f = design stress (N/mm^2).

5.2 Equipment Design and Construction

5.2.1 Introduction

Honey processing equipment usually consists of centrifugal extractors, presses, processors (warmer/pasteurizers), holding, settling and filtering tanks and packs. The extractors available in Kenya are honey presses, radial extractors with 12 or more honey comb frame holders and tangential extractors with 8 to 12 honey comb frame holders (ICIPE 2008). Because of the nature of their design (tangential and radial extractor), that is they have many frame holders, the extractor vessel used for extraction is big, and therefore expensive, apart from being imported also. Similarly, the processors available in the local market and the honey processing enterprises are big in size and also imported from outside the country. They are made of various types of stainless steel, with a capacity ranging from 200 - 300 litres and jacketed. During honey processing, the heat transfer medium in the jacket is electrically heated with a heating element. The majority of the processors are connected to the packaging machine by pipe connection through a pump making them expensive and requiring power which usually lacks in rural areas.

This equipment therefore is suitable for large quantities of honey production. Small scale beekeepers especially in rural areas who cannot afford the type of extractors available, usually extract their honey using presses or mashing methods. Honey extracted by this method has insect parts, wax debris, higher percentage of water insoluble and incomplete honey extraction (personal observation). This honey is then processed by using sufurias or pans on water bath. This process increases moisture content in honey as well as HMF, since temperature control is difficult. But honey extracted by centrifugal extractors using centrifugal force has less wax, insect parts and does not damage the honey comb. Complete extraction of honey from the combs is ensured using these types of extractors. The extracted honey is heated in a jacketed processor, allowed to settle and then filtered for packaging.

In this design work, the principles of extraction by centrifugation, indirect honey heating and gravitational filtration have been borrowed from the existing equipment and utilized in the design of new equipment. The design of both extractor and processor, which targets cost reduction and equipment suitability for small scale beekeepers, was modified to reduce their size. The equipment was designed by utilizing the honey comb frame dimensions as well as some of the results of the properties obtained from honey characterization such as density, pH, viscosity, moisture content and HMF. Thermal conductivity and specific heat capacity of honey were not determined in this work. However values of these parameters were obtained from the literature and utilized in this design.

During the designing of the equipment, honey density was used in the determination of the vessel capacity, internal pressure and heat transfer coefficient. Heat capacity of honey also determines heat transfer coefficient and the amount of energy required to raise the temperature of a given amount of honey to target temperature. Honey viscosity was used in determining heat transfer coefficient, choosing the method of honey extraction to be adopted (centrifugal extraction) and type of agitation required during processing. It was also used in determining heat transfer coefficient. Moisture content and HMF were considered in determining target temperature to which honey is raised during processing. The pH was used as a criterion of selecting the material for construction of the designed equipment.

5.2.2 Preliminary Design

In designing the equipment, two principles were borrowed from the existing honey extraction and processing equipment. They include the extraction of honey from combs using a centrifugal force and indirect heating of honey using a heat transfer medium (water) in a jacket. Using these principles, an extractor (cylindrical vessel) was designed consisting of the honey comb frame holders attached to the central shaft which effects rotation throwing honey against the vessel by a centrifugal force. The honey frame holders (shown in the sketch drawing below) to hold the honey comb frames during extraction were designed using the dimensions of the super frame (Figure 5.1). A honey processor with a jacket provision was also designed to accommodate water for indirect heating of honey.

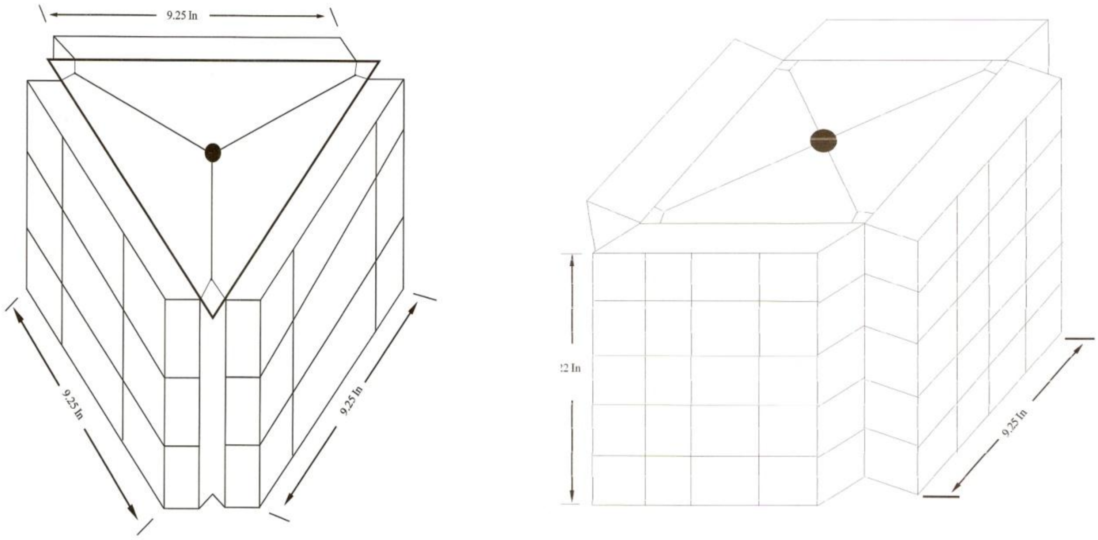


Figure 5. 1: Sketch drawing of triangular and square frame holders

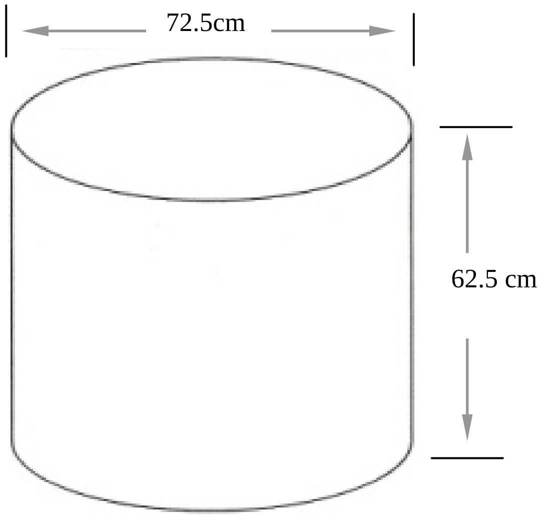
In the preliminary design, the dimensions of the honey comb frames, particularly the deep super frame (Figure 5.2) were used to determine the size of the extractors. Two types of the extractors were designed; radial and tangential. The dimensions of the deep super frame are 19" long, $9\frac{1}{4}$ " breadth and $1\frac{1}{8}$ “width (47.5 x 23 x2.8 cm).

Figure 5. 2: Deep super honey comb frame

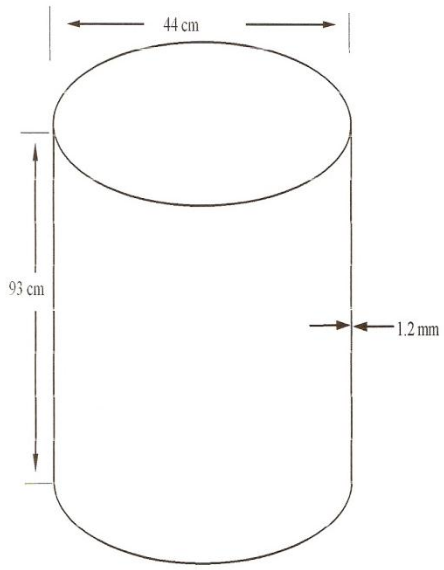
The length (19") was used to fix the height of the extractors while the breadth fixed the diameter. The heights of the processor, settling and holding tanks designed depend on production capacity required. An average beekeeper or small businessman can extract 200 kg of honey and process on average 120 kg per day. Tangential extractor radius, honey density and amount of honey to be processed were substituted in equation [5.2] to determine the height and capacity of processor, holding and settling tanks. The resulting dimensions of these vessels are given in Table 5.1 below; along with their sketch diagrams.

Table 5. 1: The determined dimensions (diameter, height and capacity) of honey processing vessels

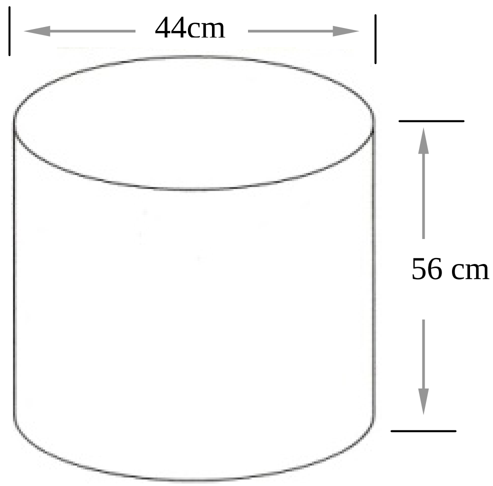
Vessels	**Diameter (cm)**	**Height (cm)**	**Capacity (cm^3)**
Radial extractor	72.50	62.50	258,016
Tangential extractor	44.00	56.00	85,150
Processor	44.00	56.00	85,150
Holding tank	44.00	93.00	141,409
Settling tank	44.00	56.00	85,150



Radial extractor



Holding tank



Processor

Figure 5. 3: Processor, tangential extractor and settling tank have the same dimensions

The processor designed is to be provided with a jacket to carry the heat transfer medium (water) for indirect heating of honey in the processor, The dimensions and capacity of the jacket vessel were determined by utilizing the total volume of processor and heating medium as well as jacket spacing and heater nut allowance (for fixing heating element). For this design, we intend to use 35 litres of heating medium in a jacket spacing of 3.00 cm which makes the diameter of the jacket vessel to be 6 cm more than that of the processor (i.e. jacket vessel diameter = 50 cm)

Volume of jacket vessel = Volume of processor (85150 cm^3) + Volume of water (35000 cm^3) = 120150 cm^3

Equating this jacket volume with equation [5.1] and substituting r with 25 cm jacket radius, 61 cm jacket height was obtained to which 5 cm was added for heater nut allowance, making the total height to be 66 cm. The following are the design sketch drawing of the jacket vessel and jacketed processor.

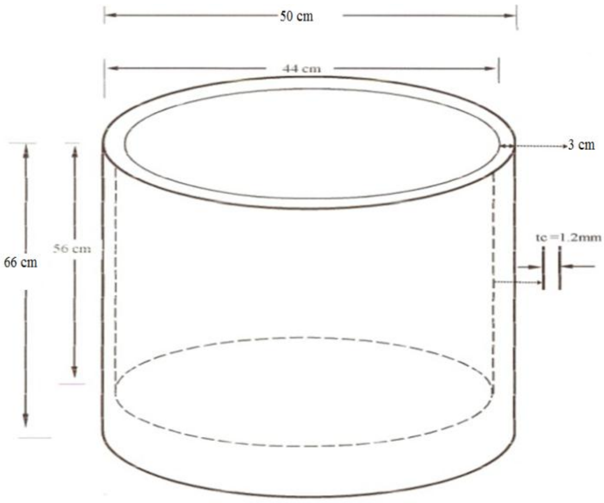


Figure 5. 4: Jacketed processor

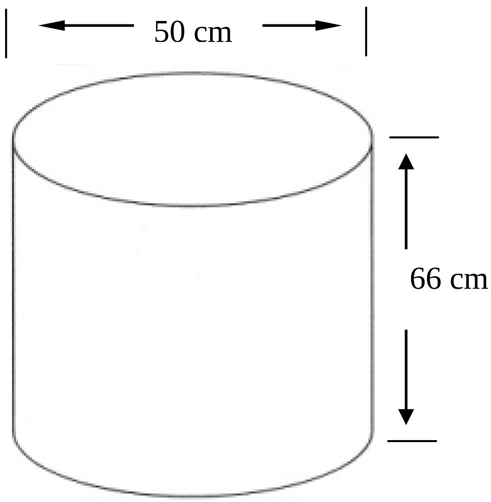


Figure 5. 5: Jacket vessel

For the purpose of selecting the optimized design to undergo detailed design, the preliminary design equipment was put into three conceptualized design assembly arrangement in the order of their operation, starting from the honey extractor, holding tank, processor and settling tank. From these, it was decided to use an assembly of combined extractor, processor and settling tank which is cost optimized and is shown in Figure 5.6

This is a single unit processor where all the honey processing operations are carried out.

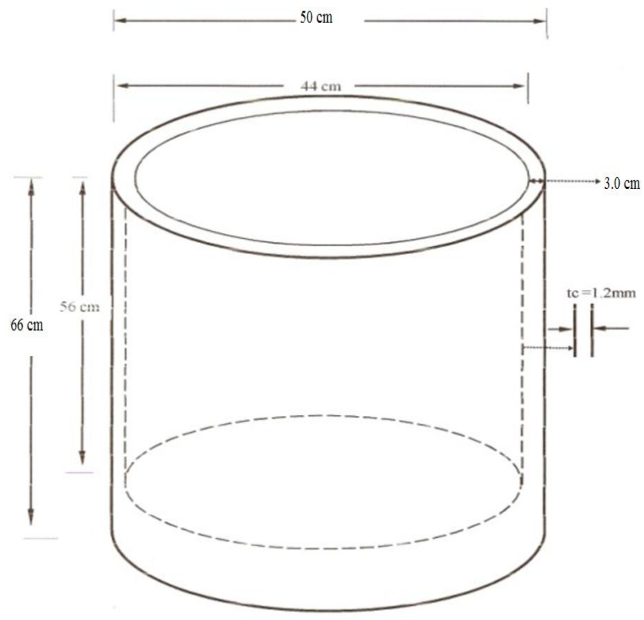


Figure 5. 6: A combined extractor, processor and settling tank.

5.2.3 Detailed Design

The conceptual design selected for detailed design is the combined honey extractor and processor assembly, which will also act as a settling and filtering tank. All the operations of honey extraction, processing, settling and filtering which could have been done by using four different equipment will now be carried out in this one unit equipment (the combined honey extractor and processor assembly). The equipment designed and constructed, will extract honey from honey combs in frames by a centrifugal force, and process it by indirect heating through a heat transfer medium and settling and filtering in the same unit for packaging.

5.2.3.1 Energy Balance

Energy balance in this design involves the amount of heat required to raise the temperature of 120 kg honey from 25 ^{o}C to 50 ^{o}C (set temperature at which all the crystals will have dissolved) using equation [2.3], and was found to be 7500 kJ. This amount was then used in determining the quantity of heat transfer medium required and also heat transfer surface area.

5.2.3.2 Amount of Heating Medium Required

The amount of heating medium required to raise the temperature of 120 kg honey from 25 °C to 50 °C while maintaining a temperature difference of 10 °C above the required temperature is given by:

$MC\Delta T = M_1 C\Delta T_3$; where; C = 4.18 kJ/kg of water, $\Delta T_3 = T_2 - T_1 = 60\ ^{C} - 25$ °C and

$MC\Delta T = 7500$ kJ

$7500 \text{ kJ} = M_1 \times 4.18 \times 35$

$M_1 = 51.26$ kg

Considering sensible heat absorbed by the processor during heating, the amount of heating medium required will be more than the calculated 51 litres of water. The heat absorbed by the equipment (sensible heat) was determined using stainless steel heat capacity ($C_s = 0.5$ kJ/kg °C), weight of processor ($M_s = 24.109$ kg), temperature difference ($\Delta T = 25$ °C) in the equation $M_s C_s \Delta T$. Therefore heat absorbed by the equipment;

$$M_s C_s \Delta T = 24.109 \times 0.5 \times 25 = 301.36 \text{ kJ}$$

The amount of heat now required (including sensible heat) to heat the processor with honey to 50 °C will be 7500 kJ + 301.36 kJ = 7801.36 kJ. Therefore, amount of heating medium (M_2) to supply this energy was determined from the following relation;

$$7801.36 \text{ kJ} = M_2\ C\Delta T_3$$

Where; C = 4.18 kJ/kg °C of water and $\Delta T_3 = T_2 - T_1 = 60\ ^{C} - 25$ °C

Therefore, $7801.36 \text{ kJ} = M_2 \times 4.18 \times 35$

$M_2 = 53.32$ litres of heating medium (water)

The total amount of heat to be absorbed by the system in order to raise the temperature of the batch to 50 ºC and that of the heating medium to 60 ºC from 25 ºC is twice 7801.36 kJ giving

15602.72 kJ.

If the heating medium (water) is heated externally, as will be the case in rural areas where there is no electrical power, and then poured into the jacket to heat the honey in the vessel, the temperature (T_4) to which it will be raised from 25 °C in order to absorb 15602.72 kJ was calculated from the relation: $M_2C\Delta Ta$ = 15602.72 kJ, where; $\Delta T_4 = T_a + T_1$

$$\text{Hence } \Delta T_a = 15602.\frac{72}{M_2C} = 15602.\frac{72}{53.32 \times 4.18} = 70\,^0c$$

Since T_1 = 25 °C, then; T_4 = 70 °C + 25 °C = 95 °C

Therefore, 53.32 kg of jacket water will have to be heated externally to 95 °C in order to raise the honey temperature to 50 °C.

5.2.3.3 Heat Transfer Coefficient

Heat transfer coefficient, which is used in the determination of surface area needed for effective heat transmission depends on the diameter of vessel, speed and diameter of agitator, honey's thermal conductivity, viscosity, density and heat capacity. The diameter of the vessel is 44 cm (0.44 m). The propeller-type of agitator with a speed of 120 rpm (used for stirring liquids of moderate viscosity), whose diameter is 30% of that of the vessel, will be used. Therefore, agitator diameter (L) and speed (N) in revolutions per hour determined are 0.15 m and 120 rph respectively. Honey density (ρ), viscosity (μ) and specific heat capacity (C) which were determined in the physicochemical parameters are 1410 kg/m^3, 4300 centipoises (average viscosity at 30 °C for all regions (Table 4.4) and 2.5 kj/kg°C respectively. In the determination of heat transfer coefficient, the above parameters were substituted in equation [5.4] as shown. (Nicholas, P. 2004).

$$\frac{UDi}{k} = a\left[\frac{L^2N\rho}{\mu}\right]^{\frac{2}{3}}\left[\frac{C\mu}{k}\right]^{\frac{1}{3}}\left[\frac{\mu b}{\mu w}\right]^{0}.14$$

Therefore $$U = \left(\frac{k}{Di}\right) \times a \left(\frac{L^2 N \rho}{\mu}\right)^{\frac{2}{3}} \left(\frac{c\mu}{k}\right)^{\frac{1}{3}} \left(\frac{\mu b}{\mu \omega}\right)^{0.14}$$

$$U = 0.67\ (0.225 \text{ x } 2360.93)^{2/3}\ (19.688 \text{ x } 64469)^{1/3} = 255.63 \text{ W/m}^2\text{K}$$

Utilising the calculated heat transfer coefficient (U = 255.63 W/m^{2}K), minimum surface area (A) required to transfer effectively 7500 kJ heat energy into 120 kg of honey in the vessel was determined.

5.2.3.4 Heat Transfer Surface Area

Heat transfer surface area (A) which is also used in the determination of the time required to heat honey from 25 °C to 50 °C was determined by using equation [5.5] as follows;

$$q = UA\Delta TL; \quad \text{where } q = 7500\text{kJ},\ U = 255.63 \text{ w/m}^2\text{k},\ \Delta TL = 39.80\ °C$$

Therefore, $$A = \frac{q}{U\Delta TL} = \frac{7500}{255.63 \text{ X } 39.7°C} = 0.7373 \text{ m}^2$$

The area was then used in determining time required for heating honey.

5.2.3.5 Time Required for Heating

The time required to heat 120 kg of honey in the designed vessel, from 25 °C to 50 °C , was determined with the help of the predetermined heating medium temperature (95 °C), heat transfer surface area (0.7373 m^2) and heat coefficient of 225.63 w/m^2 by using equation [5.7] as follows; (Nicholas, P. 2004).

$$\ln\left[\frac{T_1 - t}{T_1 - t_2}\right] = \frac{W_h C_h}{Mc}\left[\frac{k_1 - L}{k}\right]\theta$$

Where; $k_1 = \ell^{uA/W_h C_h}$, $T_1 = 95\ ^oC$, $t_1 = 25\ ^oC$, $t_2 = 50\ ^oC$, $W_h = 51.26$ kg/h , $C_h = 4.18$kg

M = 120 kg, A = 0.737 m^2, θ = time

$$Therefore;\ in\left(\frac{95 - 25}{95 - 50}\right) = \left(\frac{51.26}{120 \times 2.5}\right) \text{In}\left(\frac{95 - 25}{95 - 50}\right) = \left(\frac{51.26 \times 4.18}{120 \times 2.5}\right)\left(\frac{k_1 - 1}{k_1}\right)\theta$$

$$0.4418 = 0.71422 \textbf{ X } \left(\frac{k_1 - 1}{k_2}\right)\theta$$

$$k_1 = \ell^{UA/w_h C_h} = \ell^{(255.63 \times 0.737)/(51.26 \times 4.18)}$$

$$\ell^{0.87927} = 2.40915$$

Therefore, $$0.4418 = 0.71422 \text{ X } \left(\frac{2.40915 - 1}{2}.40915\right)\theta$$

$$(= 1hr$$

A time of 1 hour is required to raise the temperature of 120 kg honey in the processor from 25 °C to 50 °C using 51 kg of water at 95 °C initial temperature.

5.2.3.6 Minimum Wall Thickness

The vessels designed will be subjected to heat and hydrostatic pressure of both honey and water (heating medium). To be able to support the hydrostatic pressure, its own height and also transmit heat effectively, a certain minimum wall thickness of the vessel is needed.

5.2.3.7 Minimum Wall Thickness of Processor, Jacket Vessel, Heads and Nozzles

In the determination of the minimum wall thickness of the processor vessel, the internal or hydrostatic pressure exerted by honey on the vessel is used and therefore was calculated first. Equation [2.3] was used for this purpose;

$$p = \rho (H - 0.3) \times 10^2$$

Where; ρ = 0.00141 kg/cm^2 and H = 0.56 m, P = 0.00141 (0.56 – 0.3) x 10^2 = 0.03666 kg/cm^2

0.03666 kg/cm^2 is the operating internal pressure, but design pressure is 10 percent above operating pressure, which becomes 0.40326 kg/cm^2

Or $$P = 0.40326 \times 10/10 \times 10 \text{ N/mm}^2 = 0.004 \text{ N/mm}^2$$

In the determination of the shell thickness for the processor, jacket vessel, flat head, torishperical head, ellipsoidal head and nozzle, the physical constants used were design pressure (p) = 0.004 N/mm^2, design stress (f) = 150 N/mm^2, joint efficiency (j) = 1, diameter of vessel Di (Rc) = 0.44 m, stress concentration factor (Cs) = 0.45. Using the standard equation of pressure vessel design [5.8], [5.9], [5.10], [5.12], [2.16] and substituting the physical constants, the wall thickness of the above vessels, heads and nozzle determined are given in the following table.

Table 5. 2: Presenting the determined wall thickness of some parts of the equipment

Item	**Wall thickness (t) mm**
Processor	1
Jacket vessel	1
Flat head	1.5
Torispherical	0.5
Ellipsoidal	0.5
Nozzle	1.5

The sketch drawings of the heads whose wall thickness have been determined are shown below

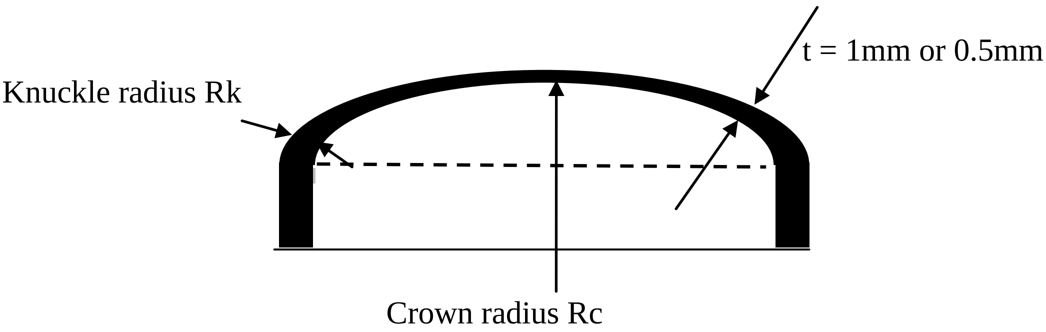


Figure 5. 7: Sketch drawing of torispherical head

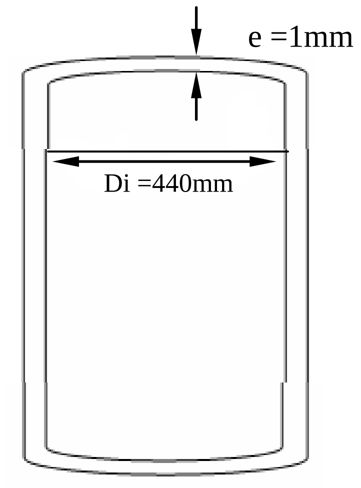


Figure 5. 8: Sketch drawing of flat head

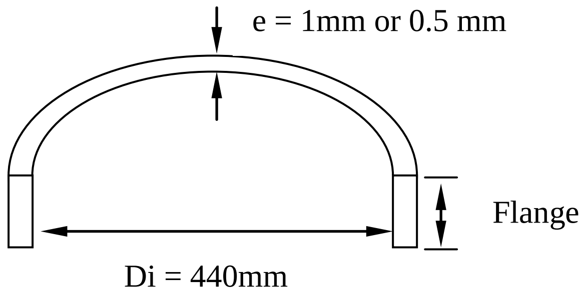


Figure 5. 9: Sketch drawing of ellipsoidal head

5.2.3.9 Design and Assembly of the Equipment Components

The complete design of the equipment consisted of the designed equipment components assembled to give parts which in turn were assembled forming the equipment. The components designed included frame cage, gears, channel, bearing housing, mountings, main shaft, drive shaft, bush bearings, drive mounting bracket, stands, water inlet spout, stiffener and cage link bars, heater nut and handle pipe. All the components designed were either machined or fabricated from stainless steel or nylon. The components were then assembled into parts such as cage assembly, drive shaft assembly, handle assembly and vessel assembly. The parts were eventually assembled to give one unit, the extractor warmer (processor) assembly.

The design drawings of the equipment components, vessels, and their assemblies and specifications are as given below. The channel onto which the drive assembly is anchored was designed a length of 562.40 mm, breadth 77 mm width of 2.0 m, with a 22 mm central bore diameter. It was given 15 mm, 90^{o} forward bend at both sides of the length. Its design drawing is given below.

