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ADDIS ABABA UNIVERSITY



ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CHEMICAL AND BIO ENGINEERING

PROCESS ENGINEERING GRADUATE PROGRAM

JAM DEVELOPMENT FROM SELECTED VARIETIES OF MANGO

BY

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ACRONYMS AND ABBREVIATIONS

AOAC	Association of Analytical Chemists
AVRDC	Asian Vegetable Research Center
CPEDC	Center for the Promotion of Export from Developing Countries
CRD	Completely Randomized Design
CSA	Central Statistical Authority
DMRT	Duncan Multiple Range Test
EHNRI	Ethiopian Health and Nutrition Research Institute
EHA	Ethiopian Horticulture Association
EHDA	Ethiopian Horticulture Development Agency
EIA	Ethiopian Investment Agency
ES	Ethiopian Standard
EU	European Union
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
MARC	Melkasa Agricultural Research Center
MoARD	Ministry of Agriculture and Rural Development
NSB	National Standard Body
QSAE	Quality and Standard Authority of Ethiopia
RSM	Response surface methodology
USDA	United States Development Agency

ABSTRACT

Two mango varieties namely Kent and Neohera(NE1) were subjected to analysis and jam was manufactured. Mango pulp was extracted and cooked using pan kettles, and then sugar, citric acid, commercial pectin, and sodium benzoate were added during cooking. Mango jams were packed into glass jars then stored at room temperature ($30\pm 5^{\circ}\text{C}$), refrigerator ($5\pm 2^{\circ}\text{C}$) and deep freezer (-18°C) for four months.

The results revealed that Kent mango had the highest pulp content (72.9%) its pulp had the highest total soluble solids (17.0°Brix), highest acidity (0.56%) and lowest pH (3.54) while NE1 Mango had high reducing sugars (2.59%) and total sugars (10.85%). Mango jams were prepared and analyzed for physicochemical, microbial and sensory parameters at 30 days storage interval for 120 days. The sensory evaluation of mango jams tested at zero time (fresh) showed that Neohera(NE1) jam was superior in color and flavor, while Kent jam was superior in consistency and overall acceptability.

The organoleptic composition of the two mango jams compared to the commercial jam showed that the kent mango jams are comparable to the highest quality jam in Ethiopia and better than the other imported commercial jam. No detectable yeast, mold and negligible total viable count were observed in all mango jam samples during storage period. A statistical model was used to optimize the factor levels for highest acceptability to produce Kent mango jam.

Keywords: Jam, Mango, Optimization, Production.

1 INTRODUCTION

1.1 Background

Mango (*Mangifera indica* L.) is one of the most profitable crops in tropical and subtropical regions in the world and it is one of the most cultivated fruits in the World; with over 26 million tons world annual production in 2004. The total production area of mango in the world is around 3.69 million hectares. Approximately 50% of all tropical fruits produced worldwide are mangos. Asia accounts for approximately 77% of global mango production and the Americas and Africa account for approximately 13% and 9%, respectively (FAO, 2009). India is the world's largest producing country of mangoes (Anon, 1990). Other Producing countries in the world include Jamaica , Mexico, Haiti, China, Taiwan, Pakistan, Ceylon, Guatemala, Venezuela, Cuba, Israel, Australia, Kenya, Tanzania, Egypt, Eastern cost of Africa and south Africa. As there has been increasing demand for mangos throughout the world, especially in the United States of America and in Europe, production has been increasing as well over the past decade (Department of Agriculture of Thailand, 1996: 2).

Mango is a fleshy yellowish-red juicy stone fruit belonging to the genus *Mangifera*, consisting of numerous tropical fruiting trees in the flowering plant family Anacardiaceae. Mango is native to the south Asia (originated in Indo-Burma regions) from where it was distributed worldwide to become one of the most cultivated fruit in the tropics. It is the most popular fruit in many countries among millions of people in the world. In the tropic areas, it is considered to be the choicest of all indigenous fruits. It also occupies a prominent place among the best fruits of the world. However, it is in constant demand, there is a pre-harvest scarcity and at times a post-harvest glut for this fruit. To increase the availability of this fruit throughout the year, the surplus production must be processed into a variety of value-added products (Saxena and Arora, 1997; Srinivasan *et al.*, 2000; Singh *et al.*, 2005).

The appreciation of mango began over 4,000 years ago in India and throughout Southeast Asia. It was there that the first selections of improved cultivars were cloned from vast orchards and untamed jungles. The total amount of mango production in the world was around 35 million tons by the year 2009 (FAO, 2009). Mango is one of the most widely cultivated and globally traded tropical and subtropical fruit trees in the world, more than 85 countries in the world cultivate mango. (Clarke, *et.al*, 2011).

Mango varieties grown in Ethiopia are divided into two main groups “Baladi” or fibrous group and “introduced” Indian group (i.e. Local & Foreign). Ethiopia has large tract of suitable land for mango production. It is mainly produced in Oromia, SNNPR, Benishangul Gumuz, Amhara, Harari and Gambela regions. Mango ranked 2nd and 3rd in total production and area coverage among fruit crops grown in Ethiopia from 2003/4 to 2013/14 respectively. Both its area coverage and total production increased by 208.4% and 247%, respectively. Despite this improvement in the last one decade, its productivity is very low, 7 tons/ha and Ethiopia produced only 72,187 tons fresh mango in 2013/14(Elias, 2007). Mango production is steadily expanding in Ethiopia. However, its productivity is below the international average. Therefore, its potential has not yet been fully utilized and markets in different parts of the country are not sufficiently supplied with the demanded quantity and quality of mango. For example, Amhara region has large tract of land with suitable climatic condition and huge irrigation water resource for mango production. However, in 2013/14, the area coverage and total annual production of mango in Amhara region is only 800ha and 2826.3 tons, respectively. In 2013/14, Amhara region shared only 5.4% and 7.7% of the total fruit and mango production areas of the country, respectively and contributed only 3.8% and 3.9% of the total fruits and mango produced in the country, respectively. In addition, the regional average yield of mango, 3.5 tons/ha, is far below the national average yield, 7 tons/ha. A fruit with many versatile properties has naturally found application for processing into several products (Elias, 2007).

Mango is a widely processed fruit to be used as a vital ingredient in many products. The increasing production of fruit and the perishable nature of the fruit and lack of facilities for transportation of the produce from the area of production to the consumer provide some necessity to manufacture it *into* various products (Mohamed, 1994) and (Koubala *et al.*, 2008). The manufacturing industrial sector is the most dynamic component of the goods producing sectors of all economy. Expansion and development of the manufacturing sector increases agricultural productivity through providing agricultural inputs and creating demand for agricultural outputs. In particular, Small- and medium-sized enterprises (SME’s) play a very important role in the overall economic growth of developing countries. In many of developing countries, smaller enterprises account for a large share of total employment. They provide a productive outlet for the entrepreneurial spirit of individuals and assist in the dispersion of business activity throughout the economy. The diversity of mango is so huge, and yet each one has individual taste and features. They are a key component in economic

life, not only because of their number and variety, but because of their involvement in every aspect of the economy; their contribution to regional development; the complementary role they play in support of the large sector; and their role as a proving ground for innovations and adaptations. Mangos can be processed into a number of unique products such as dried mango pieces, chutney, jam and mango leathers (Azeredo, *et al.*, 2006). Processing of mangos enables exporters to serve their markets even during 'off season' periods for fresh fruits. Mangos are a highly nutritious fruits containing carbohydrates, proteins, fats, minerals, and vitamins, in particular vitamin A (beta carotene), vitamin B1, vitamin B2, and vitamin C (ascorbic acid), and especially phenolic compounds. Mango fruits are very much relished for their, exotic flavor and delicious taste. Mango serves as a fruit crop and as a subsistence crop for family farms. Jam is an intermediate food prepared by boiling fruit pulp with sugar, acid, pectin and other ingredients for colouring and flavouring with preservatives to a thick consistency and firmness to hold the fruit tissues and to make slightly cohesive texture to the extent of total soluble solid not less than 60% and their natural appearance should not be retained. Mango jams were prepared and analyzed for physicochemical, microbial and sensory parameters at 30 days storage interval for 120 days.