Apart from the vessel dimensions, material and energy balance, heat transfer surface area, time required for heating and amount of heating medium already determined in this design, the complete design of the extractor warmer equipment consists of the designed equipment components. The designed components include handle bush, handle pipe, drive shaft, bevel gear driver, drive mounting bracket, water inlet spout, sight glass mounting, vessel, bearing bush, vessel bush, vessel stand, heater nut, bevel gear driven, frame cage, stiffener bar, main shaft, honey frame support, cage link bar, Y bearing mounting, bearing housing and channel. All these components were made from stainless steel apart from bevel gears and bearing bush which were made from nylon. The designed components were assembled into parts, which in turn were also assembled to give the final extractor warmer assembly design.

5.2.3.10 Extractor-warmer Assembly

The extractor warmer assembly which is the final equipment design assembly, shown in Figure 5.12, is made five main design assemblies as indicated in the figure and discussed in the following subsections.

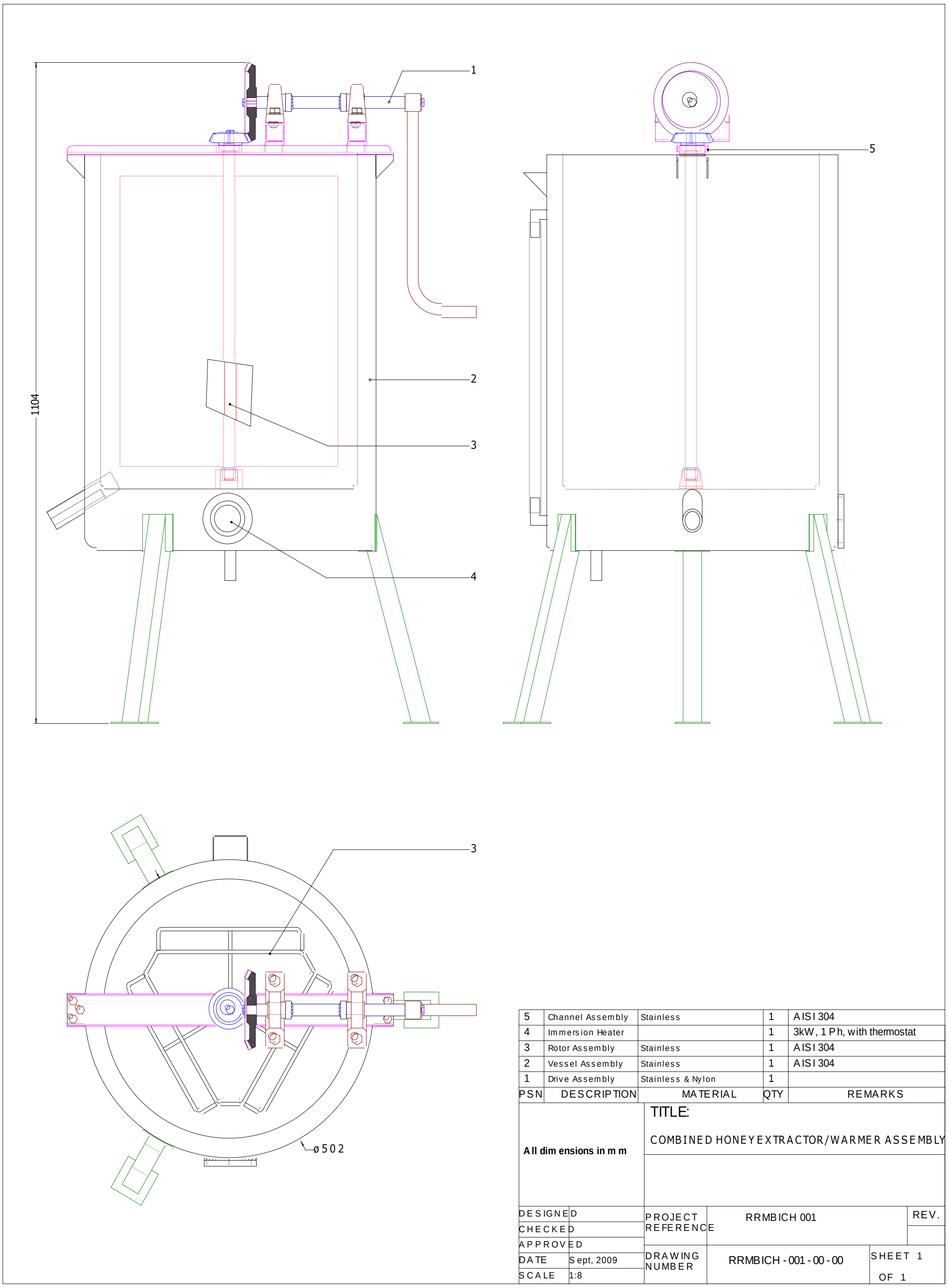


Figure 5. 10: Extractor-warmer Assembly

The designed parts assemblies forming on the extractor warmer assembly as indicated in Figure 5.12 are discussed below in the order of their numbers along with their design components

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5.2.3.10.1 Drive Assembly

The drive assembly design drawing shown in Figure 5.13 as labelled consists of the designed 1. Handle bush, 2. Handle assembly, 3. Drive shaft, 4. Y-bearing and 5. Bevel gear driver.

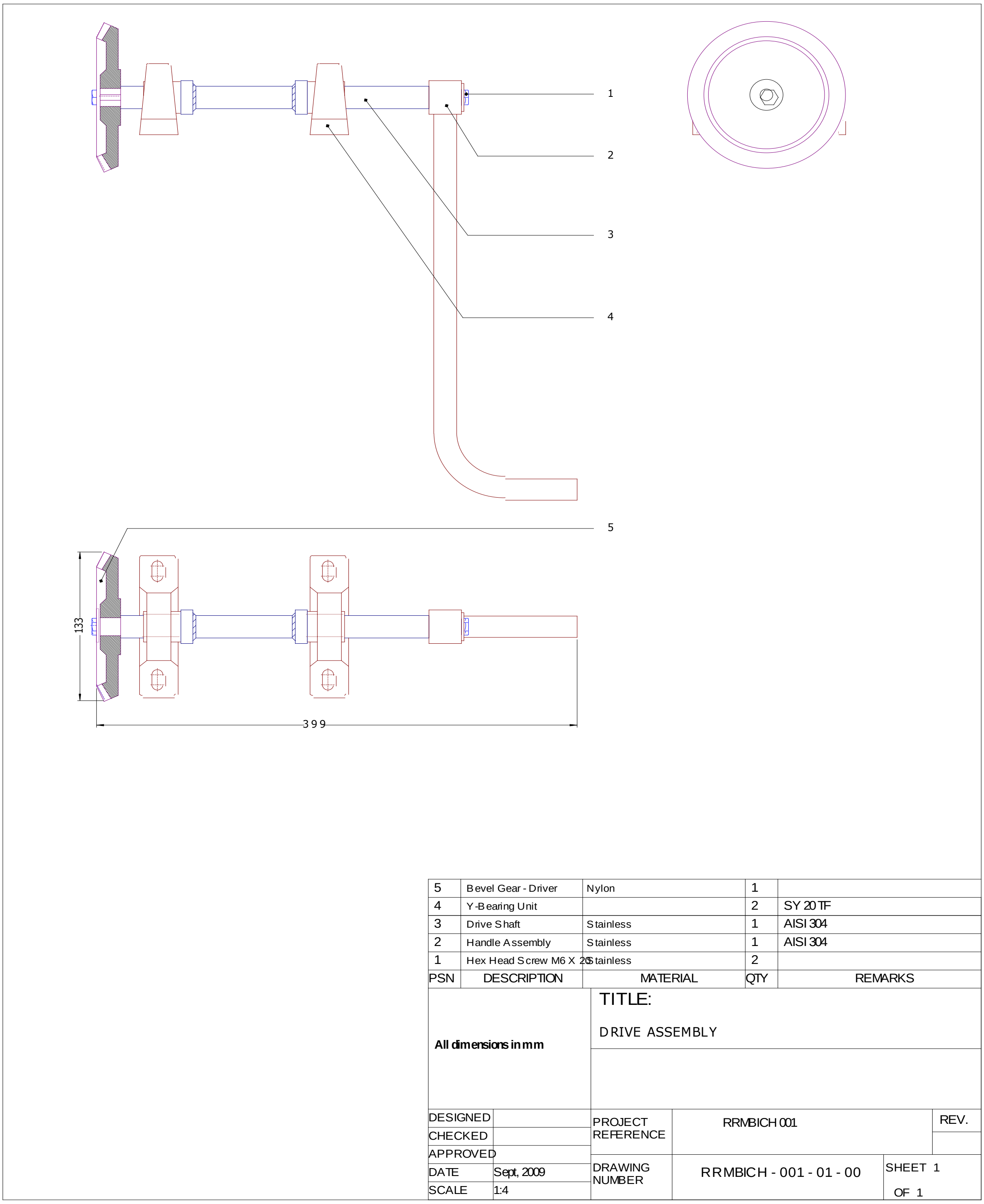


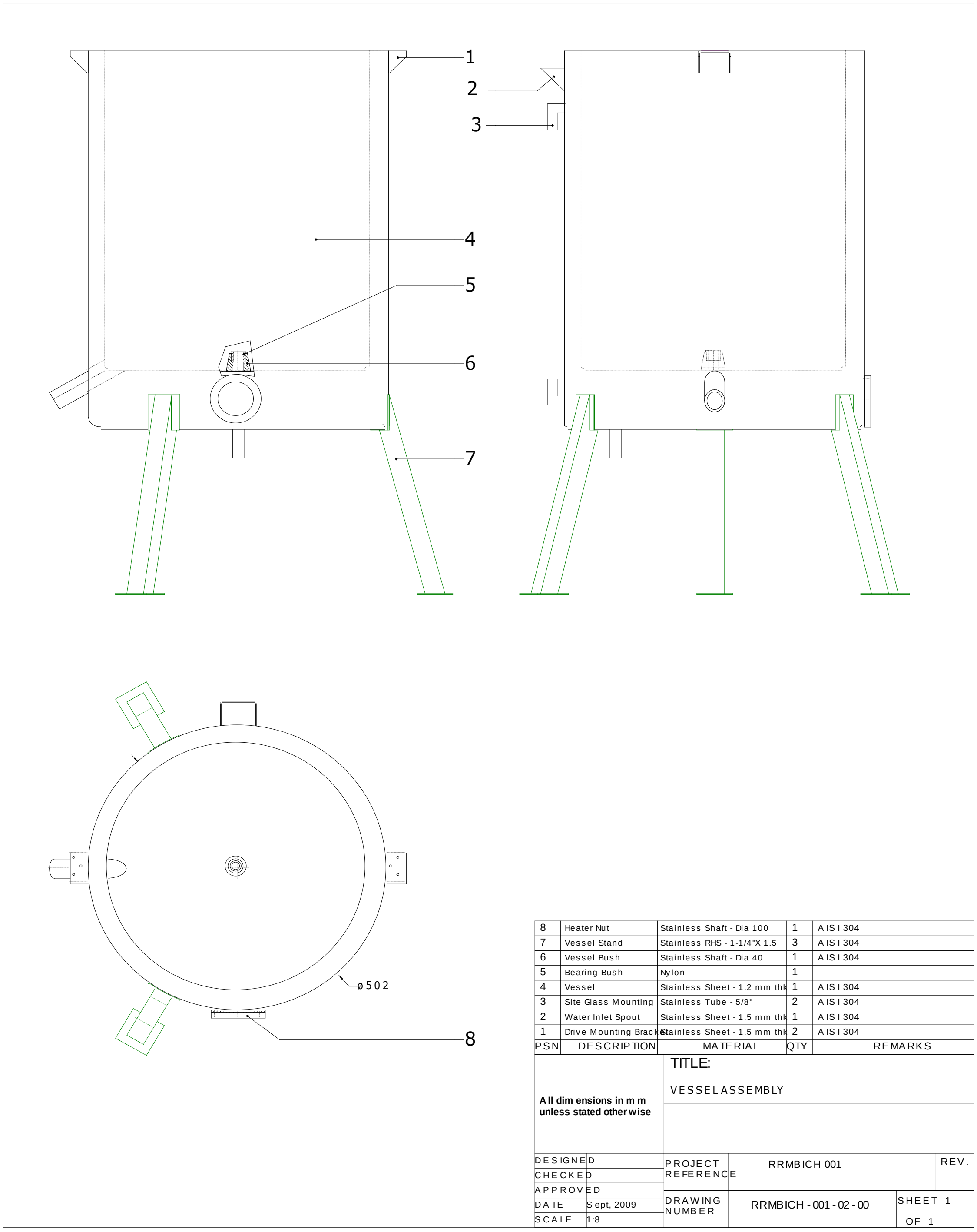
Figure 5. 11: Drive Assembly

The handle bush which connects the handle pipe and the drive shaft was designed to 30 mm (3 cm) diameter, 27 mm (2.7 cm) length and machined to a square hole of 14.4 mm. Its design drawing is indicated in Appendix 2A

A handle pipe (Appendix 2B) for rotating the drive shaft during extraction and mixing, was designed to a length of 430 mm (43 cm), 19 mm diameter and was give a bend at a length of 100 mm (10 cm) to an angle of 90^0 for easy handle operation. The drive shaft (Appendix 2C), which is to drive the bevel, was designed to a length of 300 mm (30 cm) and 30 mm (3.0 cm) diameter. It was then machined to 16 mm diameter on one end and 14.1 mm square on the other, to fit into the bevel gear drive with centre bore 16 mm diameter (Appendix 2D) and handle bush of 14.1 mm square bore (Appendix 2A) respectively.

5.2.3.10.2 Vessel Assembly

The vessel assembly design shown in Figure 5.12 below, as labelled, consists of 1. Drive mounting bracket, 2. Water inlet spout, 3. Sight glass mounting, 4. Vessel, 5. Bearing bush, 6. Vessel bush, 7. Vessel stand and 8. Heater nut.



PSN	DESCRIPTION	MATERIAL	QTY	REMARKS
8	Heater Nut	Stainless Shaft - Dia 100	1	AISI 304
7	Vessel Stand	Stainless RHS - 1-1/4"X 1.5	3	AISI 304
6	Vessel Bush	Stainless Shaft - Dia 40	1	AISI 304
5	Bearing Bush	Nylon	1	
4	Vessel	Stainless Sheet - 1.2 mm thk	1	AISI 304
3	Site Glass Mounting	Stainless Tube - 5/8"	2	AISI 304
2	Water Inlet Spout	Stainless Sheet - 1.5 mm thk	1	AISI 304
1	Drive Mounting Bracket	Stainless Sheet - 1.5 mm thk	2	AISI 304

Figure 5. 12: Vessel Assembly

A drive mounting bracket 54 mm by 30 mm (Appendix 3A) onto which the drive shaft is firmly anchored was designed and machined from a sheet of 1.5 mm thickness, 120 mm length and 30 mm breadth. The designed mounting was given a 90 degree forward bend on either side at a distance of 34.50 mm to form a bracket. Four bores of diameter 8.5 mm for bolting were drilled on the mounting.

The water inlet spout, (Appendix 3B) of 600 mm by 56.50 mm by 40 mm through which water is poured into the jacket was designed and machined from a 1.2 mm sheet thickness and 115.6 mm long and welded onto the upper part of the vessel at an angle of 45^0 as indicated in Figure 5.12.

The sight glass mounting (Appendix 3C) onto which the sight glass is mounted for monitoring of the jacket water level, was designed, machined and then welded on the nozzles bored at the top and bottom of the jacket vessel as indicated in Figure 5.12 label 3. The nozzle was 75.2 mm long including the bent part with a diameter of 16 mm (5/8$''$).

Two vessels, processor (warmer) and jacket vessels (Appendix 3D), were designed and fabricated. The processor (inner vessel) was designed to a height of 561.20 (56 cm), 438 (44 cm) diameter and 1.2 mm wall thickness while the jacket design which is the outer vessel had has 661.20 mm (66 cm) height, 502 mm (50 cm) diameter with a shell thickness of 1.2 mm.

The bearing bush which holds and offers easy rotation for the main shaft at the base of the vessel (Figure 5.12) was designed with upper and lower diameter of 25 mm and 23 mm respectively, with a central bore of 1.5.5 mm diameter to fit the lower diameter (15 mm) of the main shaft (Appendix 3). The design drawing of the bearing bush is given in Appendix 3E.

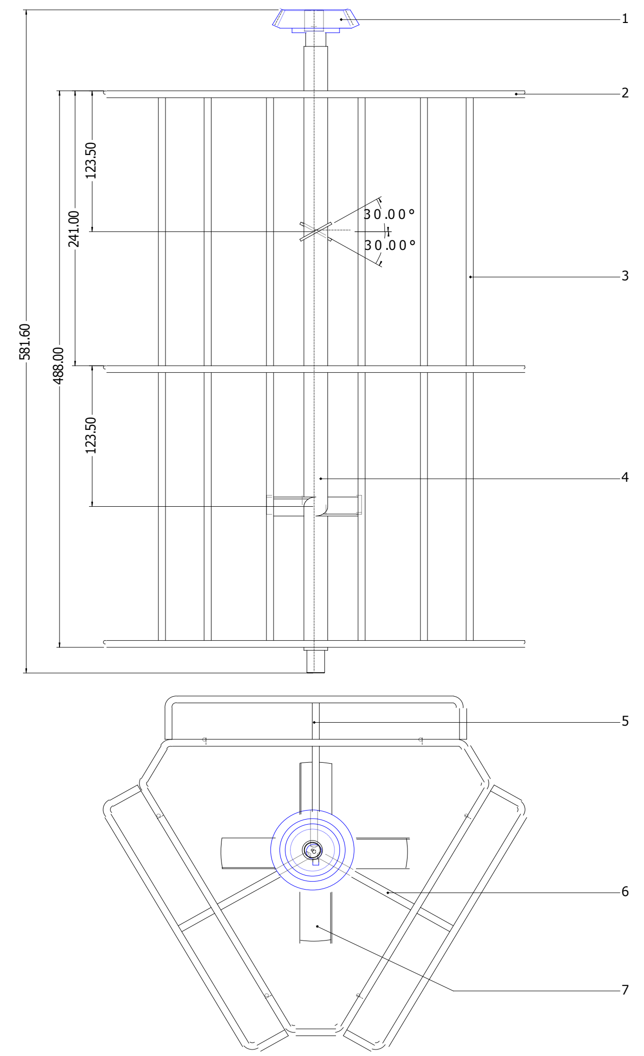
A 31 mm vessel bush, welded to the central position of the processor base to hold the bush bearing (Figure 5.12 label 5) and main shaft in place was designed and machined to upper and lower diameters of 30 mm and 40 mm respectively with a bore diameter of 23 mm and 18 mm (Appendix 3F).

Three stands to support the vessel and give it a firm stand as well as providing a comfortable equipment height for operation were designed and welded to the vessel (Figure 5.12 label 7). The stands were designed from a hollow square tube, 32 mm by 32 mm with a length of 360 mm. They were cut and machined to 90 and 75 degrees for firm and efficient welding. The design drawing of this component is shown in Appendix 3H

The heater nut (Figure 5.12 label 8) with 90 mm and 66.6 mm outer and inner diameter respectively, onto which 3 kw heater to heat the heat transfer medium in the jacket is fixed, was designed, milled and welded onto the jacket vessel. Its design drawing is indicated in Appendix 3H.

5.2.3.10.3 Triangular Rotor Assembly

This design assembly as labeled consists of 1. Bevel gear driven, 2. Frame cage (honey frame holder), 3. Stiffener bar, 4. Main shaft, 5. Honey frame support, 6. Cage link bar and 7. Mix blade.



PSN	DESCRIPTION	MATERIAL	QTY	REMARKS
7	Mixer Blade	Stainless Flat - 70 x 30 x 2 mm	4	AISI 304
6	Cage-Shaft Link	Stainless Rod - 6 mm Dia.	6	AISI 304
5	Honey Frame Support	Stainless Rod - 6 mm Dia.	3	AISI 304
4	Main Shaft	Stainless Shaft - 20 mm Dia.	1	AISI 304
3	Stiffener Bar	Stainless Rod - 6 mm Dia.	12	AISI 304
2	Frame Cage	Stainless Rod - 6 mm Dia.	3	AISI 304
1	Bevel Gear - Driven	Nylon	1	

All dimensions in mm unless stated otherwise

TITLE:

ROTOR ASSEMBLY

DESIGNED		PROJECT REFERENCE	RRMBICH 001	REV.
CHECKED				
APPROVED				
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 03 - 00	SHEET 1 OF 1
SCALE	1:5			

Figure 5. 13: Rotor Assembly

The bevel gear driven is rotated by bevel gear driver (Figure 5.13 label 1) in order to rotate the main shaft together with the frame cage (Figure 5.13 labels 2 and 4) during honey extraction, was designed. The design component had 73.2 mm outer diameter, 16 mm central bore diameter with 22 gear teeth (Appendix 4A). A single complete revolution of the bevel gear driver, gives the bevel gear driven three revolutions. This means that a single rotation of the drive shaft in Figure 5.13 effects three rotations on the main shaft (Figure 5.13), hence the speed of the extractor.

The triangular frame cage (honey frame holder) to hold the honey comb frames during extraction, was designed from a rod of 6.0 mm diameter with a length of 254.0 mm, 32 mm breadth, bent at 90^0 and fabricated (Appendix 4B). The cage was stiffened by using stiffener bar (Figure 5.13 label 3), welded onto the cage and honey frame support. A cage link bar 93.80 mm long with 6.0 mm diameter to connect the frame cage to the main shaft was also designed (Appendix 4F).

The main shaft to rotate the frame cage (honey frame holder) during extraction was designed to a length of 580 mm and 20 mm (Appendix 4D). The upper and lower ends were machined to a diameter of 16 mm and 15 mm to fit into the bevel gear driven (Figure 5.13 label 1) and the vessel bush (Figure 5.12 label 5) respectively. The main shaft also acts as a mixer (agitator) on which four mixer blades of length 70 mm, breadth 30 mm having plate thickness of 2 mm (Figure 5.13 label 7) were welded at an angle of 30^0 for efficient mixing.

5.2.3.10.4 Channel Assembly

Channel assembly shown below on which the drive assembly and rotor assembly are anchored, consists of the channel, Y-bearing mounting and bearing housing.

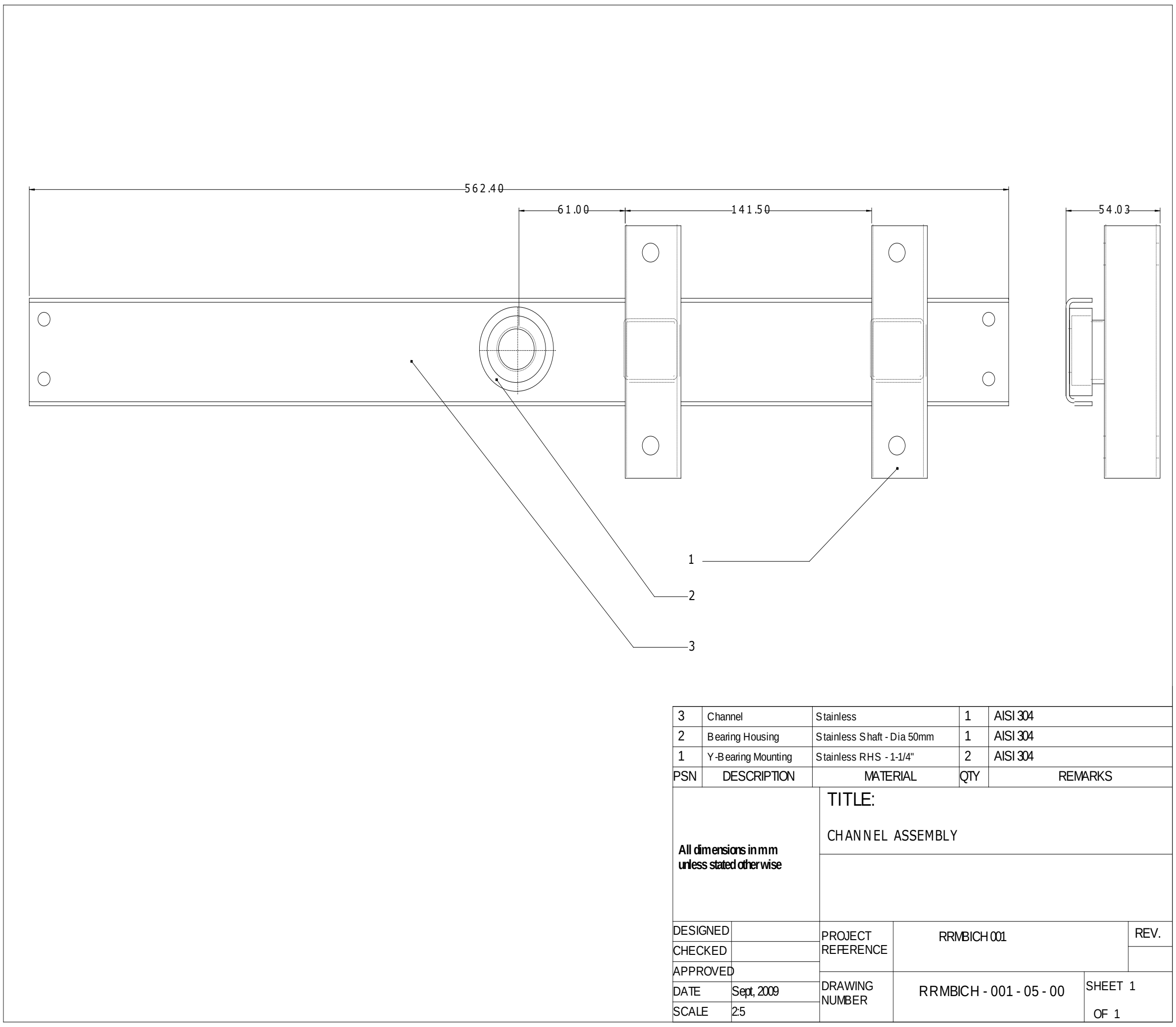


Figure 5. 14: Channel Assembly

Y-bearing mounting used for mounting the plummer bearing on the channel was designed with a length of 127 mm, breadth 32 mm and bored to 11 mm diameter at 15 mm distance from either end (Appendix 5A). A bearing housing for keeping the main shaft bearings in place was designed and machined. The outside diameter was 44 mm, with outer and inner race diameters being 35 mm and 22 mm respectively (Appendix 5B).