Ancient civilizations were known to set a variety of foods in the sun to dry in order to preserve them for later use. One of the first recorded mentions of jam making dates to the Crusades whose soldiers brought the process back from their journeys in the Middle East. Jam processing has been known since the eighteenth century and Braconnot was considered to be the first scientist who noticed the jell formation in presences of certain concentration of pectin, sugar, acid and water and that had happened in France in 1825 (Malcolm, 2005). This industry gained an important role among other industries being the most important method for fruit preservation. Preserving foods was a home-based operation until the nineteenth century. Even today, millions of people make fruit preserves in their own kitchens. An important innovation in food preservation occurred in 1810. Nicolas Appert, a French confectioner, determined that by filling jars to the brim with food so that all air is expressed out and then placing the jars in boiling water would prevent spoilage. Whether in the home kitchen or in a modern food processing plants, the procedure is essentially the same. Fruits are chopped and cooked with sugar and pectin until a jam is formed. The jam is then packed into sterilized jars. Spoilage prevention is a major concern for both the home and the commercial jam producer.

Jam is a product made by boiling fruit pulp with sufficient quantity of sugar to a reasonably thick consistency (TSS: 68 - 70 %). Jams formulated without addition of pectin were inferior in quality. Commercial pectin and Mango pulp produced jams which did not differ significantly ($p < 0.05$) in moisture content, TSS and TTA. Jams formulated with commercial pectin and Mango pulp were of acceptable quality up to four months. Sensory evaluation revealed that jam produced from mango was significantly ($p < 0.05$) superior in all sensory attributes compared to other fruits (Khalid, 2009). The use of Mango pulp as a source of pectin gave high quality jams, which compared favorably with that of commercial pectin. There are different types of jam which differ from each other in the raw material used, processing method, and additives, the jam can be classified into: Jam, Preserves, Jellies and Dietetic jellies, and according to texture it can be classified into solid, semi solid and liquid jam. The principle of the jam preserving to protect against microbial spoilage is increasing the percentage of the sugar and lower the pH. Total soluble solids (TSS) and total titratable acidity (TTA) for fruit pulps and jams were measured to obtain the required acid to sugar ratio for kent jam. Pectin content of the fruit pulps and lemon extract were also determined.

Shelf life of jams stored at room temperature was monitored for four months by determining moisture content, TSS, TTA, and microbiological changes. Sensory evaluation of the jams was performed to assess consumers' preference among the produced jams. Jams and jellies are spreads typically made from fruit, sugar, and pectin. Jelly is made with the juice of the fruit; jam uses the meat of the fruit as well. The gelling potential of mango powder is unfamiliar to both small and large scale food processors due to limited information on its characteristics. There is lack of specification on process parameters of its application to enable replication or production of consistent products, a requirement for successful commercialization. (Truneh, 2009).

The physicochemical characteristics of mango fruits and the technological qualities of their processed products vary with mango varieties as some are more suitable than others for specific applications. Mango fruit processing into jam provide added value to the fruit. Jam is usually prepared from cooked fruit or vegetable, sugars, citric acid and pectin. Ripe mango varieties are best suited for jam processing based on their viscosity (Kansci *et al.*, 2003).

1. 2 Statement of the problem

The fruit processing industry in Ethiopia is very weak, considering the potential for substantial amount of fruit that is grown in the country. No doubt, one of the reasons for this is the highly developed processing industries in other countries which are able to export into countries like Ethiopia and sell the final product at low cost. Mango puree, jam and leather products are largely unknown in Ethiopia, but may have good potential for a number of reasons. The local mango value chain is underdeveloped due to low purchasing power in the region (Truneh, 2009). Readiness of Ethiopia for a large scale mango processing facility cannot be confidently established now because although there is large population of mango trees, they may not be suitable for processing. The production, marketing and consumption of mango is restricted due to improper handling, inadequate transport and storage facility, disease problems, and sensitivity to low storage temperature.