A channel of length 562.40 mm, breadth 77 mm, wall thickness of 2.0 mm, with a 22 mm central bore diameter was designed. It was given a 15 mm 90^0 bend on both sides of the length to form a channel shape (Appendix 5C).

All the assemblies and components discussed above were made by welding, fixing or bolting. Finishing on the assembled equipment was carried out by grinding, filing, sanding, bickling and buffing. The machine was then fitted with the 3 kW heater and tested for the minimum rotational speed as well as heating. The machine passed the minimum (60 rpm) honey extraction rotational speed and also heated jacket water to the required 60 °C temperature.

The heating system of the constructed equipment was tested using water in the processor in place of honey. For fast heating of water in the processor, 39 litres of water was used instead of 35 litres as per calculations. 39 litres of water covers the jacket up to the water filling opening, ensuring maximum heat transfer both during electric power heating and also when using externally heated water. 80 litres of water was used in the processor instead of the 85 litre capacity so as to allow space for continuous stirring since water is less viscous than honey. Two tests were carried out. The first involved heating water in the jacket using electrical power through an element while in the second test, water was heated externally and then poured into the jacket manually for onward heat transmission.

In the first test, 80 and 39 litres of water at 25 °C were put into the processor (in place of honey) and the jacket respectively and heating initiated. After 1 hour and 20 minutes, the 80 litre water in the processor had attained 50 °C target temperature. Jacket water (heating medium) temperature had increased to 55 °C having a temperature gradient of 5 °C. At this temperature, electrical power was put off and the system was left intact (without draining either jacket or processor water) in order to observe the extent of heat loss by radiation after some time. After 12 hours, the processor water temperature had dropped to 45 °C. The small drop in temperature after 12 hours means that heat loss by radiation from the surface of the equipment is minimal because of its polished surface.

In the second test, 39 litres of water heated externally to 95 °C, was poured into the jacket to heat 80 litres of water (at 25 °C) in the processor. After 50 minutes, the processor water temperature had attained 45 °C and jacket water 52 °C. Ten minutes later, both jacket and processor temperature had equilibrated at 46 °C. To raise the processor temperature to 50 °C, 15 litres of heating medium (water) in the jacket had to be drained and replaced with the same quantity at 95 °C. After 15 minutes, water temperature in the processor had raised to 50 °C while jacket temperature was at 56 °C showing a temperature gradient of 6 °C, which was 3 °C less than the predetermined temperature difference of 10 °C. In this test, the amount of water at 95 °C which has been utilised to raise the temperature of water in the processor from 25 °C to 50 °C is 54 litres. This shows that the heat transfer and the heating system specifications of the designed equipment are okay.

5.2.3.11 Cost Estimation of the New Equipment

The cost of the new equipment constructed was estimated by using the present market rates the stainless steel, nylon materials and other items used as well as labour charges as shown in the Table 5.3

TABLE 5. 3: Cost Estimation of New Equipment

Item	**Size (m, ft, In, mm)**	**Price per piece**	**Cost (Ksh)**
2 Bearing plummer		600	1200
1 Ball bearing of small gear		500	500
Stainless steel sheet	8' x 4' x 1.2 mm	1500	12000
6 m square tube	1¼" x 1.5 mm	750	4500
1 m reinforced nylon hose		1200	1200
2 Clips		150	300
Cage and drive shaft material		3000	3000
18 m material for cage round bar		200	3600
1 small gear nylon (including machining)		1500	1500
1 bigger nylon (including machining)		2500	2500
Fasteners		1500	1500
Welding and finishing		18000	18000
Waxing soap buffing wheels		4800	4800
Filler wire (stainless steel)	3 kg	1200	3600
Heating element		3500	3500
Transport		2500	2500
2 Taps		1040	1040
Miscellaneous expenses		5000	5000
Total			**67,000**

The equipment designed and constructed is a full stainless steel machine with few parts of nylon materials. It is a three in one equipment which is hand operated, though it can be motor fitted. It acts as an extractor, processor/warmer and settling and filtering tank. It extracts honey from both traditional and modern hives using centrifugal force, process (warm) it to the desired temperature such as 50 °C through a jacket fitted with a thermostatic heater and then settles it for filtration and packing. In rural areas where there is no power, water is heated externally to 95 °C and poured into the jacket through a water inlet spout for heating purposes.

The equipment is portable, easy to assemble and operate, attractive and affordable to the target group which includes small scale beekeepers and businessmen. The cost of the equipment (Table 5.2) is far much less than the cost of any one single equipment imported from outside the country. For comparison purposes, the cost of the imported equipment are;

extractor Ksh 150,000, processor Ksh 180,000, holding tank Ksh 80,000, settling and filtration tank Ksh 120,000 making a total of Ksh 530,000. Our machine (Figure 5.15), which will perform all the functions of the equipment listed above, and yet costs Ksh 67,000 to construct. It is therefore much cheaper and lowers the cost of honey production significantly.

Figure 5. 15: The complete designed and constructed honey extractor-warmer machine

CHAPTER SIX

6.0 CONLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The present study reveals that the physicochemical and biochemical parameters can be used to characterize, classify, design and set processing and storage conditions of Kenyan honey. The results obtained show that Kenyan honey is characterized with high apparent sugar content, viscosity, water insolubles, and hygroscopicity, diastase activity as well as negative specific rotation. On the other hand, it has low moisture content, electrical conductivity, pH, acidity and HMF. The low moisture content indicates that Kenyan honey is safe from fermentation; but its high hygroscopicity though a desired effect on honey based products, demands that good storage conditions are observed to avoid fermentation. The low HMF observed reveals that most of the honey studied was fresh and had not been heated by farmers during harvesting and extraction. The observed high viscosity at low temperatures demonstrates that majority of the honey studied had high sugar content and low moisture content. The viscosity of Kenyan honey exhibited Newtonian behavior with no thixotropic honeys. High water insolubles observed in the study reveals that most of Kenyan honey is extracted by pressing.

The low electrical conductivity, pH, acidity, HMF and high reducing sugars and diastase activity classify Kenyan honey as predominantly floral (blossom) honey. On the contrary, there were a few samples analysed from each region exhibited high ash content, electrical conductivity and positive specific rotation and are classified as honeydew honey or compound honey. The average diastase value (150 DN) for all the four regions studied reveal that most of Kenyan honey is multifloral honey. This study demonstrates that Kenyan honey is from two botanical origins or sources (honeydew honey and blossom honey) and this can be determined by the physicochemical and biochemical parameters.

The results of this work reveal that apart from honey density, all other parameters investigated in different regions differed significantly indicating that honey from different regions and localities differ in their physicochemical and biochemical properties and this is taken into account during honey processing and equipment designing. Overall, Kenyan honey was found to meet most of the quality standards required by the international quality regulatory bodies such as the European Community Directive, Codex Alimentarius Commission and International Honey Commission.

The investigated physicochemical parameters of Kenyan honey which included density, viscosity, diastase activity, pH, HMF and moisture content were successfully applied and used to design a honey extraction and processing equipment which can be used in any part of the country. The designed and constructed equipment conforms to the requirements of the food processing unit, since it is made of stainless steel and nylon materials avoiding rusting. Nylon made parts of the equipment such as bevel gears and vessel bush, eliminate grease application and tear which may contaminate honey during processing. The construction cost of the equipment (Ksh 55,000) is more than three times cheaper compared with the imported equipment (Ksh 530,000) which could carry out the same operations.

This project work successfully achieved its objectives in which the physicochemical and biochemical properties of Kenyan honey investigated were used in characterizing, identifying and classifying Kenyan honey as well as designing a honey extraction and processing equipment which is affordable, durable, portable, attractive, manually operated, all inclusive in its operation and can be used in any part of Kenya.

6.2 Recommendation from the Study and for Further Studies

The data and information documented in this study can be used to develop codes of procedure and practice in honey production and handling and also put in place legal requirements and policy for Kenyan honey by Kenya Bureau of Standards. Kenyan honey beekeepers can now identify their honey as honeydew honey, floral honey and compound honey. Kenyan honey is good quality honey which meets most of the international quality standards and therefore recommended for export.A cheap honey processing equipment is now available and the government should therefore take over and put policies in place for its use by bee farmers and other honey processing organizations.

We recommend further research on:

i. The characterisation of honey from other regions of Kenya where beekeeping is less popular like in Nyanza, Western and Northeastern in order to have a more inclusive data and information on Kenyan honey as a whole.
ii. The identification and classification of Kenyan honey based on pollen content and have a comparative characterization of the resulting unifloral honeys.
iii. Determination of total phenolics, flavonoids and proline in relation to their radical scavenging activity.
iv. Characterisation of stingless bee honey from different regions.

On the part of honey processing equipment, we recommend the design and inclusion of the centrifugal filters into the combined extractor warmer.

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APPENDICIES

Appendix 1A Raw data for all the parameters determined

code	A	B	C	D	E	F	G	H	I	J	K	L	M	N
R1	71.65	72.46	0.77	1.490	18.65	3.9	19.0	0.061	0.258	6100	3800	3160	1900	1.42
R2	72.92	74.22	1.24	1.490	18.57	3.83	16.5	0.050	0.101	6000	4000	3300	1800	1.42
R3	68.42	69.68	1.20	1.486	20.09	3.6	22.0	0.049	0.110	3800	3340	2720	2000	1.42
R4	68.46	73.15	4.46	1.488	19.35	3.63	15.5	0.025	0.014	4400	3640	2280	1500	1.42
R5	68.74	72.02	3.11	1.483	21.27	3.58	21.0	0.042	0.076	1200	1100	1040	1000	1.41
R6	72.20	73.71	1.44	1.485	20.67	3.72	20.0	0.053	0.178	3700	2600	2520	1400	1.41
R7	71.07	72.13	1.01	1.485	20.56	3.62	20.5	0.034	0.076	4060	3140	2000	1300	1.41
R8	69.61	70.66	1.00	1.488	19.61	3.7	20.0	0.155	0.049	5600	3400	2500	1400	1.42
R9	67.95	68.79	0.80	1.491	18.25	3.9	19.0	0.032	14.251	6680	4300	3100	2100	1.41
R10	68.20	69.32	1.07	1.488	19.28	3.88	20.0	0.064	0.237	5800	4000	3040	1900	1.42
R11	71.32	72.91	1.51	1.489	18.93	3.78	20.0	0.046	0.241	17300	9600	4000	3200	1.41
R12	72.11	73.22	1.05	1.481	22.29	3.7	30.5	0.060	0.258	6800	3600	2500	2000	1.41
R13	76.50	77.40	0.85	1.491	18.35	3.74	12.5	0.020	0.022	13100	5600	3900	2800	1.41
R14	73.18	74.96	1.69	1.491	18.17	3.79	12.5	0.053	0.196	14200	8240	4600	3100	1.39
R15	68.59	70.07	1.40	1.488	19.43	4.28	10.5	0.052	0.351	5400	4000	3200	1900	1.41
R16	72.95	74.54	1.51	1.488	19.44	4.28	10.5	0.034	0.345	5600	3600	3100	2000	1.42
R17	70.37	71.03	0.63	1.489	18.97	3.7	14.5	0.035	0.165	460	3300	2500	1600	1.42
R18	68.90	71.33	2.31	1.489	18.93	3.66	15.0	0.035	0.167	2700	1960	1400	1100	1.42
R19	66.98	72.67	5.40	1.490	18.73	3.56	15.5	0.034	0.131	2700	2600	1800	1460	1.38
R20	70.01	70.33	0.31	1.490	18.8	3.79	16.5	0.038	0.121	20000	19600	13880	5000	1.39
R21	74.20	74.45	0.24	1.490	18.72	3.83	15.0	0.038	0.176	14200	8240	4600	3100	1.42
R22	72.64	73.88	1.18	1.489	19.05	3.81	15.0	0.038	0.232	3000	2260	2240	1500	1.41
R23	72.64	74.19	1.47	1.490	18.68	3.83	15.0	0.031	0.226	4100	2800	2500	1300	1.38
R24	69.58	73.99	4.19	1.490	18.8	3.85	15.0	0.032	0.140	6680	4300	3100	2100	1.41
R25	73.92	73.93	0.02	1.490	18.77	3.87	15.5	0.032	0.258	3000	2260	2240	1500	1.42
R26	72.92	73.97	1.00	1.492	17.68	3.96	9.0	0.038	0.056	3700	2600	2520	1400	1.42
R27	73.85	75.01	1.10	1.490	18.8	3.7	14.5	0.031	0.241	20000	19600	13880	5000	1.39
R28	72.11	73.38	1.20	1.490	18.77	3.85	17.5	0.032	0.284	3700	2760	2200	1500	1.40
R29	72.06	72.19	0.13	1.495	16.52	4.14	15.5	0.036	0.240	20000	19600	13880	5000	1.38
R30	69.81	71.57	1.67	1.489	19.15	4.58	10.5	0.054	0.397	5560	3900	3260	1840	1.42
R31	70.88	71.16	0.26	1.489	19.2	4.21	12.5	0.037	0.279	5900	3400	3300	1900	1.42
R32	71.05	71.82	0.73	1.488	19.33	4.59	10.0	0.054	0.440	5400	3900	3260	1840	1.42
R33	73.67	76.20	2.40	1.493	17.47	3.97	13.0	0.026	0.056	14800	9100	5400	3000	1.42
R34	71.54	72.63	1.03	1.489	19.2	4.52	10.5	0.053	0.420	4300	5100	3760	2000	1.41
R35	72.69	73.28	0.56	1.492	17.68	4.64	10.5	0.054	0.146	18800	7200	4000	3400	1.38
R36	75.45	76.55	1.04	1.492	17.99	4.12	7.5	0.046	0.052	16400	9700	4000	3200	1.42
R37	73.94	75.36	1.35	1.487	19.95	3.78	15.0	0.033	0.101	6300	3000	3080	1560	1.41
R38	70.28	70.38	0.10	1.489	19.2	4.29	14.5	0.050	0.177	5600	3600	3500	2000	1.42
R39	74.24	74.74	0.48	1.489	19.07	4.25	10.0	0.024	0.108	8200	5700	4500	2400	1.42
R40	72.30	73.59	1.22	1.489	19.19	4.3	10.0	0.030	0.133	9200	5900	3400	2200	1.41
R41	74.50	76.44	1.84	1.489	19.17	4.33	10.0	0.026	0.093	12700	4920	4800	2800	1.41
R42	73.11	73.96	0.81	1.490	18.75	4.1	10.5	0.027	0.087	14200	6040	3300	2460	1.42
R43	69.06	72.95	3.70	1.489	18.91	4.31	10.0	0.032	0.115	11500	6140	4500	2100	1.42
R44	74.76	75.96	1.14	1.490	18.68	4.1	10.5	0.027	0.124	10400	7100	4100	3100	1.42
R45	69.77	70.34	0.54	1.492	17.72	4.09	12.0	0.034	0.150	12000	8140	5740	2940	1.42
R46	72.08	72.33	0.24	1.490	18.55	4.1	12.0	0.038	0.181	9880	5800	3960	2600	1.41
R47	73.55	73.94	0.37	1.491	18.16	3.96	9.0	0.020	0.077	15500	7000	4500	3100	1.42
R48	73.09	73.24	0.14	1.491	18.24	4.05	8.0	0.020	0.080	8800	6600	3900	3000	1.42

code	A	B	C	D	E	F	G	H	I	J	K	L	M	N
R49	71.52	73.00	1.41	1.491	18.03	4.39	12.5	0.046	0.236	12600	7700	4000	3000	1.42
R50	72.94	73.37	0.40	1.491	18.28	4.04	9.5	0.026	0.069	11300	7900	6840	3000	1.42
R51	68.79	70.34	1.48	1.492	17.99	3.93	10.0	0.022	0.230	16300	7900	4080	3000	1.42
R52	75.29	76.80	1.44	1.490	18.75	3.99	10.0	0.022	0.104	7960	5400	4300	2400	1.42
R53	71.02	72.95	1.83	1.490	18.77	4.06	15.5	0.046	0.181	9400	5800	5280	2260	1.42
R54	68.21	72.60	4.17	1.489	18.83	3.89	10.5	0.023	0.121	6600	5000	3560	1260	1.42
R55	71.25	72.62	1.30	1.492	17.81	3.16	23.3	0.031	0.110	17300	9600	4000	3200	1.41
R56	71.03	72.84	1.72	1.488	19.61	4.1	12.0	0.127	0.150	3700	2760	2200	1500	1.33
R57	71.00	71.95	0.90	1.490	18.77	3.81	15.0	0.038	0.451	6800	3600	2500	2000	1.42
R58	71.10	72.47	1.30	1.490	18.68	3.78	20.0	0.032	0.078	6800	3600	2500	2000	1.42
R59	72.00	72.95	0.90	1.490	18.73	4.14	15.5	0.026	0.184	12600	7700	4000	3000	1.42
R60	69.88	70.72	0.80	1.483	21.27	3.97	13.0	0.022	0.092	3800	3340	2720	2000	1.42
R61	72.00	73.58	1.50	1.488	19.35	3.83	16.5	0.032	0.181	5600	3400	2500	1400	1.42
R62	71.50	73.46	1.86	1.490	18.8	3.88	20.0	0.053	0.087	6300	3000	3080	1560	1.41
R63	71.50	73.61	2.00	1.493	17.47	3.93	10.0	0.053	0.237	13100	5600	3900	2800	1.41
R64	70.50	72.29	1.70	1.489	19.19	3.87	15.5	0.036	0.080	18800	7200	4000	3400	1.41
R65	70.00	70.95	0.90	1.489	19.15	4.51	10.5	0.026	0.133	9400	5800	5280	2260	1.41
R66	71.20	72.78	1.50	1.495	16.52	3.7	14.5	0.038	0.397	12600	7700	4000	3000	1.42
R67	72.01	73.48	1.40	1.490	18.77	3.81	15.0	0.020	0.165	4100	2800	2500	1300	1.41
R68	70.25	71.78	1.45	1.489	18.83	3.83	15.0	0.064	0.101	5800	4000	3040	1900	1.39
R69	70.10	70.94	0.80	1.489	19.15	4.28	10.5	0.032	0.178	2700	2600	1800	1460	1.41
R70	71.50	72.03	0.50	1.489	19.05	4.39	12.5	0.020	0.121	16300	7900	4080	3000	1.42
R71	72.01	74.01	1.90	1.489	18.91	3.79	16.5	0.020	0.180	9400	5800	5280	2260	1.42
R72	73.10	73.99	0.85	1.492	17.99	3.58	21.0	0.034	14.251	2700	2600	1800	1460	1.42
R73	73.00	73.68	0.65	1.490	18.55	3.85	15.0	0.032	0.121	16300	7900	4080	3000	1.38
R74	72.80	73.35	0.52	1.492	17.99	3.74	12.5	0.027	0.140	13100	5600	3900	2800	1.38
R75	73.80	74.85	1.00	1.490	18.75	4.58	10.5	0.053	0.076	6100	3800	3160	1900	1.42
R76	70.20	71.68	1.41	1.488	19.33	3.16	23.3	0.032	0.258	8800	6600	3900	3000	1.40
R77	72.50	73.45	0.90	1.490	18.77	3.7	30.5	0.042	0.258	5400	3900	3260	1840	1.42
R78	73.00	73.57	0.54	1.492	17.72	3.79	16.5	0.042	0.121	14800	9100	5400	3000	1.42
R79	72.00	73.16	1.10	1.489	19.2	4.05	8.0	0.050	0.279	4100	2800	2500	1300	1.42
R80	70.80	72.91	2.00	1.490	18.65	4.05	8.0	0.054	0.056	12000	8140	5740	2940	1.42
MT1	70.62	72.73	2.00	1.486	20.05	4.28	37.0	0.340	0.396	3800	3400	3100	1600	1.41
MT2	68.69	69.59	0.86	1.487	19.97	4.41	25.0	0.251	0.426	3700	2900	1800	1400	1.41
MT3	72.17	76.17	3.80	1.486	20.03	4.25	38.0	0.340	0.426	3600	3300	2600	1500	1.41
MT4	67.30	69.41	2.01	1.487	19.99	4.42	37.0	0.348	1.116	3300	3300	2100	1000	1.41
MT5	66.40	68.19	1.70	1.486	20.04	4.21	39.0	0.345	0.220	3600	3600	2300	1500	1.41
MT6	65.20	66.07	0.83	1.486	20.09	4.39	25.0	0.348	5.996	3700	3700	3000	1400	1.41
MT7	71.29	72.10	0.77	1.486	20.16	4.24	38.0	0.375	0.672	3300	3300	1800	1000	1.41
MT8	67.73	68.78	1.00	1.486	20.23	4.54	37.0	0.348	0.254	3100	3100	2000	1200	1.40
MT9	66.63	67.90	1.20	1.487	19.97	4.37	39.0	0.345	0.052	3600	3600	2200	1000	1.41
MT10	69.10	71.21	2.00	1.482	21.85	4.29	25.0	0.371	0.052	8800	8800	6300	4700	1.42
MT11	66.41	67.60	1.14	1.490	18.48	4.24	22.0	0.351	0.392	3800	3800	2300	1300	1.42
MT12	71.38	72.08	0.67	1.490	18.68	4.28	24.0	0.270	0.200	2600	2600	2300	1800	1.42
MT13	68.91	69.86	0.90	1.490	18.69	4.27	22.0	0.263	0.402	5600	5600	3400	2200	1.42
MT14	71.12	73.48	2.25	1.490	18.53	4.21	24.0	0.275	0.402	2500	2500	1700	800	1.42
MT15	70.61	71.98	1.30	1.490	18.81	4.3	35.0	0.275	0.392	2200	2200	1800	1200	1.42
MT16	68.22	69.48	1.20	1.489	19.03	4.36	21.0	0.273	4.011	3000	3000	1900	1300	1.41
MT17	71.38	73.59	2.10	1.488	19.41	4.28	37.0	0.274	6.016	3100	3100	1700	1200	1.42
MT18	69.63	71.53	1.80	1.489	18.83	4.27	24.0	0.278	1.116	4000	4000	3500	1300	1.41

code	A	B	C	D	E	F	G	H	I	J	K	L	M	N
MT19	73.47	74.84	1.30	1.490	18.61	4.23	23.0	0.264	0.444	1900	1900	1200	800	1.42
MT20	70.32	73.37	2.90	1.482	21.85	4.26	23.0	0.257	4.589	5800	5800	3600	1500	1.41
MT21	73.22	76.40	3.02	1.490	18.8	4.35	23.0	0.293	0.052	3700	3700	3200	2100	1.42
MT22	74.00	74.92	0.87	1.490	18.49	4.23	24.0	0.277	0.272	5400	5400	2900	2000	1.42
MT23	68.86	72.13	3.10	1.490	18.6	4.25	25.0	0.272	0.202	3000	3000	2400	2000	1.42
MT24	73.11	77.33	4.01	1.490	18.57	4.2	21.0	0.280	0.220	4400	4400	3200	2300	1.42
MT25	71.39	73.15	1.67	1.490	18.48	4.46	22.0	0.279	0.402	4100	4100	3600	1600	1.42
MT26	74.30	75.32	0.97	1.490	18.63	4.35	21.0	0.292	10.593	2800	2800	1900	1400	1.40
MT27	71.38	74.75	3.20	1.489	18.85	4.25	22.0	0.303	0.202	4100	4100	3300	2100	1.42
MT28	71.38	72.61	1.17	1.490	18.57	4.33	21.0	0.280	0.220	2900	2900	3900	1700	1.42
MT29	70.13	72.34	2.10	1.490	18.63	4.31	21.0	0.281	0.396	8200	8200	4000	3100	1.42
MT30	71.39	74.54	3.00	1.491	18.36	4.55	22.0	0.260	4.011	2300	2300	1900	1300	1.42
MT31	71.14	74.29	3.00	1.490	18.47	4.26	24.0	0.275	0.004	4400	4400	2000	1000	1.41
MT32	71.91	72.64	0.69	1.490	18.63	4.34	25.0	0.261	0.254	4200	4200	3400	2300	1.42
MT33	68.69	69.53	0.80	1.490	18.49	4.21	23.0	0.270	7.456	4900	2600	1900	1200	1.42
MT34	66.61	67.47	0.81	1.489	18.88	4.22	22.0	0.277	0.200	3200	3000	1800	1300	1.42
MT35	71.38	72.38	0.95	1.490	18.51	4.38	22.0	0.280	0.052	6100	5300	2300	1700	1.42
MT36	69.15	72.32	3.01	1.490	18.68	4.22	23.0	0.282	0.426	4300	2700	1300	800	1.42
MT37	68.91	69.55	0.61	1.486	20.05	4.24	21.0	0.351	0.202	4400	3800	2200	1500	1.41
MT38	70.13	71.10	0.92	1.486	20.4	4.33	22.0	0.338	4.011	2300	1900	1500	1100	1.41
MT39	67.52	68.85	1.26	1.490	18.63	4.21	32.0	0.444	4.011	3700	3400	2400	1500	1.41
MT40	71.38	75.06	3.50	1.491	18.17	4.26	22.0	0.431	0.202	4200	3500	2300	2000	1.42
MT41	64.67	65.53	0.82	1.488	19.25	4.43	23.0	0.421	0.200	4000	2300	1600	1100	1.42
MT42	68.22	69.17	0.90	1.488	19.27	4.45	24.0	0.392	0.200	5100	4200	3900	1500	1.42
MT43	66.62	67.30	0.65	1.488	19.32	4.34	25.0	0.373	0.004	3700	2500	1500	1100	1.41
MT44	65.95	66.56	0.58	1.488	19.24	4.44	25.0	0.431	0.202	4100	3600	3000	1500	1.41
MT45	68.69	70.06	1.30	1.482	21.85	4.41	28.0	0.421	0.220	2100	1800	1500	1000	1.39
MT46	65.10	65.74	0.61	1.482	21.81	4.43	30.0	0.369	6.016	2100	1800	1300	1000	1.39
MT47	68.21	69.55	1.27	1.489	19.2	4.46	23.0	0.447	0.426	2600	2500	1500	800	1.41
MT48	66.50	67.76	1.19	1.482	21.92	4.28	30.0	0.354	4.011	2600	1800	1100	600	1.39
MT49	64.53	65.97	1.37	1.482	21.88	4.35	30.0	0.462	0.430	2200	1500	1300	1000	1.39
MT50	65.11	68.48	3.20	1.490	18.52	4.29	27.0	0.411	0.272	5400	4800	3800	2000	1.41
MT51	66.19	67.45	1.20	1.490	18.71	4.45	25.0	0.434	0.672	6500	5000	4300	3300	1.42
MT52	64.68	66.05	1.30	1.482	21.85	4.31	30.0	0.451	0.444	2200	1900	1200	700	1.39
MT53	67.75	68.89	1.08	1.482	21.81	4.41	30.0	0.409	0.402	2400	1800	1300	900	1.39
MT54	64.89	66.59	1.62	1.620	21.92	4.53	22.0	0.290	0.254	5300	3900	2300	1100	1.41
MT55	67.97	69.86	1.79	1.492	17.67	4.32	25.0	0.438	4.589	5400	2700	1900	1100	1.42
MT56	66.61	67.47	0.81	1.482	21.87	4.34	30.0	0.419	1.313	2000	1500	1200	1000	1.40
MT57	65.09	66.59	1.42	1.488	19.25	4.39	28.0	0.377	0.581	5300	3900	2300	1100	1.42
MT58	70.63	71.34	0.68	1.491	18.36	4.31	23.0	0.422	5.996	3800	3000	2300	1800	1.42
MT59	71.12	73.19	1.96	1.490	18.57	4.45	22.0	0.351	0.580	8300	4100	3300	1900	1.40
MT60	66.84	67.46	0.59	1.482	21.85	4.41	26.0	0.431	0.396	1900	1300	1000	700	1.40
MT61	68.92	70.37	1.38	1.491	18.33	4.33	25.0	0.371	0.052	6100	3300	1600	1600	1.40
MT62	68.22	69.72	1.43	1.482	21.85	4.31	30.0	0.441	7.456	2200	1500	800	800	1.40
MT63	64.68	65.50	0.78	1.488	19.25	4.41	25.0	0.365	0.538	3800	1600	960	960	1.41
MT64	68.52	70.42	1.80	1.490	18.61	4.57	24.0	0.345	1.116	6200	4500	2440	2440	1.41
MT65	67.24	68.19	0.90	1.488	19.33	4.3	25.0	0.451	0.392	4600	3400	1200	1200	1.41
MT66	64.24	65.04	0.76	1.488	19.25	4.45	24.0	0.356	0.092	4700	4200	1400	1400	1.41
MT67	70.13	71.12	0.94	1.488	19.31	4.28	37.0	0.421	0.402	3000	3000	1900	1300	1.41
MT68	67.52	68.58	1.00	1.482	21.81	4.4	25.0	0.475	5.996	5300	3900	2300	1100	1.41

code	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*
MT69	67.30	68.11	0.77	1.482	21.92	4.21	38.0	0.280	0.460	1900	1300	1000	700	1.41
MT70	69.40	70.71	1.24	1.482	21.87	4.31	37.0	0.341	0.200	2200	1500	1300	1000	1.41
MT71	68.45	69.29	0.80	1.488	19.25	4.27	39.0	0.414	0.402	4100	4100	3600	1600	1.38
MT72	67.30	67.82	0.50	1.490	18.71	4.27	25.0	0.344	7.456	6100	5300	2300	1700	1.41
MT73	68.12	68.98	0.81	1.488	19.24	4.33	38.0	0.451	0.581	3100	3100	1700	1200	1.41
MT74	68.68	70.38	1.62	1.482	21.81	4.24	37.0	0.483	0.254	8300	4100	3300	1900	1.40
MT75	67.75	68.43	0.65	1.482	21.87	4.2	39.0	0.331	0.480	5300	3900	2300	1100	1.41
MT76	67.52	69.02	1.42	1.488	19.25	4.29	25.0	0.445	0.200	3100	3100	2000	1200	1.42
MT77	68.91	69.61	0.66	1.488	19.24	4.3	22.0	0.375	0.402	2100	1800	1300	1000	1.42
MT78	67.06	67.72	0.63	1.482	21.85	4.29	24.0	0.465	0.004	2800	2800	1900	1400	1.42
MT79	67.53	68.90	1.30	1.482	21.81	4.29	22.0	0.385	6.016	2200	1900	1200	700	1.42
MT80	68.23	69.16	0.89	1.490	18.71	4.23	24.0	0.475	0.250	4600	3400	1200	1200	1.42
MW1	64.48	65.85	1.30	1.486	20.13	4.42	25.0	0.605	0.315	5300	2700	2000	1500	1.41
MW2	64.68	65.25	0.54	1.488	19.32	4.41	29.0	0.464	1.125	5000	2200	1800	1300	1.42
MW3	66.62	67.87	1.19	1.490	18.69	4.41	25.0	0.513	0.495	7000	2600	2000	1400	1.42
MW4	67.27	68.59	1.25	1.490	18.65	4.35	21.0	0.511	0.556	5500	3600	2400	1900	1.42
MW5	66.40	67.24	0.80	1.490	18.79	4.38	23.0	0.507	0.216	5200	3600	2800	2000	1.42
MW6	68.66	68.79	0.12	1.490	18.73	4.37	23.0	0.502	1.619	6400	4600	3400	2500	1.42
MW7	68.83	69.93	1.04	1.490	18.73	4.4	23.0	0.491	0.288	6100	4500	3600	1500	1.42
MW8	68.69	70.06	1.30	1.490	18.75	4.39	25.0	0.479	0.346	6400	5100	2000	1500	1.42
MW9	66.18	68.81	2.50	1.490	18.76	4.41	26.0	0.494	0.677	6700	5300	3800	2300	1.41
MW10	68.69	68.89	0.19	1.490	18.77	4.36	27.0	0.513	0.880	6200	4100	3100	2000	1.42
MW11	62.46	63.04	0.54	1.487	19.89	4.47	25.0	0.636	0.278	4300	1800	1300	800	1.40
MW12	67.74	70.27	2.40	1.490	18.73	4.37	21.0	0.510	0.360	3900	1600	1200	900	1.41
MW13	66.62	67.28	0.62	1.489	19.11	4.4	28.0	0.543	0.402	5000	3400	2000	1100	1.41
MW14	63.03	64.04	0.96	1.486	20.31	4.49	23.0	0.668	0.857	3800	2800	1900	1200	1.41
MW15	68.22	69.17	0.90	1.489	18.89	4.44	26.0	0.515	0.222	5100	2700	2000	1300	1.42
MW16	67.53	68.56	0.98	1.490	18.8	4.37	21.0	0.498	0.484	7400	5800	3700	1800	1.41
MW17	62.46	63.20	0.70	1.485	20.77	4.42	23.0	0.632	0.410	1700	1100	600	500	1.40
MW18	64.46	65.46	0.94	1.486	20.31	4.41	24.0	0.431	0.315	5200	2600	2000	1600	1.41
MW19	64.68	67.10	2.30	1.486	20.31	4.4	28.0	0.447	1.125	5000	2300	2000	1400	1.42
MW20	66.62	67.43	0.77	1.488	19.32	4.42	25.0	0.398	0.495	5600	3700	2500	2000	1.41
MW21	67.30	68.33	0.98	1.489	18.89	4.35	21.0	0.459	0.556	5000	3505	2700	2000	1.42
MW22	66.40	67.25	0.81	1.490	18.73	4.38	23.0	0.512	0.216	6400	4600	3500	2400	1.42
MW23	68.63	71.26	2.50	1.490	18.79	4.37	22.0	0.509	1.619	6100	4500	3800	1600	1.42
MW24	68.86	69.84	0.93	1.490	18.65	4.4	23.0	0.492	0.288	6400	5100	2200	1600	1.42
MW25	68.66	69.64	0.93	1.490	18.77	4.39	26.0	0.544	0.346	6900	5400	3800	2400	1.41
MW26	66.16	67.29	1.08	1.489	19.11	4.41	26.0	0.516	0.677	6200	4100	3100	2200	1.42
MW27	68.92	70.12	1.14	1.490	18.75	4.37	26.0	0.612	0.880	4100	2000	1500	1000	1.40
MW28	62.46	63.10	0.60	1.487	19.89	4.47	24.0	0.534	0.278	3800	1800	1200	1000	1.41
MW29	67.75	69.02	1.20	1.486	20.31	4.37	20.0	0.469	0.360	5200	3600	2100	1200	1.41
MW30	66.63	67.63	0.96	1.485	20.77	4.4	28.0	0.529	0.402	4000	2700	2000	1400	1.41
MW31	62.97	63.84	0.83	1.490	18.73	4.49	23.0	0.617	0.857	5300	2800	2100	1600	1.41
MW32	68.21	69.40	1.13	1.489	18.89	4.44	26.0	0.579	0.222	5000	2800	2000	1500	1.42
MW33	67.52	68.45	0.88	1.490	18.69	4.37	23.0	0.417	0.484	5200	3600	2600	2000	1.40
MW34	62.45	64.45	1.90	1.489	19.11	4.41	24.0	0.420	0.410	5000	2500	2000	1600	1.40
C1	66.63	67.51	0.84	1.485	20.75	4.5	30.0	0.212	.	4800	2000	1600	1300	1.40
C2	68.22	69.59	1.31	1.488	19.31	4.45	25.0	0.211	0.268	4200	2100	1400	1100	1.41
C3	69.64	71.33	1.60	1.487	19.63	4.46	22.0	0.231	0.940	6500	3600	2300	1500	1.42
C4	68.69	69.53	0.80	1.489	18.97	4.75	30.0	0.396	0.080	4000	2500	2200	1600	1.42

code	***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***K***	***L***	***M***	***N***
C5	69.89	70.84	0.90	1.487	19.63	4.53	30.0	0.351	0.268	10500	5900	4100	2800	1.41
C6	68.92	70.05	1.07	1.483	21.33	4.57	20.0	0.275	2.087	6700	6000	4600	3300	1.42
C7	65.52	66.31	0.75	1.490	18.47	4.7	20.0	0.338	0.511	9800	3100	2200	1800	1.42
C8	69.64	71.01	1.30	1.488	19.45	4.57	35.0	0.382	0.268	6400	3700	2100	1400	1.41
C9	70.13	71.15	0.97	1.490	18.47	4.71	30.0	0.236	0.102	5600	4300	3300	2100	1.42
C10	70.35	71.62	1.20	1.468	27.43	4.58	30.0	0.278	0.511	10100	4500	3600	2100	1.41
C11	58.56	59.32	0.72	1.483	21.33	4.68	25.0	0.122	0.469	2100	1600	1200	1100	1.40
C12	53.38	54.43	1.00	1.487	19.63	4.25	23.0	0.214	0.511	6100	2700	2000	1400	1.42
C13	66.57	67.72	1.10	1.483	21.33	4.53	34.0	0.401	0.469	5200	2500	2000	1400	1.40
C14	70.39	71.38	0.94	1.488	19.31	4.71	31.0	0.347	0.268	4300	1600	1200	700	1.41
C15	70.13	71.07	0.90	1.490	18.47	4.57	30.0	0.271	0.313	5500	2300	1800	1500	1.42
C16	68.21	70.84	2.50	1.488	19.45	4.51	21.0	0.378	0.002	6800	3700	2700	1500	1.42
C17	68.45	69.10	0.62	1.483	21.33	4.48	26.0	0.357	0.088	5800	2600	2300	1600	1.40
C18	67.30	67.96	0.63	1.487	19.63	4.46	23.0	0.237	0.268	5600	2600	2200	1600	1.41
C19	70.14	71.07	0.88	1.488	19.31	4.68	30.0	0.256	0.080	6800	3400	2400	1800	1.42
C20	69.40	72.76	3.20	1.489	18.97	4.51	31.0	0.239	0.102	5000	3000	2300	1800	1.42
C21	69.88	73.14	3.10	1.487	19.63	4.57	21.0	0.381	0.158	11000	6400	4600	3000	1.42
C22	70.36	71.36	0.95	1.488	19.45	4.69	20.0	0.391	0.268	6400	5800	4800	3200	1.42
C23	70.12	71.38	1.20	1.468	27.43	4.53	36.0	0.352	0.940	9600	3200	2000	1800	1.42
C24	69.89	71.26	1.30	1.487	19.63	4.71	30.0	0.341	0.002	6800	3800	2200	1600	1.41
C25	68.92	70.29	1.30	1.468	27.43	4.57	25.0	0.321	0.313	6200	4000	3100	2100	1.42
C26	70.13	71.10	0.92	1.489	18.97	4.65	35.0	0.312	0.469	10400	4800	3800	2200	1.41
C27	69.64	70.59	0.90	1.468	27.43	4.25	23.0	0.371	5.059	5600	3000	2400	2000	1.40
C28	68.22	69.49	1.20	1.487	19.63	4.51	34.0	0.381	3.223	6900	2900	2300	1800	1.42
C29	68.22	69.09	0.83	1.487	19.63	4.71	30.0	0.239	0.276	5600	2900	2200	1900	1.40
C30	69.88	71.15	1.20	1.489	18.97	4.57	31.0	0.297	0.511	4300	1600	1200	800	1.41
C31	67.30	67.98	0.65	1.488	19.31	4.51	26.0	0.329	2.087	5600	2400	2000	1600	1.42
C32	68.68	69.62	0.90	1.485	20.75	4.47	23.0	0.258	0.202	6900	3800	2700	1600	1.42
C33	69.39	71.29	1.80	1.468	27.43	4.46	30.0	0.371	3.223	5200	2400	2000	1600	1.40
C34	69.87	70.84	0.92	1.487	19.63	4.67	35.0	0.391	0.088	5400	2600	2200	1800	1.41
C35	68.92	69.56	0.61	1.490	18.47	4.51	31.0	0.351	0.080	6600	3600	2300	1600	1.42
C36	67.75	69.11	1.30	1.468	27.43	4.58	23.0	0.371	0.158	10100	6100	4300	2900	1.42
C37	68.06	68.89	0.79	1.489	18.97	4.7	24.0	0.297	0.940	6700	6200	4800	3000	1.41
C38	70.38	71.33	0.90	1.487	19.63	4.51	25.0	0.341	3.223	9800	3300	2400	2000	1.42
C39	69.79	70.84	0.99	1.487	19.63	4.71	22.0	0.296	0.276	6400	3700	2100	1400	1.42
C40	69.16	70.53	1.30	1.488	19.31	4.57	20.0	0.346	0.102	5600	4300	3300	2100	1.41
TH1	74.10	77.05	2.81	1.493	17.25	5.02	33.0	1.583	0.831	14500	7700	4100	2600	1.42
TH2	72.16	75.13	2.82	1.495	16.65	4.99	33.2	1.640	0.862	6000	3700	3000	1700	1.42
TH3	72.78	75.81	2.88	1.493	17.43	4.06	50.8	1.993	1.065	6700	5100	2800	1500	1.42
TH4	71.79	75.03	3.08	1.493	17.41	4.71	40.5	1.657	0.844	5400	3800	2600	1600	1.42
TH5	72.29	74.69	2.28	1.496	16.24	5.02	32.0	1.407	0.727	19600	8600	5100	3800	1.41
TH6	70.76	73.79	2.88	1.489	18.93	5.02	32.0	1.617	0.848	4900	3600	2600	1900	1.41
TH7	72.02	75.20	3.02	1.495	16.48	4.98	33.5	1.430	0.741	14800	67700	4400	3300	1.41
TH8	70.66	74.10	3.27	1.489	19.12	4.38	43.5	1.113	0.561	4300	3200	2300	1600	1.42
TH9	72.34	75.42	2.93	1.493	17.39	4.06	30.0	1.623	0.850	8100	6100	4800	3200	1.41
TH10	71.99	75.22	3.07	1.492	17.73	4.96	34.5	1.753	0.941	12200	5800	4200	2600	1.42
TH11	70.78	73.81	2.88	1.489	18.99	5.05	30.5	1.780	0.940	6040	3000	2400	2000	1.41
TH12	71.94	75.16	3.06	1.494	17.21	5.07	29.0	1.343	0.689	6040	3000	2400	2000	1.41
TH13	72.33	74.78	2.32	1.493	17.55	5.02	31.5	1.370	0.711	11600	7400	4000	2800	1.41
TH14	72.22	75.23	2.86	1.493	17.52	5.04	31.0	1.567	0.817	4300	3500	2800	2300	1.39

code	A	B	C	D	E	F	G	H	I	J	K	L	M	N
TH15	72.26	75.27	2.86	1.495	16.43	4.98	32.5	1.347	0.696	18800	7400	4900	3700	1.41
TH16	71.86	75.10	3.08	1.493	17.28	4.96	34.0	1.720	0.906	13880	6600	4800	3200	1.42
TH17	70.80	74.26	3.28	1.489	18.96	4.42	46.0	1.217	0.619	4300	3500	2800	2300	1.42
TH18	70.94	74.28	3.17	1.463	29.6	4.5	44.5	1.570	0.820	4900	3600	2600	1900	1.42
TH19	72.01	75.18	3.01	1.469	27.17	4.95	33.5	1.553	0.811	14800	67700	4400	3300	1.38
TH20	71.31	74.84	3.35	1.494	16.97	4.14	48.2	1.287	0.658	9000	5600	4000	2400	1.39
TH21	71.08	74.20	2.96	1.492	17.93	4.71	41.8	1.350	0.694	11500	3900	3000	1900	1.42
TH22	72.64	74.96	2.20	1.496	16.11	4.89	38.0	1.433	0.742	9100	4200	3100	1700	1.41
TH23	71.79	75.02	3.07	1.494	17.13	4.95	33.5	1.390	0.716	4100	3200	2300	1500	1.38
TH24	72.27	74.68	2.29	1.496	16.24	4.32	44.0	1.213	0.614	6040	3000	2400	2000	1.41
TH25	72.19	75.16	2.82	1.493	17.52	4.96	35.0	1.673	0.880	11900	6400	4100	2700	1.42
TH26	76.07	78.27	2.08	1.498	15.44	4.29	46.5	1.050	0.523	6400	2800	2200	1900	1.42
TH27	72.14	75.34	3.04	1.495	16.44	4.21	47.5	1.343	0.690	7000	3500	2800	2300	1.39
TH28	71.99	75.20	3.05	1.488	19.55	4.89	38.0	1.420	0.732	6700	5300	2700	1700	1.40
TH29	71.88	75.06	3.01	1.494	17.19	4.9	38.2	1.533	0.798	4100	3200	2300	1500	1.38
TH30	72.19	75.31	2.97	1.496	16.19	4.7	42.7	1.607	0.839	6040	3000	2400	2000	1.42
TH31	70.60	73.65	2.90	1.489	18.83	4.48	45.2	1.840	0.979	19400	9700	4800	4000	1.42
NK1	70.01	73.66	3.46	1.488	19.23	4.35	35.0	0.697	0.320	7600	4600	3300	2100	1.42
NK2	67.24	71.54	4.09	1.485	20.61	4.67	46.6	1.613	0.849	2900	2100	1600	1500	1.42
NK3	70.70	73.64	2.79	1.490	18.44	4.37	33.5	0.820	0.390	15500	6200	4400	3000	1.41
NK4	65.89	70.61	4.49	1.480	22.47	4.28	61.5	0.693	0.316	1800	1200	1100	1000	1.38
NK5	70.51	73.43	2.78	1.489	19.09	4.53	48.0	1.287	0.660	2900	2100	1600	1500	1.42
NK6	70.58	73.62	2.88	1.490	18.77	4.49	48.5	1.177	0.594	5000	3400	3000	2100	1.41
NK7	65.90	70.62	4.48	1.479	22.84	4.25	62.8	0.753	0.354	1800	1100	1040	760	1.42
NK8	67.08	71.32	4.03	1.484	20.88	4.29	20.0	0.523	0.220	4320	2400	1900	1500	1.42
NK9	67.29	71.54	4.04	1.485	20.64	4.46	36.2	0.920	0.448	4000	2500	2000	1600	1.41
NK10	67.50	71.63	3.92	1.486	20.16	4.52	36.5	1.107	0.476	2900	2100	1600	1500	1.41
NK11	67.10	71.33	4.02	1.486	20.25	4.56	31.0	1.063	0.527	4100	2000	1800	1500	1.42
NK12	70.75	73.77	2.88	1.490	18.79	4.31	47.5	0.980	0.482	2900	2700	1900	1400	1.42
NK13	70.59	73.65	2.91	1.489	18.84	4.33	46.5	1.163	0.544	4320	2400	1900	1500	1.42
NK14	68.98	72.87	3.70	1.488	19.4	4.35	46.3	1.537	0.798	4000	2500	2000	1600	1.42
NK15	66.21	70.83	4.39	1.482	21.65	4.6	39.7	1.047	0.519	2000	1600	1300	1200	1.41
NK16	65.86	70.71	4.60	1.478	23.24	4.31	68.0	0.413	0.156	1400	1000	1000	1000	1.42
NK17	70.59	73.65	2.91	1.489	18.88	4.31	49.0	0.917	0.448	5500	3700	3200	2500	1.42
NK18	71.03	74.15	2.96	1.492	17.77	4.6	39.3	1.290	0.661	2000	1600	1300	1200	1.42
NK19	67.39	71.72	4.12	1.485	20.57	4.65	41.0	0.633	0.280	2800	2100	1700	1400	1.42
NK20	67.19	71.52	4.12	1.485	20.53	4.7	45.2	0.987	0.479	2800	1900	1700	1400	1.42
NK21	70.73	73.79	2.90	1.489	18.96	4.32	34.5	1.617	0.844	2000	1600	1300	1200	1.42
NK22	67.16	71.47	4.10	1.485	20.52	4.38	42.7	1.590	0.830	2900	2700	1700	1500	1.42
NK23	70.92	74.05	2.98	1.492	17.88	4.54	38.2	1.453	0.750	4320	2400	1900	1500	1.42
NK24	68.90	72.77	3.68	1.486	20.08	4.3	47.7	1.220	0.619	4000	2500	2000	1600	1.41
NK25	66.03	70.54	4.28	1.482	21.63	4.52	46.5	1.253	0.637	2100	1500	1200	1100	1.33
NK26	70.82	73.85	2.87	1.489	19.04	4.28	45.0	1.290	0.654	6700	3700	3300	2700	1.42
NK27	67.02	71.42	4.17	1.485	20.76	4.37	39.7	0.417	0.157	6500	4100	2800	1800	1.42
NK28	66.19	70.61	4.20	1.484	20.99	4.36	40.5	0.403	0.149	5300	2900	2500	1600	1.42
NK29	71.03	74.16	2.97	1.491	18.08	4.26	37.8	1.540	0.788	2300	1600	1600	1200	1.42
NK30	59.64	72.29	12.02	1.475	24.72	4.62	82.2	1.307	0.668	3000	2300	1700	1200	1.42
NK31	70.80	73.84	2.88	1.489	18.95	4.11	42.5	0.910	0.441	5200	2800	2500	1900	1.41
NK32	68.88	72.76	3.69	1.487	19.99	4.26	47.5	0.857	0.414	2300	1600	1600	1200	1.41
NK33	54.10	70.19	15.29	1.470	26.8	4.26	86.3	1.640	0.859	3000	2300	1700	1200	1.41

code	A	B	C	D	E	F	G	H	I	J	K	L	M	N
NK34	71.01	74.16	2.99	1.491	18.05	4.14	49.5	1.537	0.791	2300	1600	1600	1200	1.41
NK35	70.62	73.58	2.81	1.489	18.95	4.27	47.7	1.223	0.624	4600	2800	2200	1500	1.42
NK36	70.95	73.85	2.76	1.489	19.05	4.29	44.0	1.137	0.570	3540	3200	2000	1500	1.41
NK37	68.86	72.77	3.71	1.486	20.23	4.37	45.0	1.267	0.646	5500	4000	3200	2300	1.39
NK38	68.90	72.75	3.65	1.487	19.83	4.32	44.0	1.117	0.557	2300	1600	1600	1200	1.41
NK39	67.43	71.71	4.07	1.485	20.55	4.51	46.7	1.703	0.892	3000	2300	1700	1200	1.42
NK40	68.95	72.84	3.70	1.486	20.08	4.56	44.0	1.223	0.621	2300	1600	1600	1200	1.42
NK41	70.80	73.69	2.75	1.489	19.13	4.27	45.7	1.133	0.571	5000	3400	2700	2200	1.42
NK42	65.86	70.55	4.46	1.482	21.93	4.31	53.3	1.987	1.056	1300	1200	1200	1100	1.38
NK43	66.06	70.51	4.22	1.483	21.24	4.63	46.5	1.703	0.892	3540	3200	2000	1500	1.38
NK44	68.82	72.64	3.63	1.487	19.64	4.34	44.0	1.220	0.619	5500	4000	3200	2300	1.42
NK45	70.77	73.73	2.81	1.488	19.27	4.26	44.2	1.413	0.725	3800	1400	1400	1400	1.40
NK46	69.01	72.94	3.73	1.484	21.03	4.04	40.0	2.253	1.213	2600	1900	1600	1000	1.42
NK47	70.63	73.62	2.84	1.490	18.71	4.22	33.5	1.633	0.853	6100	3900	3000	2500	1.42
NK48	70.78	73.79	2.86	1.489	19.12	4.26	44.5	1.137	0.570	4600	2400	1900	1500	1.42
NK49	70.68	73.73	2.89	1.490	18.76	4.42	40.0	1.313	0.675	6400	4600	3100	2300	1.42
NK50	68.90	72.82	3.73	1.487	19.68	4.38	49.2	1.240	0.629	2600	1900	1600	1000	1.41
NK51	68.92	72.85	3.73	1.488	19.6	4.32	50.5	1.337	0.688	3000	2300	1700	1300	1.41
NK52	68.86	72.73	3.68	1.487	19.76	4.43	48.5	1.267	0.647	4600	2400	1900	1500	1.41