In poor countries like Ethiopia, malnutrition is primarily due to the limited availability of good quality and sufficient foodstuffs. Thus, even without famine, the poor quality of available food provokes chronic malnutrition. Ethiopia is a country that is often associated with famine and food shortage. Whilst this perception is the reality for much of the country at certain times, there are also regions within Ethiopia that are well suited to producing a surplus for particular agricultural commodities. One such location is the Asossa – Homosha region in western Ethiopia, which is particularly suitable to the production of mangoes. According to Kadir (2009) the current postharvest loss of mango fruits in Ethiopia is more than 26.3%. Ethiopia's wide range of agro-climatic conditions and soil types make it suitable for the production of diverse varieties of fruits and vegetables, including temperate, tropical and sub-tropical crops. Most of the soil types in fruits and vegetables producing regions of the country range from light clay to loam and are well suited for horticultural production.

The source of varieties of fruits and vegetables in Ethiopia can be categorized into two major groups: foreign and local ones. State farms and newly emerged private commercial farms usually use exotic varieties, while the small farm holders are mainly confined to local or traditional varieties. The survey on small scale manufacturing industries conducted by in Central Statistical Agency in 2009 has identified three major problems limiting the industries from working at full capacity: low market demand (57.1%), shortage of raw material supply (11.1%) and shortage of spare parts (7.1%) respectively. The industries were not full operation at all the year round due to shortage of market demand and water.

The major reason for lack of market are not competing with local and foreign products in price. The survey result further indicates lack of information to decide type of activity and markets were major problems. It was reported that 37.8 % of the total industries face shortage of initial capital when commencing operation. All the above stated problems are result of lack of detail feasibility study before planning to establish the manufacturing industries.

In Ethiopia, the number of fruits and vegetables processing industries is limited. Currently, there are not more than 15 fruits and vegetables processing plants in the country. These plants presently process limited products: tomato paste, orange marmalade, vegetable soup, frozen vegetables and wine. Most of the processing plants fall in the small-scale processing unit's category. In general, processed products are mainly geared to domestic markets. An abundance of locally grown mangoes has let to low market value, and increase spoilage of fresh mangoes, this thesis was developed to enable participants to make mango jam at home or in their communities for their own consumption, or for sale at local markets. The major Constraints of mango production in Ethiopia include: Lack of knowledge, skills and facilities in production, harvesting and post harvest handling, Irrigation water scarcity, pest and disease and technology limitation are the major factors influencing the production of mango in Ethiopia. The major causes of mango produce loss in Ethiopia are birds, wind, wounding, microorganisms and maturity stage. From those birds are more challengeable cause during maturity stage and wind is so problematic starting from fruiting to harvesting stage of the produce (Seid and Zeru, 2013). Realizing the importance of mango fruit, nutrition, perishable nature, seasonal availability and no indigenous research work on jam development from selected varieties of mango (Truneh, 2009).

1.3 Objective of the thesis

A) The general objective of this thesis research is to introduce and develop mango jam from selected mango fruit varieties grown in Ethiopia (Kent and NE1).

B) The specific objectives of the study were:

- To evaluate the varietal differences between two mango varieties.
- Conduct physicochemical analysis of both mango pulp and mango jam
- Introduce and develop mango jam in Ethiopia
- Compare the sensory analysis of commercial jam to the selected variety jam.
- Analyzing optimization of mango jam production (pH and sugar parameters)

1.4 Significance and scope of the Study

The study is believed to be **significant** in that it will:

- Produce the best quality mango jam
- Reassure the consumer that the mango product(jam) is safe for consumption
- Optimize the processes for production of good quality mango jam products
- It create opportunity to introduce and develop processing technology locally

Scope of the study

The study generally covers:

The preparation method and Laboratory analysis of mangos jam; namely physicochemical analysis, microbiological analysis, sensory evaluation and optimization of mango jam production