code	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
R1	11.13	18.02	23.86	-13.50	0.15	0.22	78.18	1.13	0.00	0.23	42.01	132.96	536.37
R2	7.20	22.40	11.94	-10.50	0.02	0.22	95.91	1.13	0.00	0.11	22.5	275.27	525.51
R3	12.67	27.25	39.15	-13.00	0.10	0.21	94.91	1.75	0.00	0.17	12.26	311.76	756.74
R4	7.10	7.79	30.71	-15.00	0.25	0.15	83.45	1.96	0.00	0.17	11.81	250.45	822.98
R5	12.29	16.41	25.59	-22.50	0.13	0.20	88.18	1.75	0.00	0.17	41.01	281.56	566.37
R6	12.38	16.02	14.19	-13.50	0.01	0.24	104.64	1.33	0.00	0.11	32.99	176.86	744.02
R7	6.33	15.03	32.35	-15.50	2.53	0.22	93.18	2.79	0.93	0.23	21.62	160.65	589.02
R8	8.52	17.38	35.28	-18.00	0.02	0.23	103.55	2.38	0.00	0.23	33.08	282.46	655.53
R9	3.16	76.73	69.99	0.00	2.37	0.21	106.09	0.50	0.00	0.11	32.29	162.96	756.37
R10	2.87	9.40	17.61	-13.50	0.40	0.25	104.09	0.08	0.93	0.11	13.31	282.76	815.12
R11	9.47	21.98	47.13	-14.50	0.06	0.20	107.09	6.13	0.00	0.23	23.47	312.06	764.91
R12	8.04	10.77	14.76	-5.00	0.04	0.20	93.09	6.54	0.00	0.23	43.62	261.96	548.71
R13	2.20	13.76	15.32	-18.00	0.02	0.25	96.09	7.79	0.00	0.17	21.93	191.16	655.22
R14	6.22	15.86	91.65	-9.75	0.08	0.21	90.73	3.21	0.93	0.23	23.09	291.56	754.65
R15	6.33	23.94	13.62	-13.25	0.05	0.22	86.91	0.50	0.00	0.23	32.81	194.47	787.86
R16	4.50	19.67	9.09	-11.00	0.35	0.23	92.91	1.33	0.00	0.23	31.47	284.57	654.29
R17	0.67	24.17	31.26	-11.00	0.85	0.25	103.64	4.04	0.93	0.11	21.18	292.56	828.39
R18	5.07	12.41	5.68	-18.00	0.00	0.23	83.64	0.92	0.00	0.06	22.34	191.16	620.63
R19	4.21	16.12	58.52	-18.00	0.07	0.23	103.27	1.33	0.00	0.17	33.83	161.26	786.46
R20	4.31	20.42	26.75	-15.50	0.13	0.22	100.40	1.54	0.00	0.23	24.68	231.96	755.22
R21	8.61	11.41	35.87	-12.25	0.01	0.23	93.36	1.13	0.00	0.23	22.3	231.76	687.99
R22	4.02	9.60	48.28	-18.00	0.32	0.22	78.18	5.71	0.00	0.17	41.44	304.16	633.99
R23	5.37	18.11	7.97	-17.50	0.47	0.21	94.82	0.92	0.00	0.11	21.31	283.76	753.58
R24	5.93	8.03	35.84	-13.50	0.07	0.21	101.27	0.50	0.00	0.00	20.14	164.36	764.54
R25	5.65	12.02	31.26	-10.00	0.05	0.23	103.82	4.67	0.00	0.00	41.66	263.76	654.09
R26	4.50	18.02	27.86	-10.50	0.52	0.23	104.04	0.50	0.00	0.11	43	254.47	625.22
R27	4.21	53.76	32.42	-13.50	4.46	0.24	94.91	1.75	0.00	0.23	22.34	253.96	815.73
R28	3.35	18.53	47.16	-9.25	1.69	0.21	78.82	5.92	0.00	0.23	13.45	131.66	860.71
R29	6.12	12.28	35.84	-10.25	0.71	0.23	87.09	0.92	0.00	0.11	11.81	223.56	586.04
R30	12.15	17.47	23.32	-10.50	0.87	0.22	84.45	0.71	0.00	0.00	10.11	302.26	764.76
R31	6.60	11.03	30.67	-14.00	1.87	0.22	93.27	6.54	0.00	0.17	21.69	292.36	569.63
R32	6.22	21.98	10.23	-10.00	0.02	0.22	106.73	2.17	0.00	0.11	33.08	133.66	768.35
R33	4.80	6.59	14.22	-16.00	0.06	0.23	91.14	1.75	0.00	0.11	20.12	223.56	759.58

code	*O*	*P*	*Q*	*R*	*S*	*T*	*U*	*V*	*W*	*X*	*Y*	*Z*	*AA*
R34	6.14	53.76	15.88	-11.00	0.04	0.20	92.91	3.00	2.78	0.11	31.66	320.45	579.53
R35	7.39	10.55	14.20	-18.50	4.46	0.23	93.91	1.54	0.00	0.45	12.14	332.86	866.24
R36	5.18	9.01	10.22	-25.50	0.51	0.36	83.09	3.21	0.00	0.11	23.01	201.66	540.68
R37	8.35	21.07	39.22	-20.00	0.65	0.31	81.73	5.08	0.00	0.11	10.95	290.65	850.68
R38	8.45	14.35	24.46	-9.00	0.37	0.28	93.55	0.50	0.00	0.00	23.05	231.06	568.67
R39	3.17	10.77	6.26	-22.00	2.55	0.29	100.18	1.54	0.00	0.00	23.31	291.16	814.63
R40	10.85	23.08	31.27	-11.25	0.04	0.51	83.55	1.33	0.00	0.11	22.62	181.86	745.01
R41	5.66	16.57	5.68	-11.00	0.15	0.29	94.55	0.71	0.93	0.06	33.11	233.36	675.32
R42	8.35	3.83	11.95	-7.50	0.62	0.30	79.04	1.75	0.00	0.11	32.79	190.55	582.86
R43	7.20	16.18	28.96	-9.25	0.80	0.29	104.09	1.13	0.00	0.11	33.01	191.76	655.83
R44	7.29	5.81	31.27	-9.75	1.57	0.29	94.55	1.33	0.00	0.11	35.79	301.86	815.73
R45	8.35	6.81	102.91	-9.00	1.31	0.30	98.09	1.54	0.00	0.17	44.3	201.76	736.24
R46	7.39	8.22	103.47	-9.75	3.02	0.31	87.09	0.08	0.00	0.11	34.83	230.45	716.55
R47	6.24	14.15	91.48	-11.50	2.69	0.30	84.45	0.71	0.00	0.11	13.11	261.56	596.55
R48	10.75	19.57	93.73	-14.25	3.02	0.31	100.18	0.08	0.00	0.00	17	182.46	675.22
R49	3.17	22.92	39.23	-10.25	5.23	0.29	104.55	0.92	0.00	0.11	31.79	260.65	614.75
R50	8.45	16.13	102.76	-11.75	0.16	0.30	94.91	0.92	0.00	0.11	37.02	173.56	642.96
R51	6.53	16.34	13.07	-10.50	0.44	0.30	82.64	1.33	0.00	0.11	11.81	141.36	518.6
R52	7.10	19.01	26.75	-16.50	0.15	0.30	79.27	0.50	0.00	0.17	0.001	125.55	653.68
R53	7.39	46.88	30.69	-9.50	0.02	0.09	79.82	1.13	0.93	0.11	23.41	290.55	576.45
R54	8.16	10.85	8.52	-16.50	0.10	0.30	99.64	1.96	0.00	0.11	32.11	190.65	595.73
R55	7.01	5.34	10.21	-8.25	0.25	0.30	103.91	3.63	0.00	0.17	22.5	253.16	619.32
R56	5.28	1.14	24.46	15.50	0.13	0.25	105.91	1.13	0.00	0.11	23.81	161.96	677.99
R57	3.17	14.15	39.15	-13.50	0.01	0.30	104.64	1.33	0.00	0.11	2.55	322.46	815.73
R58	2.78	10.55	32.42	-10.50	2.53	0.29	93.14	1.54	0.00	0.23	21.99	161.36	582.48
R59	7.39	18.53	33.49	-13.00	0.02	0.21	101.27	0.50	0.00	0.00	22.68	271.56	626.55
R60	10.56	20.42	39.23	-15.00	0.07	0.21	107.73	0.50	0.00	0.00	23.29	231.86	544.76
R61	11.13	16.34	36.95	-21.00	0.13	0.21	93.91	3.63	0.00	0.17	33.31	301.76	615.32
R62	8.16	19.57	102.67	-13.25	0.29	0.22	84.82	0.92	0.00	0.11	2.59	201.66	544.63
R63	9.41	5.81	25.04	-15.50	0.73	0.23	93.18	2.79	0.93	0.23	11.31	232.76	518.62
R64	10.27	9.40	13.06	-17.75	1.54	0.23	88.18	1.13	0.00	0.23	4.01	171.86	815.53
R65	6.43	16.13	26.69	-13.50	1.17	0.23	98.18	1.13	0.00	0.23	43	272.26	716.24
R66	7.01	3.83	40.36	-14.25	2.05	0.20	93.36	1.13	0.00	0.23	4.01	302.16	625.01
R67	9.21	17.47	50.05	-5.25	4.47	0.29	83.27	6.54	0.00	0.17	32.68	261.26	538.71
R68	7.10	24.17	36.95	-17.75	0.15	0.36	106.73	2.17	0.00	0.11	22.69	221.96	575.53
R69	5.09	22.40	32.38	-9.50	0.02	0.25	102.91	3.00	2.78	0.11	33.08	313.36	685.63
R70	4.90	16.02	26.75	-13.00	0.06	0.30	103.09	3.21	0.00	0.11	22.14	311.86	645.73
R71	8.16	20.42	52.27	-11.00	0.26	0.23	104.09	0.08	0.93	0.11	12.14	281.96	616.24
R72	10.56	76.73	30.08	-18.00	0.20	0.24	103.55	0.50	0.00	0.00	41.31	251.56	516.55
R73	7.20	9.40	44.91	-18.25	0.51	0.29	101.27	0.50	0.00	0.00	1.05	172.46	715.32
R74	8.64	18.13	27.31	-15.75	0.03	0.21	101.14	1.54	0.00	0.23	12.31	243.56	733.58
R75	6.14	12.02	10.23	-12.00	0.13	0.21	84.91	1.75	0.00	0.17	26.34	132.16	643.88
R76	8.73	15.03	11.91	-18.00	0.08	0.31	93.91	1.54	0.00	0.45	25.26	280.65	615.73
R77	7.29	18.02	14.21	-17.75	0.04	0.22	88.09	1.54	0.00	0.17	29.14	320.87	569.32
R78	8.06	18.02	38.66	-10.50	0.48	0.21	88.09	1.54	0.00	0.17	14.3	231.96	567.99
R79	6.43	11.41	32.37	-9.00	0.08	0.23	94.45	0.71	0.00	0.00	31.83	222.46	815.73
R80	4.99	15.03	25.54	-10.50	0.05	0.21	103.64	0.92	0.00	0.06	20.11	181.36	757.48
MT1	45.93	10.50	625.65	-13.75	0.42	0.11	146.27	0.92	0.93	0.80	29.76	274.97	790.15
MT2	28.87	7.78	815.84	-6.00	2.01	0.18	198.18	0.08	0.00	0.74	39.67	304.97	657.53
MT3	38.88	4.48	641.27	-17.75	1.21	0.24	201.91	0.92	0.93	0.57	36.48	305.27	789.53
MT4	34.88	10.21	653.20	-24.00	1.18	0.23	198.18	1.96	0.93	0.80	50.03	204.77	792.26
MT5	29.15	12.90	689.15	-14.50	0.69	0.02	192.55	0.08	0.00	0.40	57.09	284.16	819.63
MT6	38.89	4.58	638.97	-9.25	1.41	0.77	184.82	0.92	0.93	0.91	48.89	295.07	765.63
MT7	32.65	11.47	628.21	-20.50	0.35	0.52	192.28	1.13	0.00	0.80	32.57	275.17	647.55
MT8	39.84	9.34	686.28	-21.50	1.12	0.10	195.73	1.54	0.93	0.74	29.11	294.97	769.63
MT9	15.75	19.31	564.18	-8.00	0.21	0.48	123.18	0.92	1.39	0.85	51.32	286.17	785.53
MT10	14.18	10.22	415.54	-22.00	1.12	0.22	132.45	1.33	0.93	0.57	28.34	244.67	783.63

code	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
MT11	13.37	7.74	400.28	-19.75	1.00	0.20	154.27	6.96	1.39	0.68	36.57	274.47	669.84
MT12	14.64	6.35	413.67	-18.00	1.50	0.25	122.64	0.08	0.00	0.68	56.03	304.52	829.84
MT13	14.53	14.75	419.28	-19.25	0.31	0.29	203.91	2.38	0.93	0.57	60.12	314.57	769.73
MT14	13.50	11.33	385.23	-19.50	1.02	0.25	154.45	0.29	0.00	0.57	47.85	304.47	881.33
MT15	10.22	10.50	383.97	-15.25	1.10	0.24	146.82	1.75	0.93	0.63	46.23	255.17	776.56
MT16	9.64	3.48	402.18	0.00	0.31	0.25	149.82	0.08	0.00	0.57	57.16	294.57	820.39
MT17	10.41	10.50	406.91	-17.00	0.95	0.30	159.91	0.08	0.00	0.45	38.14	254.67	822.03
MT18	17.16	7.61	412.06	-19.75	0.31	0.27	135.82	2.38	0.00	0.63	46.34	274.67	789.73
MT19	14.46	4.70	395.43	-16.25	0.11	0.25	126.09	0.92	0.93	0.57	56.02	284.47	860.43
MT20	11.97	7.22	400.52	0.00	0.21	0.20	188.82	1.13	0.93	1.02	59.76	304.57	780.6
MT21	11.94	12.66	394.39	2.00	1.00	0.19	199.13	1.96	1.85	0.63	45.94	314.47	749.63
MT22	12.13	8.69	394.78	-12.50	0.13	0.23	139.91	0.29	1.85	0.57	46.98	294.57	817.78
MT23	10.71	10.04	369.09	-12.50	1.77	0.46	198.16	0.50	0.00	0.57	37.13	284.36	819.84
MT24	12.52	9.41	414.76	-17.25	2.00	0.22	166.73	0.29	2.78	0.51	38.94	264.67	857.49
MT25	10.52	13.20	427.24	-15.25	0.20	0.09	126.82	1.13	0.00	0.51	37.51	224.47	854.87
MT26	29.21	13.53	351.13	-13.00	0.91	0.21	129.64	0.29	0.93	0.45	55.75	254.26	650.27
MT27	12.27	19.25	335.21	-14.25	0.20	0.22	119.90	0.29	0.00	0.74	56.19	244.36	829.63
MT28	12.82	14.05	407.91	-19.25	2.00	0.20	194.82	0.50	0.00	0.51	56.96	294.47	799.73
MT29	13.98	5.89	413.67	-7.25	0.12	0.35	182.18	1.13	0.93	0.57	35.44	204.77	799.32
MT30	12.37	12.03	403.44	-9.75	1.01	0.24	175.73	0.08	0.00	0.80	58.43	305.37	874.58
MT31	11.02	10.41	402.30	-17.75	1.01	0.24	130.73	9.46	0.00	0.74	49.34	304.57	824.56
MT32	14.14	10.37	373.93	-19.00	0.10	0.30	192.73	0.92	0.93	0.68	45.95	204.87	898.61
MT33	14.15	10.54	373.78	-9.25	0.21	0.15	200.55	0.71	0.93	0.51	55.1	294.67	780.53
MT34	11.35	9.77	411.33	-14.25	0.32	0.22	204.82	20.50	0.93	0.40	46.44	294.57	799.73
MT35	5.85	7.80	367.67	-17.25	0.91	0.23	118.27	0.71	0.93	0.34	36.29	284.67	868.38
MT36	6.60	10.22	392.17	-14.50	0.91	0.31	119.90	0.50	0.00	0.51	38.73	274.57	859.12
MT37	8.14	9.27	665.22	-8.00	0.21	0.32	124.82	1.33	0.93	0.74	48.84	305.37	849.63
MT38	7.19	10.37	661.49	-20.75	0.88	0.22	119.93	3.21	2.78	0.91	50.61	300.57	797.99
MT39	6.79	9.48	567.03	-4.00	1.21	0.22	195.64	1.54	1.85	0.85	61.13	305.57	877.68
MT40	8.60	12.14	485.00	-13.75	1.01	0.20	202.82	1.13	1.39	0.57	56.31	284.87	719.63
MT41	12.44	23.08	292.97	-3.25	0.10	0.24	196.27	0.92	0.93	0.80	29.11	274.67	817.99
MT42	5.46	13.51	298.80	-9.75	0.65	0.22	199.16	0.50	0.00	0.57	55.95	284.47	895.58
MT43	4.31	12.84	276.95	-3.50	0.12	0.17	200.18	0.92	1.39	0.85	65.57	264.77	797.58
MT44	8.31	11.25	311.14	-3.75	0.16	0.21	139.55	0.71	0.93	0.51	46.02	295.57	829.43
MT45	16.06	7.63	518.30	-6.75	0.32	0.21	169.73	0.29	2.78	0.51	57.85	274.97	808.4
MT46	4.78	22.11	485.19	-3.00	0.41	0.17	189.82	1.13	0.93	1.02	46.29	254.06	784.99
MT47	8.60	14.92	305.58	-2.75	1.10	0.25	145.82	1.75	0.93	0.63	55.95	244.36	716.55
MT48	10.49	19.23	515.95	-3.50	1.01	0.18	199.64	0.50	0.00	0.51	48.43	254.97	837.58
MT49	14.19	7.50	495.51	-6.35	0.20	0.10	136.55	0.71	0.93	0.51	32.57	245.57	794.63
MT50	12.92	10.49	419.16	-6.25	1.03	0.23	155.73	0.08	0.00	0.80	36.44	264.36	808.71
MT51	8.13	33.26	728.87	-4.25	1.01	0.22	156.73	1.54	0.93	0.74	46.96	314.67	798.64
MT52	4.60	29.83	514.95	-6.00	1.03	0.19	149.82	20.50	0.93	0.40	55.94	312.57	849.02
MT53	12.17	17.93	494.53	-5.25	1.20	0.18	129.18	1.13	0.93	0.57	46.03	311.57	848.71
MT54	6.52	14.03	291.85	-3.25	1.10	0.19	201.13	1.96	1.85	0.63	29.67	314.87	783.58
MT55	5.55	33.25	400.03	-3.75	1.00	0.26	203.91	2.38	0.93	0.57	60.03	302.07	868.71
MT56	5.63	15.25	503.51	-6.50	1.02	0.19	188.18	0.08	0.00	0.74	47.85	254.97	769.63
MT57	6.99	13.51	288.36	-3.00	1.04	0.20	178.55	0.08	0.00	0.40	28.89	254.77	719.02
MT58	5.45	18.54	395.38	-4.25	1.01	0.19	200.82	1.75	0.93	0.63	32.57	284.67	849.73
MT59	12.22	23.41	469.21	-5.25	1.10	0.15	200.28	1.13	0.00	0.80	35.31	294.87	888.51
MT60	16.15	22.52	479.41	-4.25	1.01	0.20	198.28	1.13	0.00	0.80	38.14	304.57	798.71
MT61	8.68	33.75	412.27	-2.50	1.00	0.19	202.82	1.13	1.39	0.57	47.09	244.16	818.34
MT62	64.16	25.76	451.08	-4.00	1.00	1.31	203.82	2.38	0.00	0.63	49.76	294.97	856.55
MT63	12.06	24.94	259.91	-5.25	1.09	0.30	204.82	0.92	0.93	0.91	29.76	285.07	857.68
MT64	6.58	25.48	396.35	-4.50	1.01	0.27	196.27	0.92	0.93	0.80	26.23	274.97	854.15
MT65	1.53	8.38	291.76	-3.50	1.10	0.22	186.27	0.92	0.93	0.80	26.98	294.57	749.12
MT66	6.42	16.84	302.74	-11.00	1.02	1.13	194.82	0.08	0.00	0.57	37.13	244.57	989.56
MT67	5.08	23.08	288.51	-4.50	0.42	0.19	193.91	0.29	1.85	0.57	56.94	264.67	868.6

code	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
MT68	6.42	13.51	355.52	-2.50	1.02	0.25	205.16	0.50	0.00	0.57	58.94	285.37	799.63
MT69	7.86	12.84	258.71	-6.50	1.10	0.22	196.73	0.29	2.78	0.51	62.57	294.57	864.56
MT70	10.06	11.25	504.75	-7.50	1.10	1.31	202.82	1.13	0.00	0.51	56.19	274.36	849.84
MT71	5.94	7.63	369.17	-4.25	1.21	0.19	206.28	1.13	0.00	0.80	46.34	294.77	869.02
MT72	8.15	24.18	400.03	-3.25	0.10	0.22	194.64	0.29	0.00	0.74	57.85	244.57	769.02
MT73	10.35	15.03	394.20	-4.75	2.00	0.52	202.09	0.92	0.93	0.57	56.48	264.36	796.55
MT74	11.79	3.48	479.71	-9.00	1.10	0.30	204.82	1.75	0.93	0.63	58.94	284.52	879.84
MT75	4.51	23.41	625.93	-8.00	1.10	0.25	205.82	1.75	0.93	0.63	59.34	264.87	897.58
MT76	8.72	11.25	402.18	-7.25	1.03	1.13	201.91	0.92	0.93	0.57	55.95	254.97	798.4
MT77	5.18	10.22	394.20	-7.75	1.50	0.32	202.82	1.13	0.00	0.51	45.94	264.67	859.53
MT78	7.09	19.25	407.91	-6.50	1.04	0.29	202.82	1.13	0.00	0.51	56.03	274.57	847.68
MT79	7.85	16.84	396.35	-8.25	1.10	0.22	208.13	1.96	1.85	0.63	61.44	294.97	839.53
MT80	10.60	22.52	665.22	-4.75	0.32	0.52	193.91	2.38	0.93	0.57	65.44	275.17	780.6
MW1	87.40	27.56	785.61	-2.25	0.10	0.21	191.91	0.29	0.00	0.17	61.81	267.27	832.5
MW2	92.41	23.60	720.36	-8.00	0.20	0.24	138.73	0.92	0.00	0.11	61.79	256.77	928.66
MW3	84.48	22.39	751.87	-6.00	0.08	0.24	179.18	0.71	0.00	0.11	51.07	286.67	848.92
MW4	96.09	20.93	733.42	-9.50	0.69	0.25	224.13	0.50	0.93	0.17	50.66	276.57	951.56
MW5	92.69	5.34	701.53	-4.25	1.43	0.59	215.55	0.29	1.39	0.17	46.71	295.07	850.98
MW6	80.73	21.34	674.01	-4.25	0.07	0.24	213.91	0.50	0.00	0.11	60.71	305.77	812.56
MW7	88.19	23.86	714.84	-3.25	0.12	0.27	141.36	0.29	0.00	0.11	80.49	306.67	784.88
MW8	96.03	21.99	703.69	-6.50	0.10	0.24	193.18	0.08	0.00	0.23	71.46	310.87	842.76
MW9	92.21	18.00	721.02	-5.50	0.11	0.25	182.09	0.29	0.00	0.11	81.05	312.27	933.08
MW10	80.83	21.52	658.13	-5.25	0.10	0.27	222.82	0.71	0.00	0.11	70.87	306.67	833.08
MW11	82.45	21.39	770.61	-3.50	0.10	0.22	213.18	0.50	0.00	0.11	61.01	313.27	935.14
MW12	79.20	21.53	728.78	-6.50	1.06	0.26	213.55	0.71	0.46	0.06	82.79	296.77	808.46
MW13	81.40	21.39	747.23	-3.50	0.10	0.24	133.73	0.50	0.00	0.11	71.78	457.07	936.6
MW14	82.74	21.65	803.06	1.75	0.11	0.22	224.36	0.29	0.00	0.11	83.48	643.38	841.3
MW15	83.50	20.57	831.29	-3.75	0.12	0.29	225.27	0.08	0.00	0.00	51.02	648.67	939.24
MW16	82.55	17.34	677.34	-5.75	0.11	0.49	202.15	0.71	0.00	0.11	71.84	454.47	832.5
MW17	88.48	10.06	833.00	-1.75	0.11	0.23	155.55	0.29	0.93	0.17	84.83	408.28	936.65
MW18	84.65	26.78	785.39	-7.75	0.11	0.26	162.27	0.29	0.00	0.17	45.43	426.07	838.66
MW19	83.50	23.70	719.19	-8.00	0.14	0.29	192.27	0.92	0.46	0.11	48.77	326.77	842.76
MW20	77.00	22.33	753.63	-9.00	0.11	0.29	193.36	0.50	0.00	0.11	60.75	377.27	820.76
MW21	80.83	18.00	729.66	-9.50	0.10	0.21	196.82	0.29	0.00	0.17	85.99	396.57	933.08
MW22	93.26	5.27	703.53	-7.50	0.10	0.26	183.18	0.08	0.00	0.11	85.68	356.67	851.56
MW23	86.56	24.87	682.83	-7.25	0.11	0.24	156.27	0.50	0.00	0.17	51.6	365.07	963.28
MW24	88.19	24.10	717.18	-7.00	0.20	0.24	164.09	0.71	0.00	0.00	83.64	381.76	814.6
MW25	90.58	21.79	705.63	-4.00	0.11	0.27	192.55	0.50	0.00	0.11	65.53	386.77	910.5
MW26	88.48	21.45	723.77	-8.25	0.13	0.24	193.09	0.71	0.93	0.11	63.47	376.87	820.76
MW27	89.43	17.87	660.46	-4.75	3.10	0.22	182.09	0.08	1.39	0.23	77.05	396.37	814.6
MW28	89.63	21.58	660.35	-5.25	0.20	0.22	201.13	0.71	0.00	0.17	7.83	356.57	935.14
MW29	90.39	21.38	733.13	-6.00	0.10	0.24	203.55	0.29	0.00	0.17	86.91	346.17	839.24
MW30	94.22	21.82	751.21	-8.75	0.11	0.25	213.45	0.29	0.00	0.11	88.32	386.77	810.5
MW31	96.13	21.41	796.86	-8.00	0.10	0.24	211.91	1.33	0.00	0.00	71.85	297.07	940.76
MW32	92.88	21.52	842.40	-5.50	0.10	0.22	211.64	0.29	0.00	0.11	80.91	298.18	985.14
MW33	90.39	17.12	679.53	-4.75	0.11	0.24	215.55	0.50	0.00	0.17	66.85	287.98	989.56
MW34	88.00	20.74	842.16	-9.25	0.10	0.22	215.36	0.92	0.00	0.11	74.47	366.07	842.76
TH1	3.53	11.72	205.83	-14.75	0.09	0.23	225.12	0.50	1.85	0.23	58.49	349.18	872.14
TH2	3.46	13.89	191.70	-15.33	0.08	0.22	214.55	0.50	1.85	0.23	58.35	388.18	951.83
TH3	3.48	12.96	471.23	-17.50	0.07	0.25	209.73	0.71	1.85	0.00	66.74	457.27	825.66
TH4	4.52	15.21	634.90	-13.50	0.07	0.24	208.09	0.71	1.85	0.11	65.28	427.57	872.14
TH5	2.66	11.57	235.17	-14.67	0.08	0.24	213.45	1.13	1.85	0.11	69.75	425.87	929.28
TH6	4.48	14.06	326.90	-16.58	0.08	0.24	213.82	0.92	0.93	0.23	71.66	418.48	841.83
TH7	3.15	14.24	531.10	-15.75	0.44	0.24	213.82	0.92	0.00	0.23	64.45	437.77	952.14
TH8	3.01	15.41	464.03	-16.58	0.09	0.23	208.09	0.92	0.93	0.00	55.16	418.08	962.96
TH9	2.98	15.03	460.07	-16.75	0.08	0.24	211.18	0.50	0.93	0.00	85.25	318.68	812.04
TH10	3.14	10.78	574.00	-17.33	0.08	0.24	222.13	0.92	1.85	0.11	66.62	307.87	862.86

code	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
TH11	2.90	12.83	440.77	-16.33	0.07	0.22	214.55	1.33	1.85	0.34	56.61	407.27	829.28
TH12	2.13	14.55	390.17	-16.50	0.08	0.23	252.13	1.13	0.93	0.23	81.76	457.07	925.66
TH13	2.47	13.99	464.63	-16.08	0.07	0.24	213.45	0.50	0.93	0.11	61.94	417.98	842.04
TH14	1.11	13.43	691.07	-11.25	0.07	0.24	214.45	1.33	1.85	0.23	66.39	438.18	942.55
TH15	1.74	15.13	278.53	-7.25	0.07	0.23	211.91	0.92	1.85	0.11	55.03	418.88	942.45
TH16	3.51	14.77	280.60	-15.75	0.08	0.24	211.45	0.50	0.93	0.23	64.97	398.28	962.45
TH17	2.54	14.15	704.70	-15.50	0.08	0.76	214.91	1.13	0.93	0.23	56.36	357.67	942.14
TH18	1.30	17.00	303.23	-16.50	0.07	0.24	210.91	0.71	1.39	0.11	68.41	385.77	843.47
TH19	2.49	15.40	264.50	-13.25	0.08	0.23	212.09	0.50	1.85	0.17	48.08	297.67	942.65
TH20	4.61	13.45	676.47	-11.75	0.08	0.24	212.09	0.92	0.93	0.23	48.19	287.87	792.14
TH21	0.81	16.37	621.70	-13.83	0.08	0.23	209.45	1.33	0.93	0.11	76.43	268.08	812.86
TH22	3.72	15.02	469.30	-7.58	0.07	0.24	203.55	0.50	1.39	0.11	84.24	357.77	881.93
TH23	4.24	14.23	417.00	-16.33	0.08	0.25	190.82	1.75	0.93	0.23	84.67	276.27	941.83
TH24	4.41	13.89	422.57	-17.50	0.07	0.21	212.09	1.13	0.93	0.17	88.32	335.77	819.5
TH25	3.59	15.21	475.20	-16.83	0.07	0.24	211.45	1.75	0.93	0.11	48.41	457.77	980.83
TH26	3.11	10.66	457.00	-14.25	0.07	0.23	211.45	1.96	1.85	0.17	48.31	450.87	842.45
TH27	3.87	11.35	509.70	-15.08	0.07	0.24	213.55	2.58	0.93	0.23	54.91	557.47	952.45
TH28	3.96	13.44	486.77	-16.83	0.08	0.24	212.82	1.13	0.93	0.45	56.78	445.57	986.24
TH29	2.20	13.19	434.77	-15.42	0.08	0.23	215.64	0.92	0.93	0.63	55.39	285.57	926.24
TH30	4.20	14.81	470.37	-14.42	0.07	0.23	216.73	0.71	0.93	0.40	70.61	269.78	818.09
TH31	3.23	11.41	480.37	-12.58	0.08	0.21	133.91	1.54	0.00	0.28	59.11	354.36	866.24
NK1	3.48	11.15	671.63	-9.00	0.08	0.23	120.55	0.71	2.78	0.51	45.83	349.68	847.99
NK2	5.09	13.06	648.03	-13.75	0.07	0.79	167.64	0.71	0.93	0.51	570.8	384.97	975.73
NK3	4.83	12.33	539.07	-9.75	0.08	0.23	165.18	1.75	0.93	0.40	54.98	295.57	787.27
NK4	2.47	14.43	132.03	-11.83	0.08	0.21	215.82	1.96	1.85	0.40	41.32	414.57	796.24
NK5	5.21	11.01	561.13	-16.25	0.07	0.21	222.36	1.75	0.93	0.91	51.99	456.67	806.96
NK6	3.86	13.07	561.13	-15.75	0.08	0.79	222.15	0.71	0.93	0.57	46.38	455.37	837.58
NK7	2.93	13.56	128.17	-15.67	0.07	0.21	210.18	1.13	0.00	0.57	61.99	459.58	847.48
NK8	2.55	14.16	388.97	-8.08	0.07	0.21	219.27	0.92	0.00	0.51	65.34	424.67	876.24
NK9	1.17	14.18	397.43	-10.42	0.08	0.19	218.18	0.92	0.93	0.34	56.62	419.58	867.78
NK10	2.52	10.25	615.97	-15.83	0.07	0.21	223.82	0.92	1.85	0.23	69.12	429.68	947.99
NK11	5.55	12.23	532.13	-16.25	0.07	0.22	147.27	1.13	0.93	0.45	73.71	428.38	907.17
NK12	3.41	14.15	248.30	-16.33	0.08	0.22	199.17	0.29	0.00	0.51	77.18	393.96	955.73
NK13	4.77	13.43	235.97	-14.33	0.08	0.24	139.09	0.71	0.00	0.23	53.83	348.68	977.27
NK14	5.22	12.83	539.73	-15.58	0.07	0.22	198.36	0.71	0.00	0.28	57.73	367.77	947.68
NK15	3.70	14.41	489.53	-7.92	0.08	0.24	202.36	1.13	0.93	0.23	65.87	355.47	827.99
NK16	1.91	14.19	167.73	-15.25	0.08	0.22	190.09	0.71	0.93	0.17	77.72	376.47	846.65
NK17	4.81	13.63	273.43	-14.42	0.08	0.24	200.64	1.75	1.85	0.34	79.87	297.57	876.96
NK18	5.16	16.24	383.20	-15.00	0.07	0.21	133.64	1.54	1.85	0.34	82.03	275.77	916.96
NK19	2.99	13.42	616.07	-16.58	0.08	0.24	206.09	2.38	0.93	0.68	87.59	291.76	792.34
NK20	2.94	12.93	546.50	-14.33	0.08	0.17	164.36	1.33	0.93	0.45	85.87	286.27	788.3
NK21	3.02	15.64	533.47	-16.42	0.09	0.19	207.55	0.92	0.93	0.45	81.85	358.68	786.07
NK22	5.17	14.58	519.87	-17.25	0.08	0.12	203.18	0.71	2.31	0.23	82.03	348.18	866.86
NK23	2.21	13.49	371.03	-16.17	0.30	0.21	189.27	1.33	0.93	0.40	80.47	394.47	795.83
NK24	5.51	13.11	439.00	-17.17	0.07	0.24	205.64	0.71	0.00	0.40	83.23	382.86	936.35
NK25	3.88	14.39	646.47	-16.33	0.08	0.24	139.45	2.58	1.85	0.63	81.32	419.68	818.5
NK26	3.41	10.07	267.10	-14.25	0.08	0.12	159.91	0.92	1.85	0.40	87.73	449.08	783.78
NK27	2.05	10.81	262.47	-14.25	0.09	0.79	149.91	0.29	0.93	0.34	82.06	438.08	876.86
NK28	2.54	12.66	662.50	-16.25	0.08	0.79	193.27	1.54	1.85	0.51	78.27	429.78	868.09
NK29	3.90	12.54	296.87	-14.25	0.08	0.21	151.18	3.42	0.93	1.19	56.2	397.57	796.96
NK30	5.76	14.06	146.77	-13.00	0.07	0.22	200.55	1.13	0.93	0.45	81.21	379.78	787.78
NK31	6.10	10.88	249.07	-17.25	0.08	0.17	220.55	2.38	1.85	0.57	73.03	388.48	790.79
NK32	6.45	11.04	631.07	-15.00	0.07	0.24	206.09	1.75	1.85	0.57	79.84	288.08	980.68
NK33	5.63	12.90	467.83	-14.75	0.07	0.23	209.73	0.71	0.00	0.51	55.53	298.18	846.96
NK34	3.74	14.55	386.03	-17.17	0.09	0.21	207.76	1.33	0.46	0.45	65.34	288.08	876.76
NK35	5.07	13.98	349.83	-14.75	0.08	0.21	217.36	1.13	0.93	0.28	77.69	293.06	863.68
NK36	2.23	13.43	356.20	-16.00	0.07	0.22	217.27	4.67	0.93	0.57	66.42	299.48	797.78

code	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
NK37	4.09	15.13	385.47	-13.00	0.07	0.19	213.18	0.29	1.85	0.34	75.34	298.68	787.58
NK38	5.55	14.79	382.07	-14.75	0.08	0.79	155.64	0.50	0.00	0.40	84.73	285.36	946.14
NK39	4.19	14.14	422.33	-16.00	0.08	0.21	192.27	0.50	0.00	0.40	65.53	425.37	937.58
NK40	5.61	17.04	404.33	-17.00	0.09	0.21	194.27	1.75	0.00	0.45	66.42	449.18	907.68
NK41	5.88	13.77	363.80	-17.00	0.08	0.22	163.82	1.33	1.85	0.51	81.84	292.16	942.04
NK42	5.42	13.48	387.57	-14.83	0.08	0.19	169.27	0.92	0.93	0.40	71.99	303.96	834.56
NK43	4.01	16.36	400.03	-15.58	0.07	0.21	206.64	0.92	1.85	0.34	86.42	307.98	784.73
NK44	6.14	15.01	463.17	-16.00	0.08	0.12	207.91	0.50	0.00	0.40	56.07	386.77	956.55
NK45	2.59	13.65	554.30	-9.00	0.07	0.21	209.91	0.08	0.00	0.23	82.02	409.58	787.37
NK46	5.87	16.11	448.10	-17.00	0.07	0.22	187.64	1.96	0.93	0.51	86.43	408.18	817.27
NK47	3.66	12.18	456.43	-14.17	0.07	0.22	198.63	1.75	0.93	0.51	53.03	415.37	857.78
NK48	2.02	15.01	517.93	-15.58	0.09	0.19	188.64	1.33	1.85	0.57	77.44	429.48	948.09
NK49	5.59	15.05	320.50	-16.00	0.08	0.22	199.82	1.13	1.85	0.34	83.23	402.86	786.35
NK50	4.47	16.59	232.37	-17.33	0.07	0.21	215.91	0.92	0.93	0.57	53.83	408.68	947.27
NK51	5.96	15.95	598.33	-16.00	0.08	0.22	210.18	1.13	1.85	0.45	65.39	425.57	926.24
NK52	2.54	11.36	412.23	-14.83	0.08	0.22	155.64	0.50	1.85	0.40	86.42	439.18	867.68
C1	52.85	6.35	246.25	-19.00	0.20	0.29							
C2	4.79	15.74	422.76	-10.25	0.43	0.22							
C3	19.53	7.55	372.43	-6.25	0.69	0.14							
C4	0.00	11.27	451.31	-9.75	2.31	0.23							
C5	4.02	10.07	330.36	-10.25	6.26	0.22							
C6	47.69	7.55	408.04	-6.00	0.12	0.24							
C7	5.75	10.41	382.96	-7.25	2.11	0.24							
C8	3.06	10.29	338.60	-8.25	0.32	0.24							
C9	20.02	9.88	421.45	-12.00	0.33	0.21							
C10	5.55	8.93	332.75	-10.50	0.52	0.28							
C11	4.50	10.12	510.52	-8.50	1.09	0.20							
C12	4.88	3.07	371.56	5.25	1.20	0.22							
C13	19.44	10.20	254.38	-18.75	0.95	0.18							
C14	44.53	8.81	365.83	-14.50	1.09	0.26							
C15	41.28	7.21	388.43	-10.75	0.41	0.20							
C16	7.37	11.31	333.86	2.00	0.16	0.28							
C17	4.88	7.60	393.26	-11.00	1.10	0.21							
C18	7.76	15.90	248.69	-8.75	1.00	0.24							
C19	8.33	7.84	409.57	-8.25	0.31	0.20							
C20	8.43	11.31	338.47	-7.00	0.91	0.24							
C21	8.72	7.78	456.80	-6.75	0.24	0.26	211.45	1.96	1.85	0.23	68.13	253.06	981.16
C22	7.85	10.64	307.81	-7.50	2.13	0.21	217.36	0.50	0.93	0.11	80.44	285.8	924.42
C23	6.03	9.07	410.12	-6.25	1.11	0.26	139.45	0.92	0.93	0.57	46.29	316.66	871.32
C24	4.50	17.13	387.39	-14.50	1.12	0.24	149.91	1.13	1.85	0.11	58.66	395.57	823.29
C25	54.59	8.43	337.44	-8.25	1.92	0.24	212.09	0.50	1.85	0.23	56.01	414.77	981.73
C26	5.55	10.23	432.76	-13.00	1.22	0.24	211.18	0.50	1.85	0.06	79.22	450.15	790.68
C27	20.30	9.28	332.84	-14.00	0.32	0.22	212.27	0.29	0.93	0.23	83.76	457.58	822.45
C28	4.50	7.44	502.19	-7.00	0.22	0.24	211.91	0.50	1.85	0.23	61.69	438.08	872.34
C29	49.51	11.20	365.83	-7.50	2.04	0.14	215.27	0.92	1.85	0.23	62.12	428.68	922.45
C30	6.51	7.71	252.10	-8.50	1.11	0.22	211.45	0.50	1.85	0.11	68.15	397.87	925.66
C31	0.57	10.19	413.45	-7.00	1.11	0.20	210.91	0.50	1.85	0.17	84.15	398.48	825.66
C32	20.59	7.92	389.75	-12.50	1.30	0.29	211.18	0.50	1.39	0.17	56.42	348.68	951.83
C33	5.84	7.07	330.49	-10.25	1.10	0.23	208.09	0.92	1.85	0.11	65.61	438.98	862.04
C34	53.92	7.85	389.60	-9.50	1.33	0.22	205.27	0.92	0.93	0.17	56.68	449.08	892.14
C35	34.96	15.60	299.65	-9.75	0.20	0.28	210.82	0.50	1.85	0.11	66.53	440.25	821.69
C36	5.65	7.84	419.22	-8.00	0.43	0.24	210.91	0.71	1.85	0.06	48.31	446.77	872.04
C37	7.09	6.35	385.17	-12.75	0.69	0.24	214.45	0.92	1.85	0.28	64.09	457.17	821.96
C38	10.73	12.62	453.23	-9.00	2.31	0.22	217.91	1.33	1.85	0.23	65.44	446.28	912.14
C39	12.74	11.22	440.66	-8.25	0.31	0.28	211.45	0.50	1.85	0.17	83.01	458.7	852.45
C40	13.70	17.20	262.35	-7.25	0.12	0.28	165.27	0.92	1.85	0.23	54.35	296.77	818.26

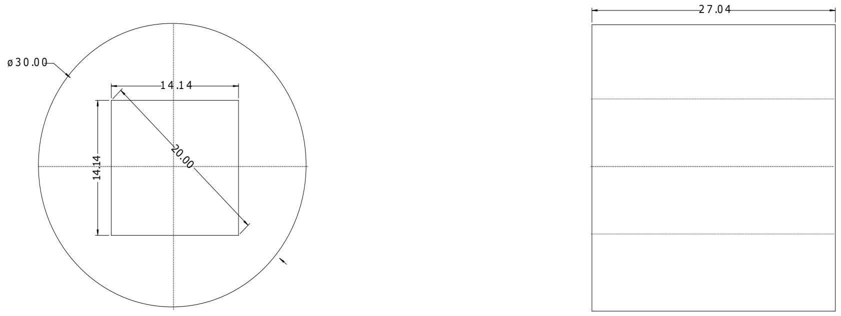
KEY:

A:Reducing sugar before hydrolysis
B:Reducing sugar after hydrolysis
C:Sucrose content
D:Refractive index
E:moisture content
F:pH
G:Free acidity
H:Electrical conducitivity
I:percentage ash content
J:viscosity at 25ºC
K:Viscosity at 30ºC
L:Viscosity at 35ºC
M:Viscosity at 40ºC
N:Density
O:HMF
P:Diastase activity
Q:proline content
S:Insoluble matter
S:Insoluble matter
T:Hygroscopicity
U:Calcium concentration in Mg/L
V:Iron concentration in Mg/L
W:Copper concentration in Mg/L
X:Manganese concentration in Mg/L
Y:Magnesium concentration in Mg/L
Z:Sodium concentration in Mg/L
AA:Potassium concentration in Mg/L

Appendix 1B:Relationship of Water Content of Honey to Refractive Index

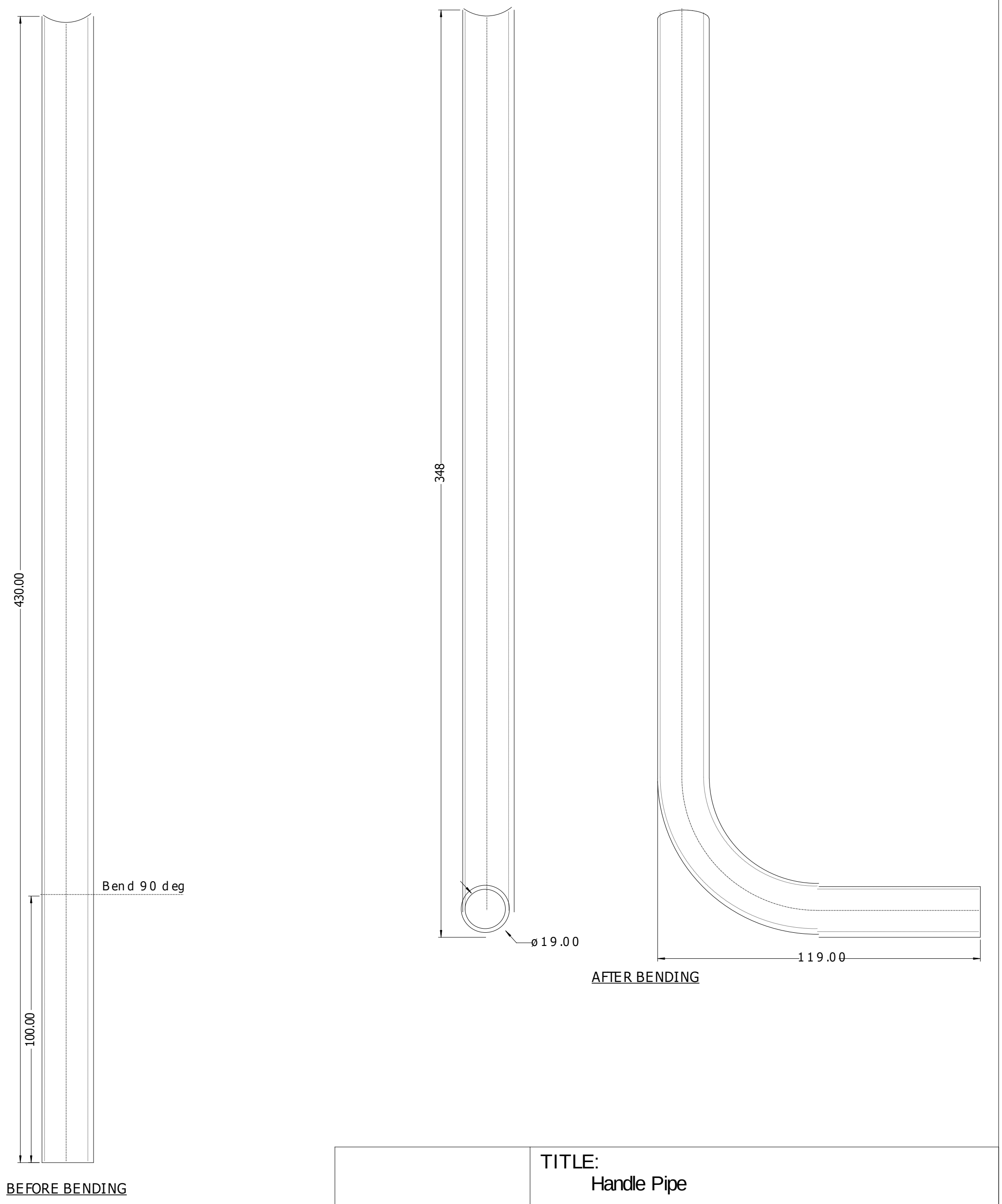
Water Content	**Refractive Index**	**Water Content**	**Refractive Index**
g/100 g	20^{o} C	g/100 g	20^{o} C
13.0	1.5044	19.2	1.4885
13.2	1.5038	19.4	1.4880
13.4	1.5033	19.6	1.4875
13.6	1.5028	19.8	1.4870
13.8	1.5023	20.0	1.4865
14.0	1.5018	20.2	1.4860
14.2	1.5012	20.4	1.4855
14.4	1.5007	20.6	1.4850
14.6	1.5002	20.8	1.4845
14.8	1.4997	21.0	1.4840
15.0	1.4992	21.2	1.4835
15.2	1.4987	21.4	1.4830
15.4	1.4982	21.6	1.4825
15.6	1.4976	21.8	1.4820
15.8	1.4971	22.0	1.4815
16.0	1.4966	22.2	1.4810
16.2	1.4961	22.4	1.4805
16.4	1.4956	22.6	1.4800
16.6	1.4951	22.8	1.4795
16.8	1.4946	23.0	1.4790
17.0	1.4940	23.2	1.4785
17.2	1.4935	23.4	1.4780
17.4	1.4930	23.6	1.4775
17.6	1.4925	23.8	1.4770
17.8	1.4920	24.0	1.4765
18.0	1.4915	24.2	1.4760
18.2	1.4910	24.4	1.4755
18.4	1.4905	24.6	1.4750
18.6	1.4900	24.8	1.4745
18.8	1.4895	25.0	1.4740
19.0	1.4890		

Appendix 2A: Component Drawings of Drive Assembly-**Handle Bush**



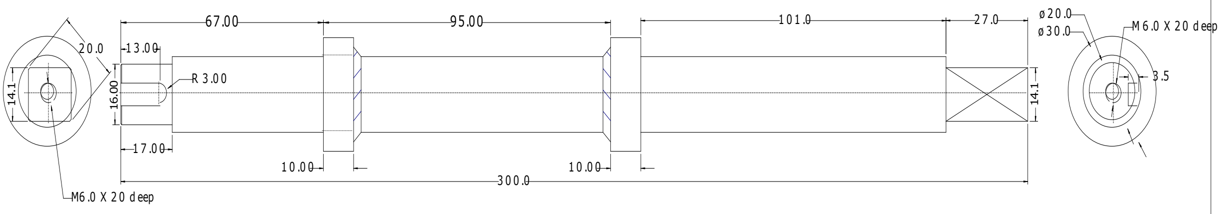
All dimensions in mm.		TITLE: Handle Bush			
DESIGNED		PROJECT REFERENCE	RRMBICH 001		REV.
CHECKED					
APPROVED					
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 01 - 02 - 1	SHEET 1 OF 1	
SCALE	2:1				

Appendix 2B: Component Drawings of Drive Assembly-**Handle Pipe**



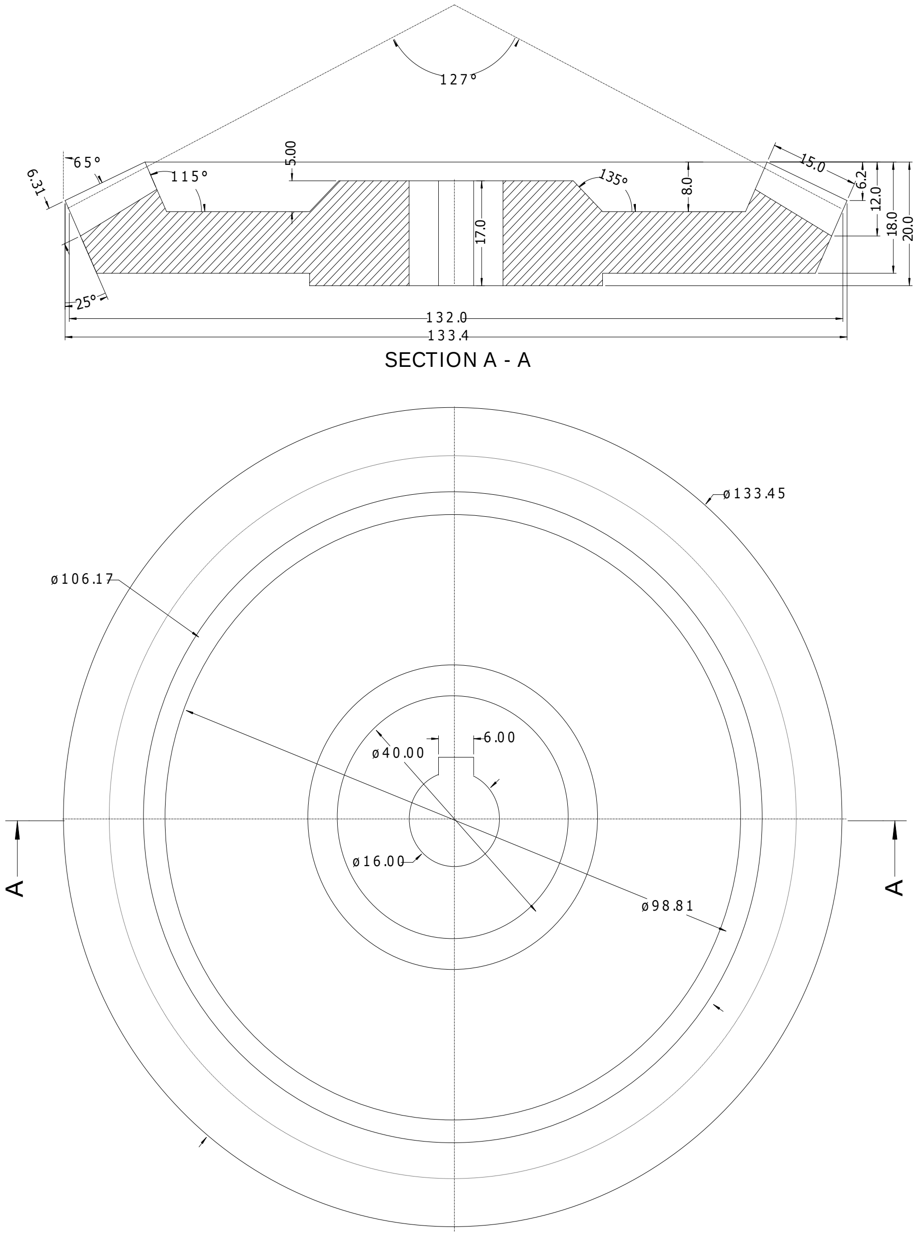
All dimensions in mm.		TITLE: Handle Pipe			
DESIGNED		PROJECT REFERENCE	RRMBICH 001		REV.
CHECKED					
APPROVED					
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 01 - 02 - 2	SHEET 1 OF 1	
SCALE	1:2				