2 LITERATURE REVIEW

2.1 General description

The scientific name of mango plant (*Mangifera indica* L.), belongs to Anacardiaceae family, (ElBanna and Hejazi, 1987). The mango trees grow from the sea level up to altitude of 1500m, withstand dry conditions and heavy rain fall but severe frosts during winter may endanger the tree. Mango tree is an erect branched evergreen plant reaching about forty meter high and may live up to hundred years, (Gibbon and pain, 1985). Jam production from mango species well developed in china and India. The mango species used by these countries different from Ethiopia has. The knowledge on the mango characteristics and total chemical composition of the mango culms, which is a very good source of vitamins, enables the country to develop strategy on the resource development and utilization. Jam is a product containing both soluble and insoluble fruit constituents and Conserve or preserve – large pieces of fruit are present. The essential ingredients of a preserve are sugar, fruit, pectin and acid. The sugar content is expressed as percent soluble solids or °Brix. It is usually measured with a refractometer. The best quality preserves are made when the mixture is brought to a boil as quickly as possible, boiled as vigorously as possible until the desired solids content is reached, then filled, sealed and cooled as quickly as possible, pulp with sugar (sucrose), pectin, acid, and other ingredients (preservative, coloring and flavoring materials) to a reasonably thick consistency, firm enough to hold the fruit tissues in position. Total soluble-solids content of the finished jam or preserve should be between 60% and 65% or greater and the product should contain at least 45% fruit.

2.2 Overview of mango and its production in Ethiopia

Mango is one of the main fruit crop produced and exported in Ethiopia. It has diverse climate and altitude conditions which are conducive to various agricultural activities. There are several lakes and perennial rivers that have great potentials for irrigated agriculture. The groundwater potential of the country is about 2.6 billion cubic meters in 2004. Ground water in the country is generally of good quality and it is frequently used to supply homes and farmsteads. The potentially irrigable land area of the country is estimated at 10 million hectares, out of which only about 1% is currently under irrigation. Mango production covers 35% of the total acreage allotted for fruit production in Harari and Assosa. In Ethiopia mango is produced mainly in-west and east of Oromia, SNNPR, Benishangul and Amhara (Desta,

2005). Agriculture sector highly depends on the weather circumstances. Most of the soil types in fruits and vegetables producing regions of the country range from light clay to loam and are well suited for horticultural production. Endowed with favorable weather, altitude, adequate water and availability of suitable soils, the potential to develop horticultural crops, such as fruits, vegetables, root crops and cut flowers is great in Ethiopia. Its wide range of agro climatic conditions and soil types make it suitable for the production of diverse varieties of fruits including temperate, tropical and subtropical fruits.

Mangoes contributed about 12.61% of the area allocated for fruit production and took up 12.78% of fruit production in comparison to other fruits growing in the country and the annual consumption of mango by the processing plant at full production capacity is 8.6 tones which is only 1.8% of the current production of mango in 2006 (Elias, 2007). But, according to CSA (2013) cropping season mangoes contributed about 14.21% of the area of land allocated for fruit production and holds 14.55% of quintals of fruits produced in the country. Therefore, the main objectives of this review is to review mango production and marketing system with their respective constraints in Ethiopia, to identify major actors along mango value chain and their respective functions along the chain, to review current status and potential opportunities of mango in Ethiopian economy.

The mango industry in Ethiopia is in its infant stage. However, mango is grown in many parts of the country, especially in the Rift Valley, western and southwestern parts of the country. The national research system has developed a number of varieties but is not widely spread. Experiences from other countries in growing this crop will therefore contribute to the success and widespread of this fruit. Ethiopia has a comparative advantage in a number of horticultural commodities due to its favorable climate, proximity to European and Middle Eastern markets and cheap labor. However, the production of horticultural crops is much less developed than the production of food grains in the country. On average more than 2,399,566 tons of vegetables and fruits are produced by public and private commercial farms, this is estimated to be less than 2 percent of the total crop production According to recent information obtained from the Central Statistics Authority, the total area under fruits & vegetables is about 12,576 hectares in 2011. The total land area under cultivation in the country during the same year, the area under fruits and vegetables is less than one per cent (i.e. 0.11%), which is insignificant as compared to food crops. According to FAO (2009) the total cultivated area for mango in Ethiopia is not more than 12, 000 hectares. The highest annual production estimate in the past five years is 180,000 Mt and more area coverage is