Appendix 2C: Component Drawings of Drive Assembly-**Drive Shaft**



All dimensions in mm.		TITLE: Drive Shaft			
DESIGNED		PROJECT REFERENCE	RRMBICH 001		REV.
CHECKED					
APPROVED					
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 01 - 03	SHEET 1 OF 1	
SCALE	2:3				

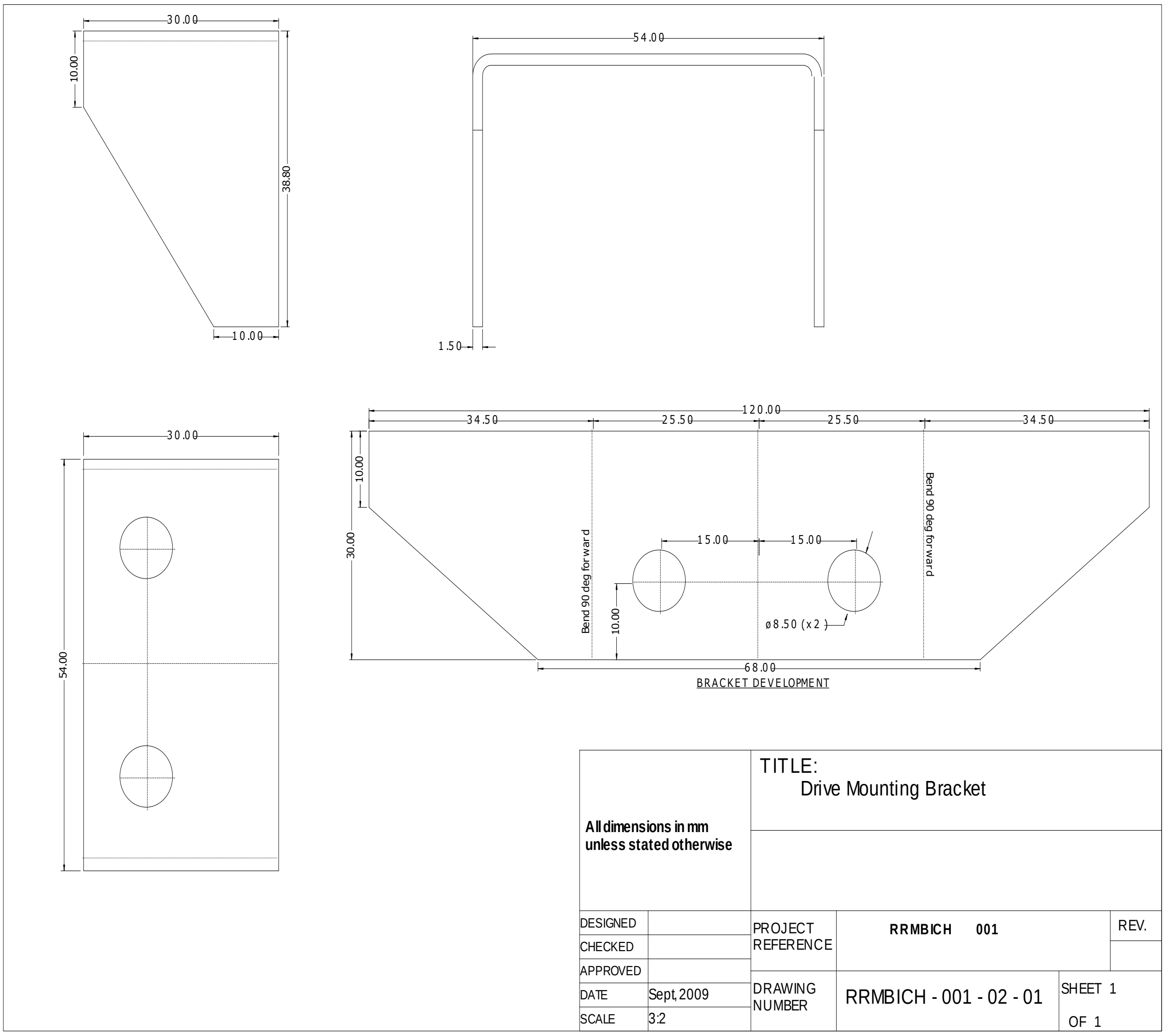
Appendix 2D: Component Drawings of Drive Assembly-**Bevel Gear Driver**



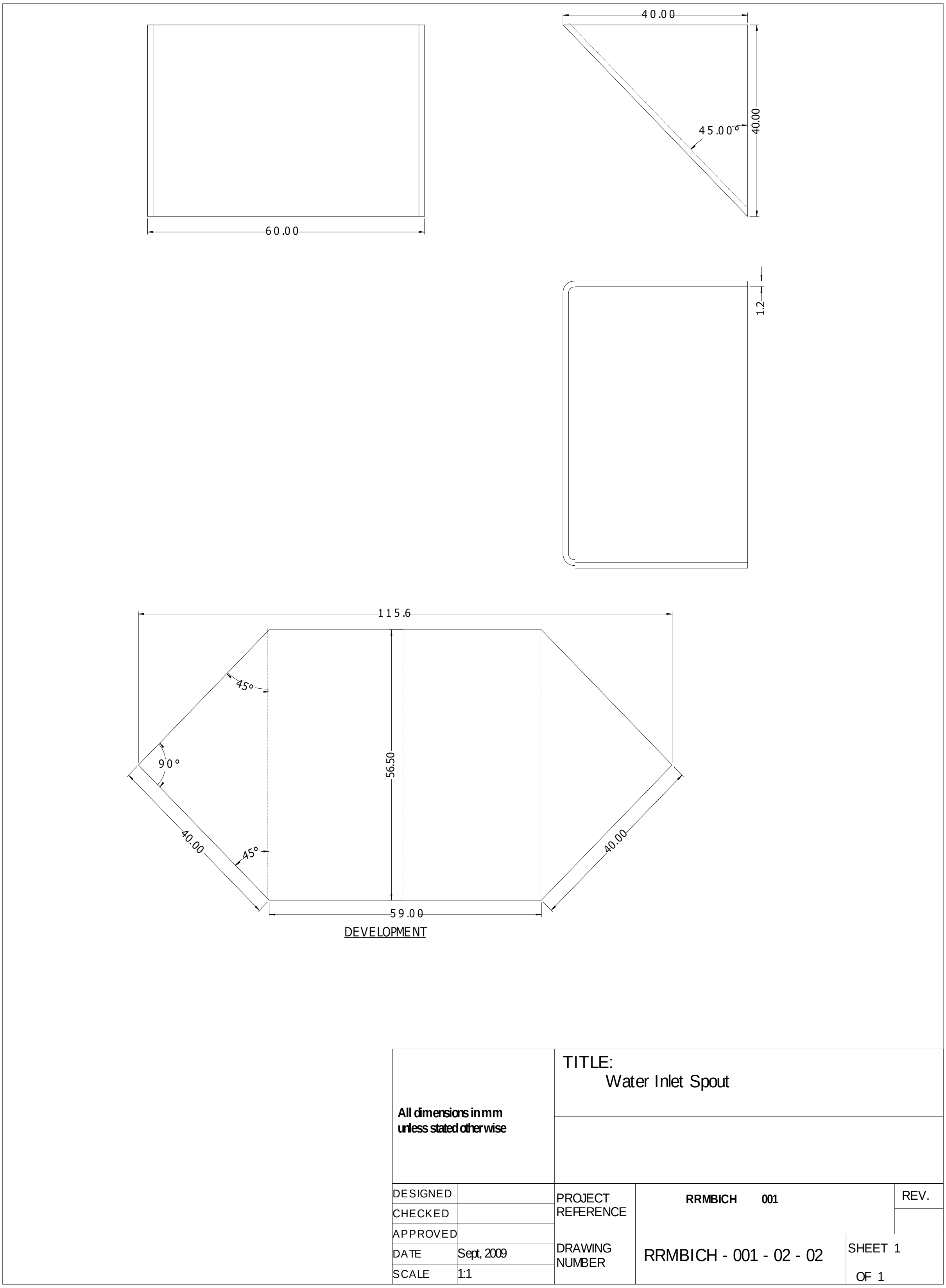
All dimensions in mm. unless stated otherwise		TITLE: Bevel Gear - Driver		
DESIGNED		PROJECT REFERENCE	**RRMBICH 001**	REV.
CHECKED				
APPROVED				
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 01 - 05	SHEET 1
SCALE	1:1			OF 1

NOTES:
Material: Nylon
Module: 3
No. of teeth: 44

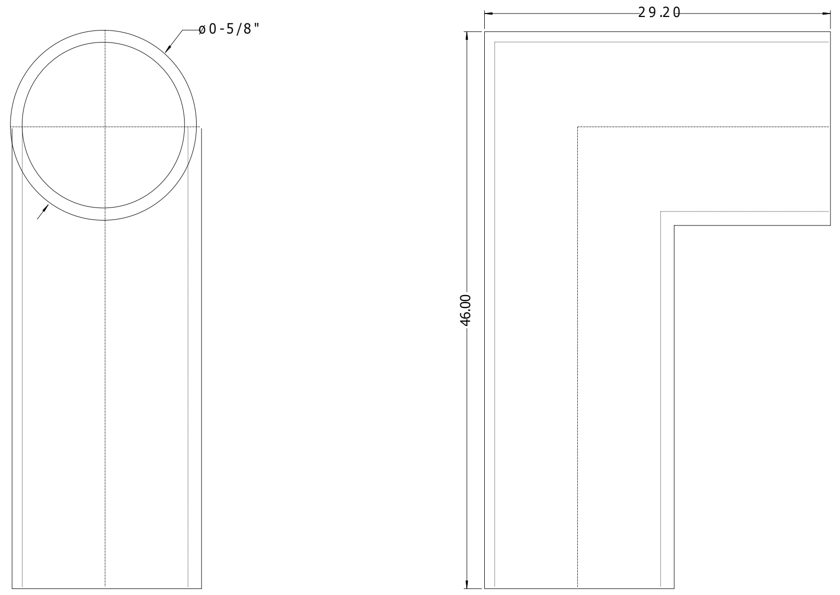
Appendix 3A: Design Component Drawings of Vessel Assembly-**Drive Mounting Bracket**



Appendix 3B: Design Component Drawings of Vessel Assembly-**Water Inlet Spout**

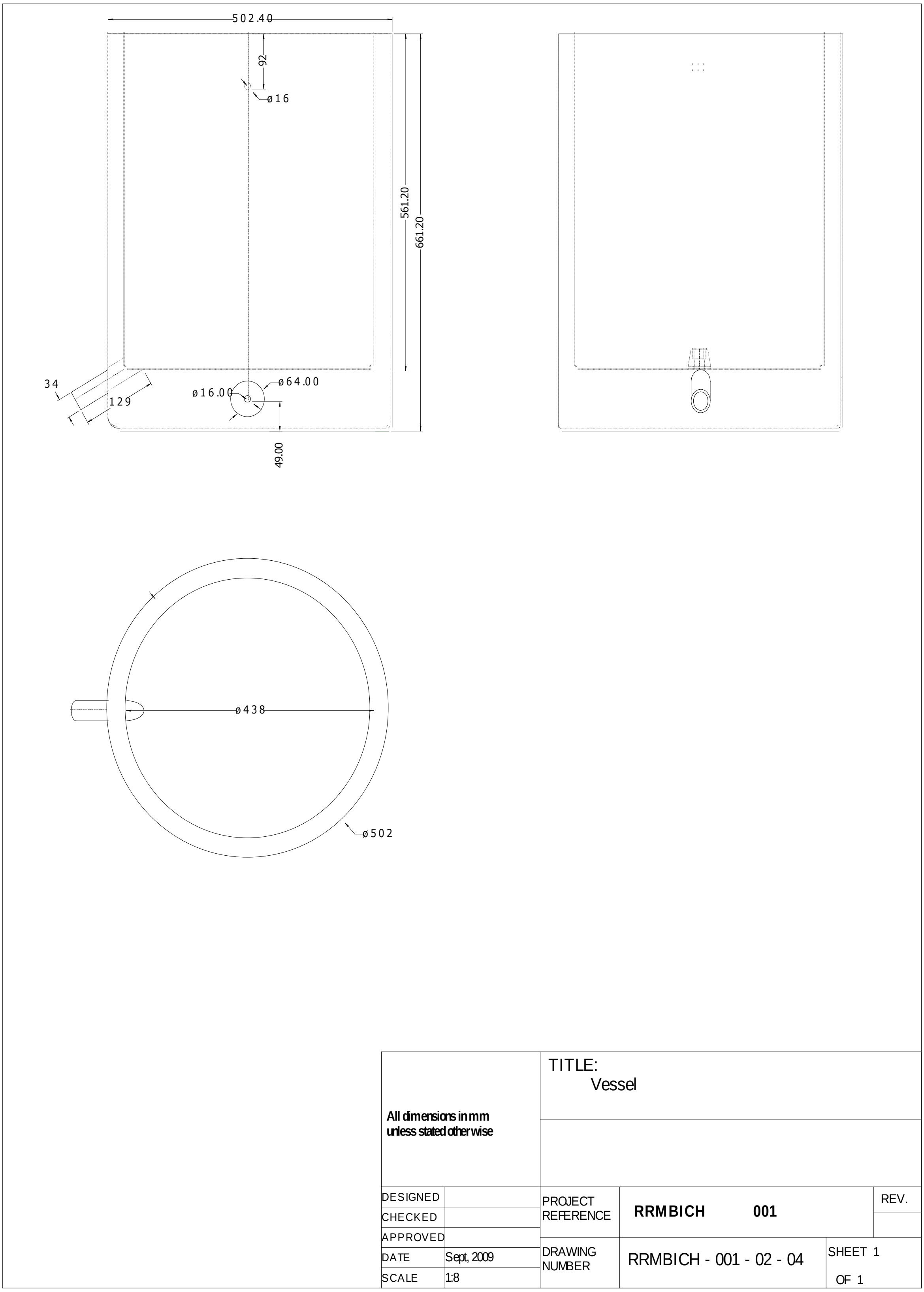


Appendix 3C: Design Component Drawings of Vessel Assembly-**Sight Glass Mounting**

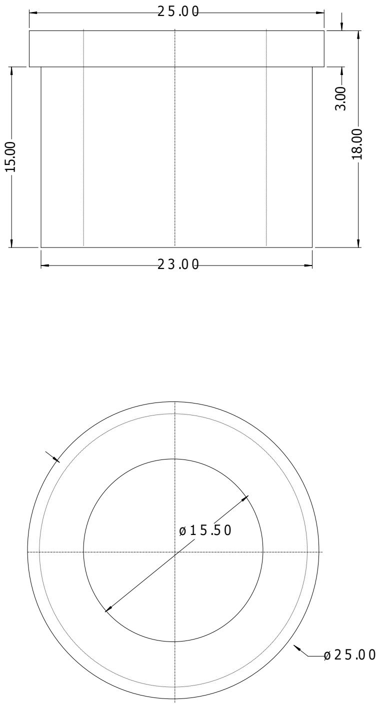


All dimensions in mm unless stated other wise		TITLE: Sight Glass Mounting		
DESIGNED		PROJECT REFERENCE	RRMBICH 001	REV.
CHECKED				
APPROVED				
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 02 - 03	SHEET 1 OF 1
SCALE	2:1			

Appendix 3D: Design Component Drawings of Vessel Assembly-**Vessel**

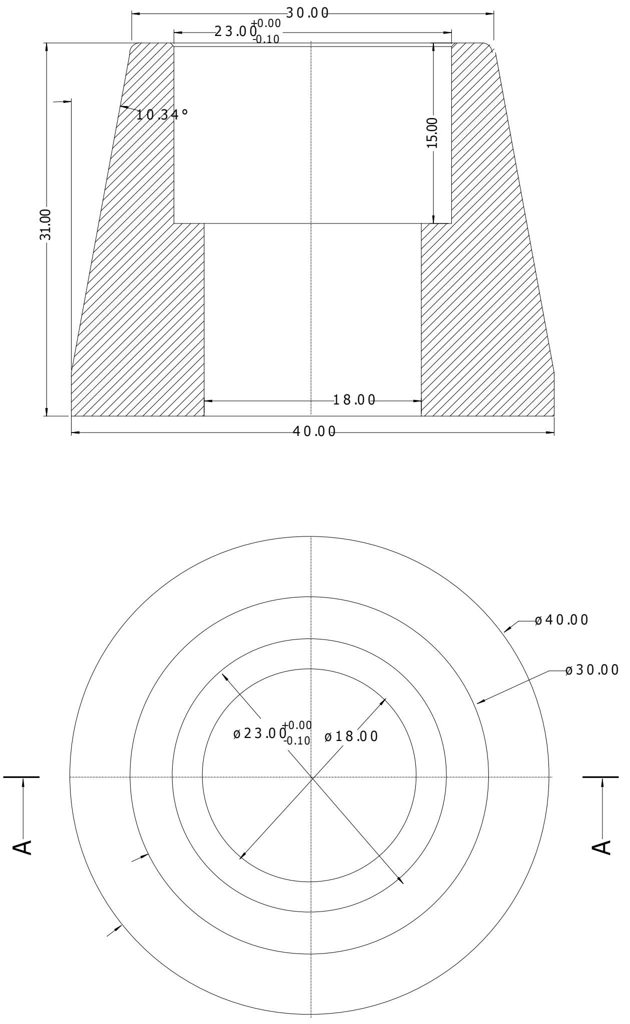


Appendix 3E: Design Component Drawings of Vessel Assembly-**Bearing Bush**



All dimensions in mm.		TITLE: Bearing Bush			
DESIGNED		PROJECT REFERENCE	RRMBICH 001		REV.
CHECKED					
APPROVED					
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 02 - 05	SHEET 1 OF 1	
SCALE	2:1				

Appendix 3F: Design Component Drawings of Vessel Assembly-**Vessel Bush**

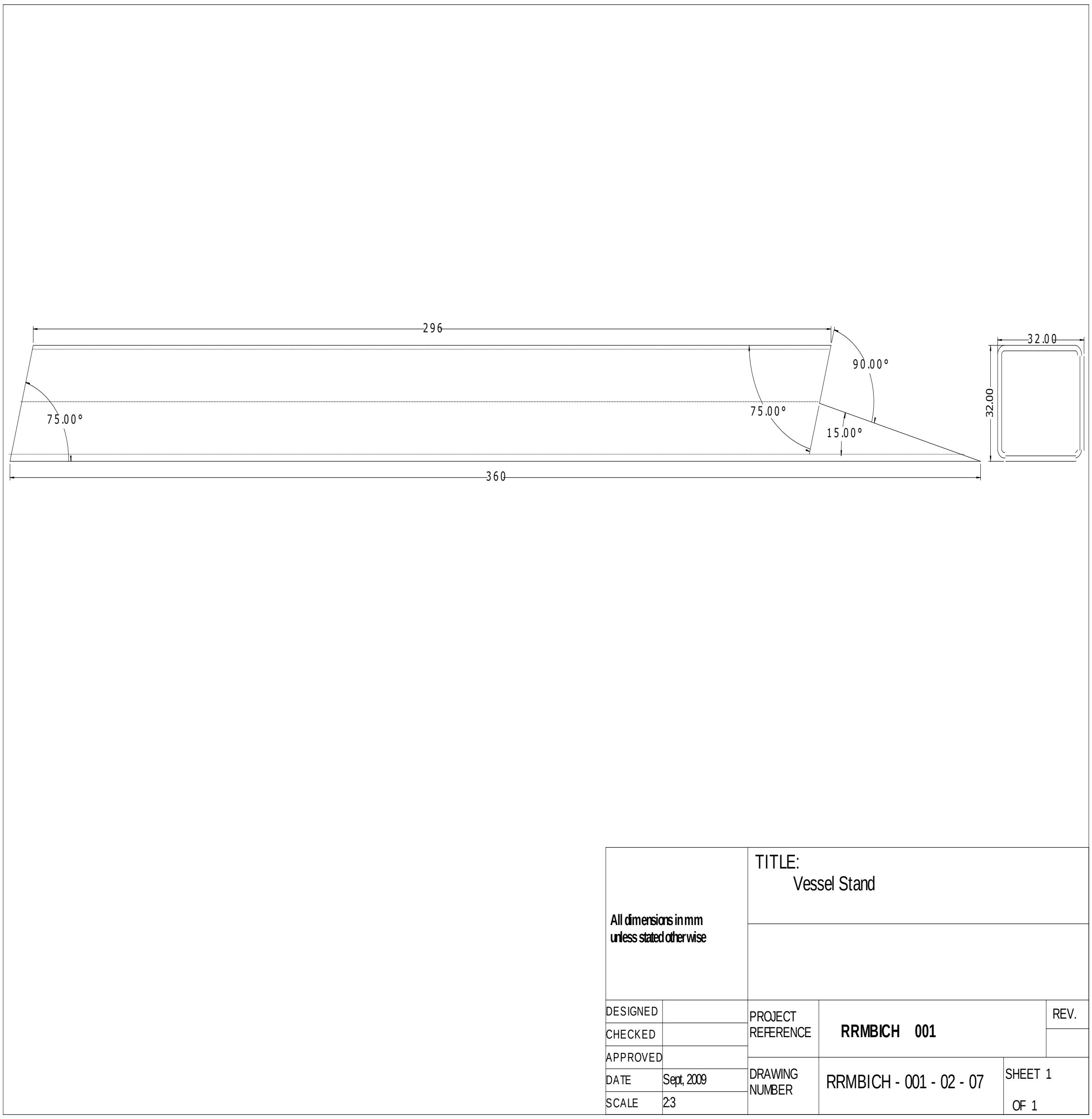


All dimensions in mm
unless stated other wise

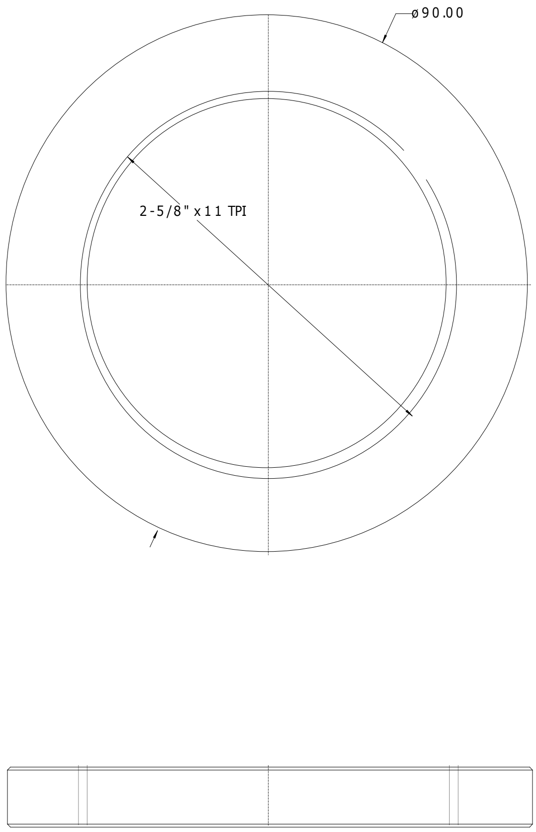
TITLE:
Vessel Bush

DESIGNED		PROJECT REFERENCE	RRMBICH 001		REV.
CHECKED					
APPROVED		DRAWING NUMBER	RRMBICH - 001 - 02 - 06	SHEET 1 OF 1	
DATE	Sept, 2009				
SCALE	2:1				

Appendix 3G: Design Component Drawings of Vessel Assembly-**Vessel Stand**

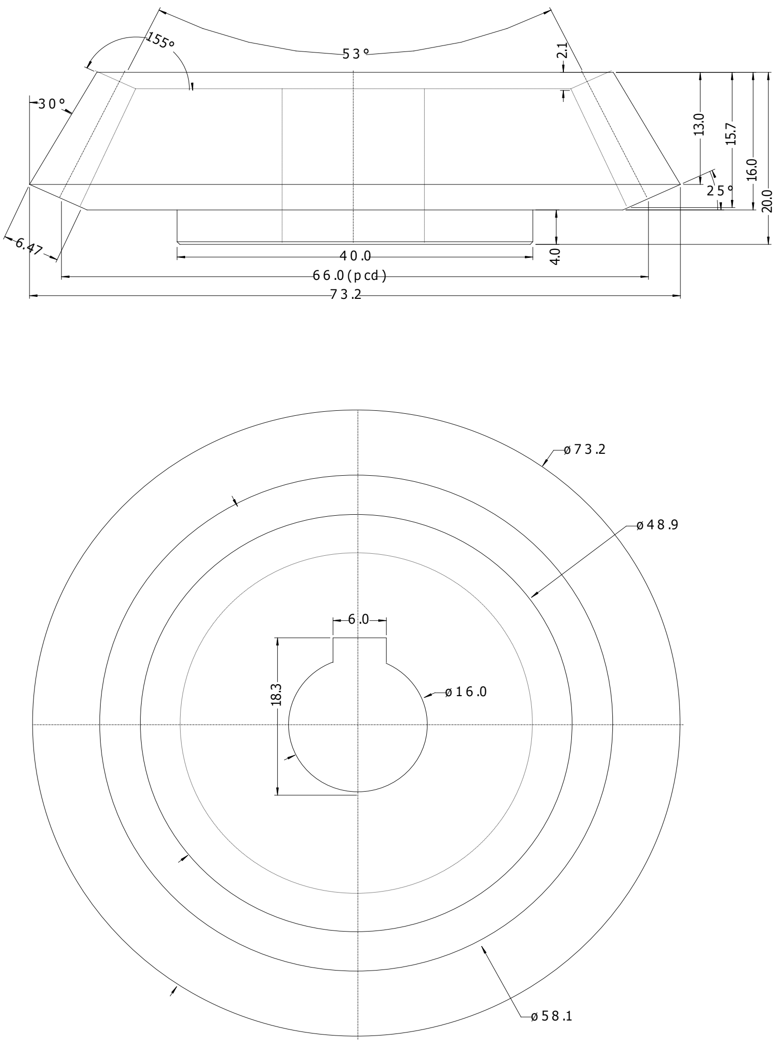


Appendix 3H: Design Component Drawings of Vessel Assembly-**Heater Nut**



All dimensions in mm unless stated otherwise		TITLE: Heater Nut		
DESIGNED		PROJECT REFERENCE	RRMBICH 001	REV.
CHECKED				
APPROVED				
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 02 - 08	SHEET 1 OF 1
SCALE	1:1			

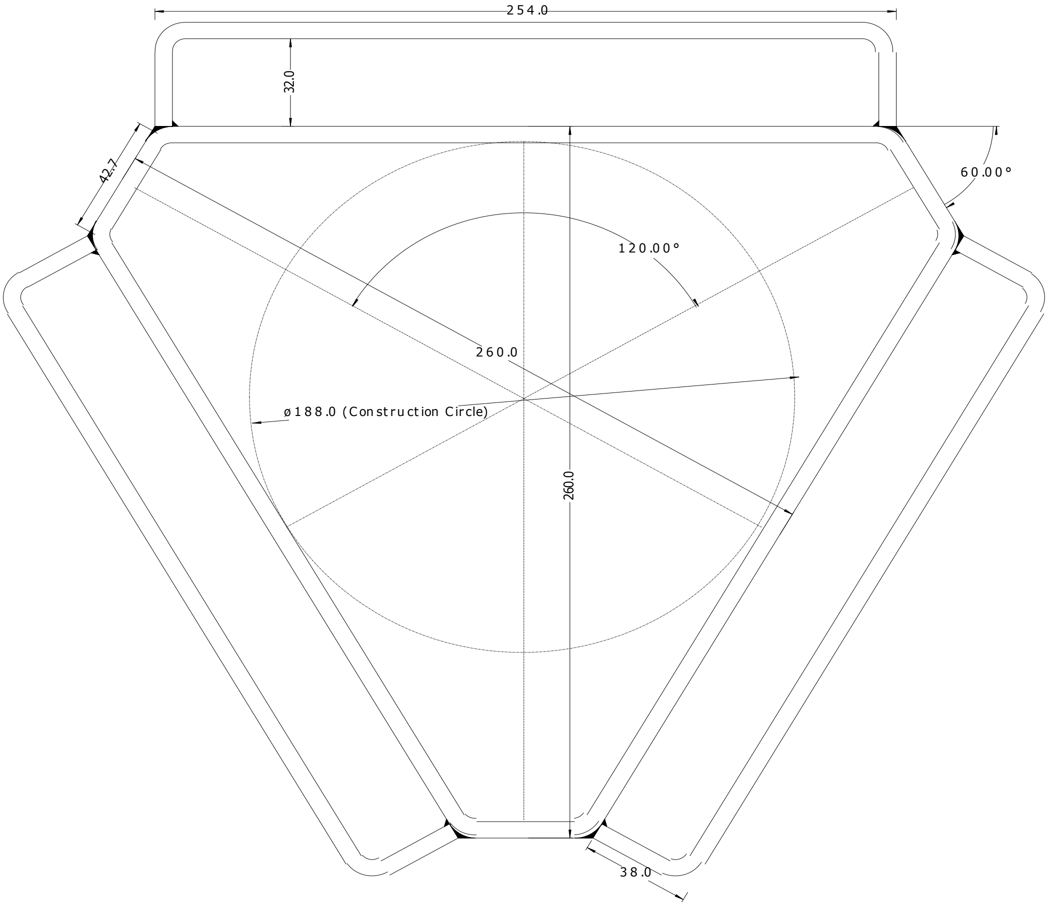
Appendix 4A: Design Component Drawings of Rotor Assembly-**Bevel Gear Driven**



All dimensions in mm unless stated otherwise		TITLE: Bevel Gear - Driven		
DESIGNED		PROJECT REFERENCE	**RRMBICH 001**	REV.
CHECKED				
APPROVED				
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 03 - 01	SHEET 1 OF 1
SCALE	3:2			

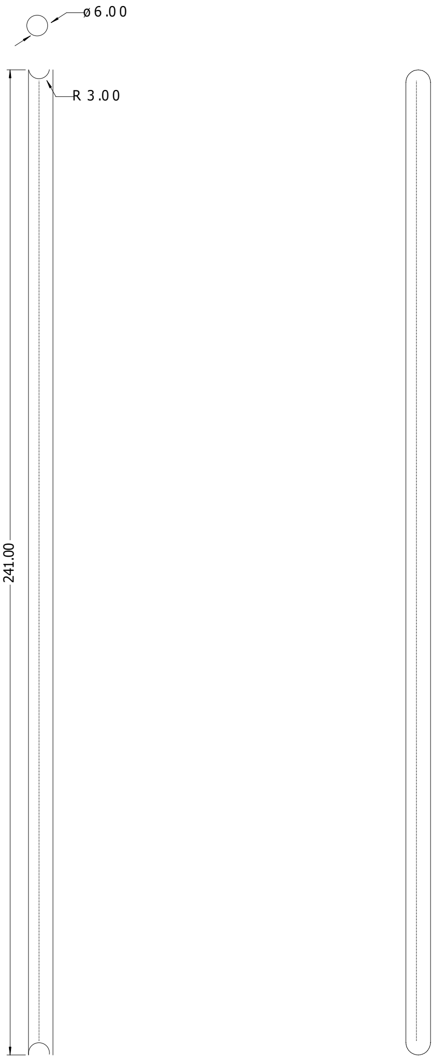
NOTES:
Module-3
No. of teeth - 22

Appendix 4B: Design Component Drawings of Rotor Assembly-**Frame Cage**



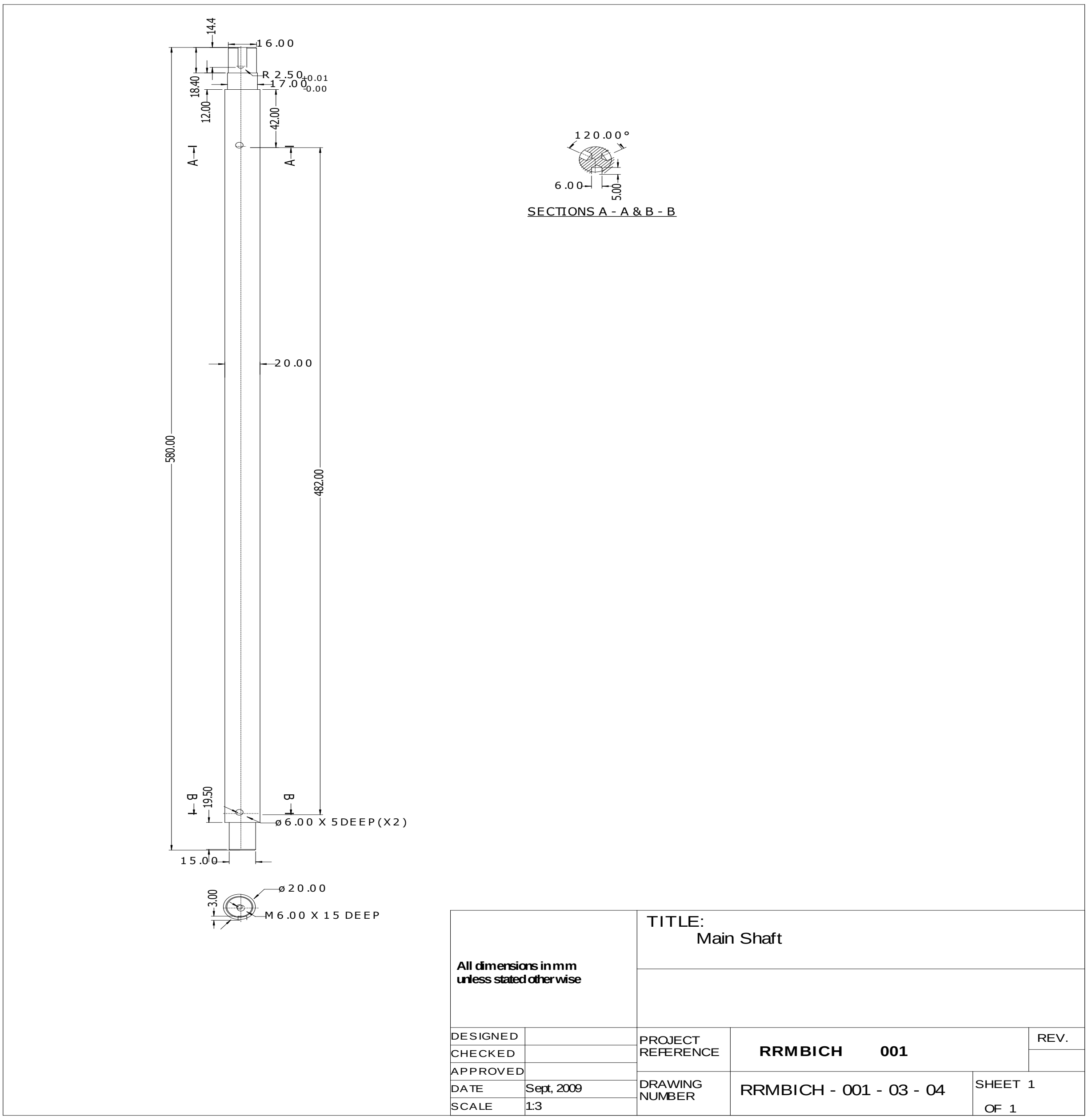
All dimensions in mm unless stated otherwise		TITLE: Frame Cage		
DESIGNED		PROJECT REFERENCE	RRMBICH 001	REV.
CHECKED				
APPROVED		DRAWING NUMBER	RRMBICH - 001 - 03 - 02	SHEET 1 OF 1
DATE	Sept, 2009			
SCALE	1:2			

Appendix 4C: Design Component Drawings of Rotor Assembly-**Stiffener Bar**

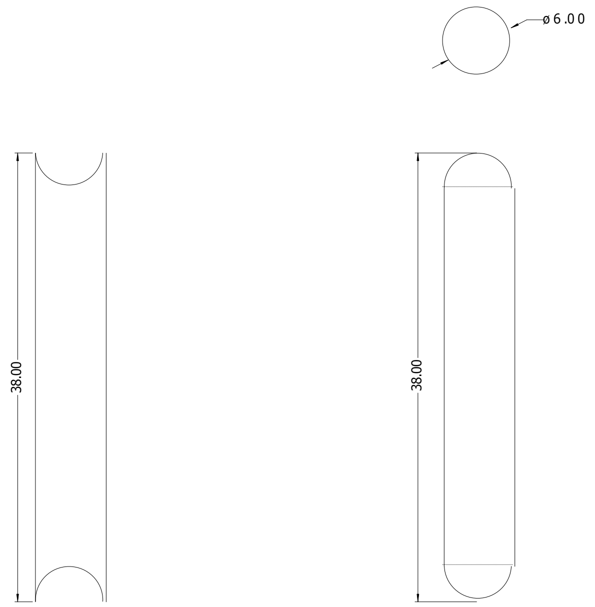


All dimensions in mm unless stated otherwise		TITLE: Stiffener Bar		
DESIGNED		PROJECT REFERENCE	**RRMBICH 001**	REV.
CHECKED				
APPROVED				
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 03 - 03	SHEET 1 OF 1
SCALE	2:3			

Appendix 4D: Design Component Drawings of Rotor Assembly-**Main Shaft**

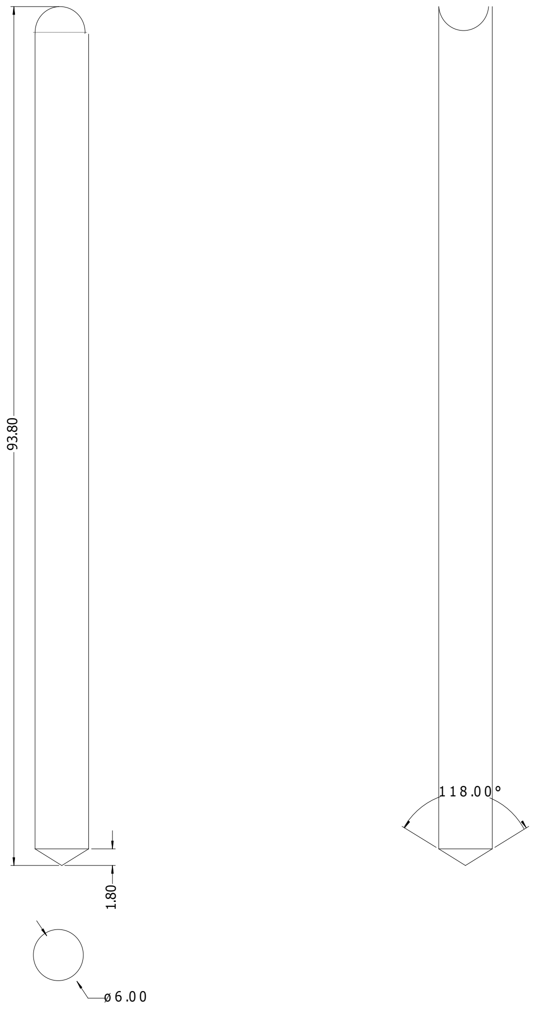


Appendix 4E: Design Component Drawings of Rotor Assembly-**Honey Frame Support**



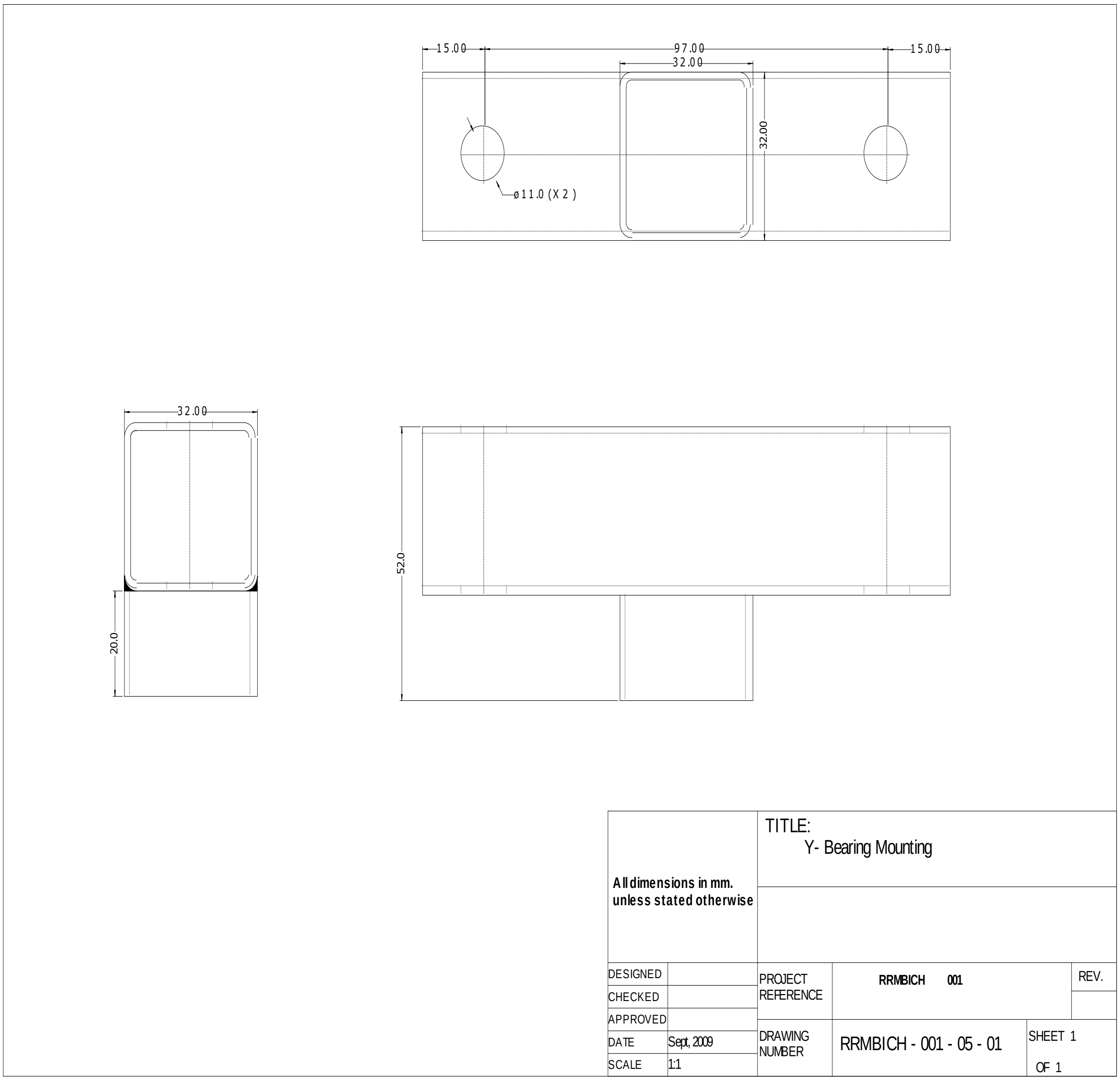
All dimensions in mm unless stated otherwise		TITLE: Honey Frame Support			
DESIGNED		PROJECT REFERENCE	RRMBICH 001		REV.
CHECKED					
APPROVED					
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 03 - 05	SHEET 1 OF 1	
SCALE	2:1				

Appendix 4F: Design Component Drawings of Rotor Assembly-**Cage Link Bar**

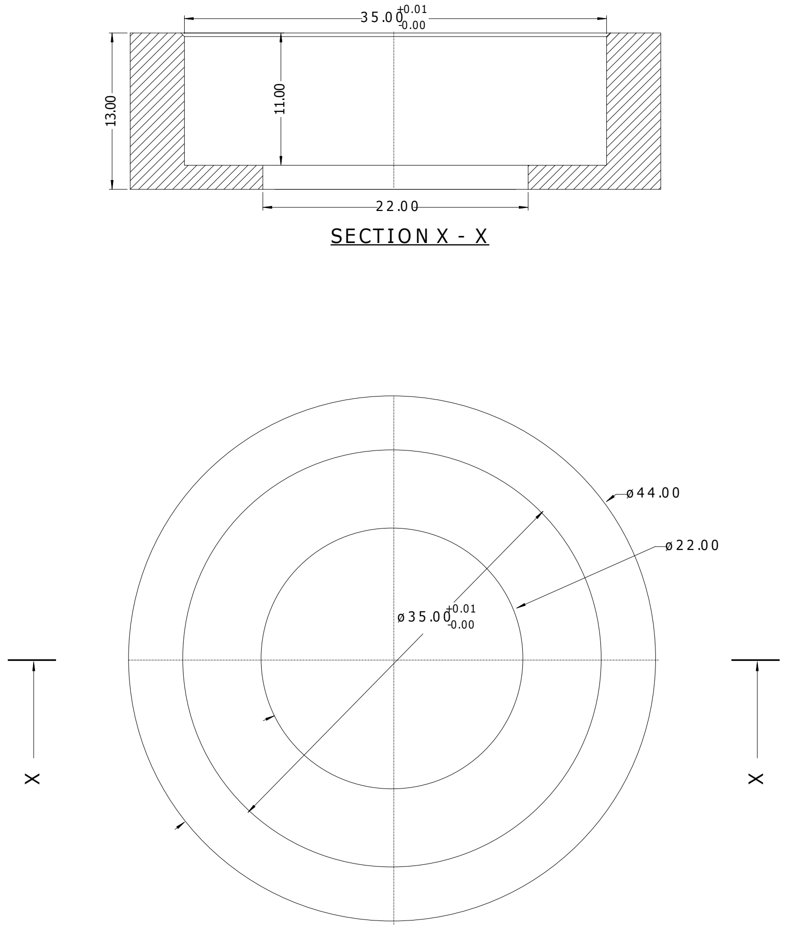


All dimensions in mm unless stated other wise		TITLE: Cage Link Bar		
DESIGNED		PROJECT REFERENCE	**RRMBICH 001**	REV.
CHECKED				
APPROVED				
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 03 - 06	SHEET 1 OF 1
SCALE	3:2			

Appendix 5A: Design Component Drawings of Channel Assembly-**Y-Bearing Mounting**

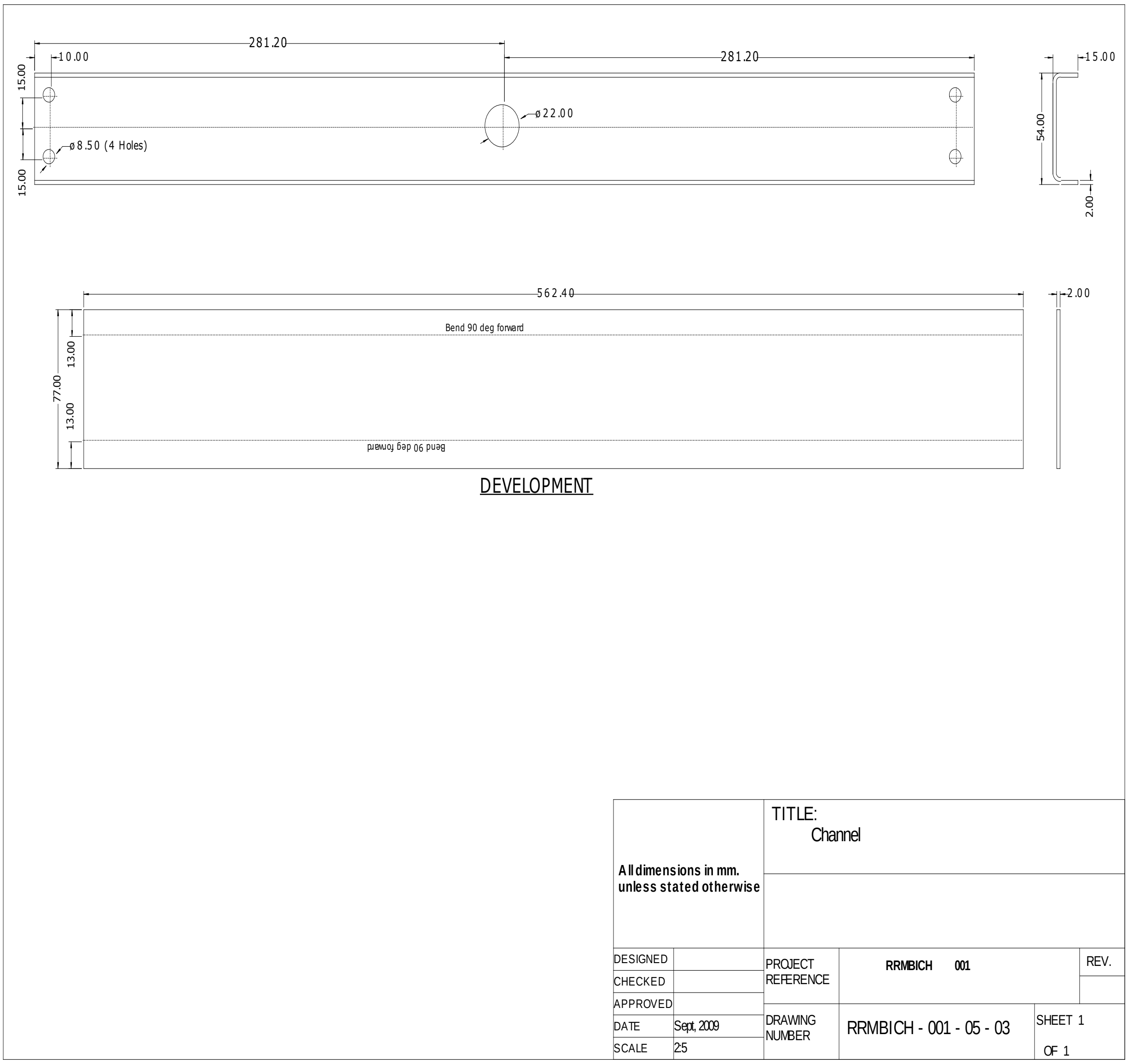


Appendix 5B: Design Component Drawings of Channel Assembly-**Bearing Housing**



All dimensions in mm. unless stated otherwise		TITLE: Bearing Housing		
DESIGNED		PROJECT REFERENCE	**RRMBICH 001**	REV.
CHECKED				
APPROVED				
DATE	Sept, 2009	DRAWING NUMBER	RRMBICH - 001 - 05 - 02	SHEET 1 OF 1
SCALE	2:1			

Appendix 5C: Design Component Drawings of Channel Assembly-**Channel**



Appendix 6: Sample Calculations for Specific Sugars

Sample calculations of the specific sugars of some Rift Valley honey samples (R10, R16, R23, R29 and R39) which were analysed by HPLC and gave the peaks in Figs 4.13, 4.14, 4.15 and 4.16 were carried out using the formula;

$$\frac{A_1 \times V_1 \times M_1 \times 100}{A_2 \times V_2 \times M_o}$$

Where; A_1 = Peak height of sugar compound in sample

A_2 = Peak height of sugar compound in standard

V_1 = Total volume sample solution in ml (100 ml)

V_2 = Total volume of standard solution in ml (100 ml)

M_1 = Mass amount of standard taken

M_o = Mass amount of sample taken

The mass amounts (M1) of the standard sugars taken were;

Fructose (M_1) 2.00 g

Glucose (M_1) 1.50 g

Sucrose (M_1) 0.250 g

Maltose (m_1) 0.150 g

The mass amount (M_o) of honey samples taken is 5.00 g.

V_1 and V_2 are 100 ml solutions.

From fig. _, the average peak heights used in the following calculations of fructose, glucose, sucrose and maltose were 24165.5, 16192, 845.5 and 705 respectively.

$$\text{Fructose content} = \frac{A_1 \times V_1 \times M_1 \times 100}{A_2 \times V_2 \times M_o} = \frac{24165.5 \times 100 \times 2 \times 100}{24165.5 \times 5 \times 100}$$

$$= 39.08\%$$

Glucose content = $\frac{16192 \, x \, 100 \, x \, 1.50 \, x \, 100}{14664 \, x \, 5 \, x \, 100}$ = 33.13%

Sucrose content = $\frac{845.5 \, x \, 0.25 \, x \, 100 \, x \, 100}{5196.5 \, x \, 100 \, x \, 5} = 0.814\%$

Maltose content = $\frac{705 \, x \, 0.15100 \, x \, 100}{5196.5 \, x \, 100 \, x \, 5} = 1.17\%$

Similar calculations were done in all the samples analysed. The specific sugar content obtained for the above samples are given in the table below.

Appendix 7: Specific Sugars of Some Rift Valley Honey Samples

Sample	Specific Sugar Content (%)			
	Fructose	Glucose	Sucrose	Maltose
R 10	39.0	33.13	0.814	1.17
R 16	39.58	34.9	0.40	_
R 23	38.5	35.5	0.40	0.96
R 29	38.9	34.77	0.30	_
R 39	40.44	37.86	0.50	_