expected in the south-western and other parts of the country due to more conducive climatic and other factors. Even if the farmer’s livelihood is highly supplemented by the income from their mango trees, there is a declining trend in yield and quality of mango due to old age, poor management and seedling originated nature of the trees. However, there are exceptionally good yielding trees with best quality fruits. Apart from its economic importance, it is forest and environmentally friendly to fight against drought, use as shade and fire wood. Ethiopia is a country that is often associated with famine and food shortage. Whilst this perception is the reality for much of the country at certain times, there are also regions within Ethiopia that are well suited to producing a surplus for particular agricultural commodities. One such location is the Asossa – Homosha region in western Ethiopia, which is particularly suitable to the production of mangoes.

Around 47 thousand hectare of land is under fruit production in Ethiopia. Banana contributed about 60.6 % of fruit areas followed by mango that contributed about 12.61 % of the area (CSA, 2009). Total fruit production in Ethiopia is about 500 thousand tones. Fruits have significant importance with a potential for domestic and export markets and industrial processing in Ethiopia, It is agro-ecologically diverse and has a total area of 1.13 million km². Many parts of the country are suitable for growing temperate, sub-tropical or tropical fruits. In addition, there are also many rivers and streams which could be used to grow various fruits. Ethiopia has a potential irrigable area of 3.5 million ha with net irrigation area of about 1.61 million ha, of which currently only 4.6 % is utilized. Mango production in Ethiopia is in fluctuated conditions, because of occurrence of diseases, lack of proper management and also weather conditions (CSA, 2009).

Table 1: Summary of major fruit crops produced in Ethiopia in 2012/2013

Fruit crop	Area in hectare	Production (quintal)	Productivity (quintal/hectare)
Avocados	8,938.24	256,331.64	28.68
Bananas	36,012.19	3,025,022.32	84.00
Lemons	754.23	55,167.50	73.14
Mangoes	8,808.64	697,507.30	79.18
Oranges	2,999.21	357,458.39	119.18

Source: CSA, 2013, Agricultural Sample Survey Result

Mango is the third most important fruit crop in the country after banana. Traditionally, many farmers have relied on shaking mango trees, thrashing the branches and using scissors or hooks to cut the fruits as the main mango harvesting techniques. But these methods damage or bruise both the mature and immature mango fruits. In a 2006 study, it was estimated that as much as 28% of the mangoes sold in the capital Addis Ababa, were grown in the Asossa region. Reports shows that Ethiopian mango fruit varieties are more than 30 varieties “Baladi” varieties are more produced and there is about 2,000,000 trees of them in Asossa , Oromiya and southern Ethiopia , the varieties that cover most of production area are Neohera(NE1) and Kent . Mango is a perennial tree which can live more than 50 years and it is also the leading fruit produced in most parts of eastern and south-western Ethiopia both in area coverage and quantities produced. There are also ample garden mango trees in different parts of the country at farmer’s holdings.

The livelihood of most of these farmers is highly supplemented by the sale of mango fruits. The area coverage under mango in eastern Ethiopia has reached about 35% of the total acreage allotted for fruit production. The Gamo Gofa zone in southern region is an important mango producing region in Ethiopia and a key supplier of the fruit to the national market. Mango farming is expanding rapidly in the region. Better harvesting techniques and post-harvest handling processes introduced by the Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) project have improved smallholder mango production in the Gamo Gofa zone of southern Ethiopia. LIVES introduced mango harvesting tool to more than 50 smallholder producers in the zone. It is a metallic fruit picker with nylon box attached to a long wooden pole that enables to reach the fruits.

While the metallic fruit picker could be designed and produced by village workshops, the wooden poles are prepared by the smallholder mango producers themselves. Smallholder farmer’s education on the importance of harvesting only mature and healthy mangoes based on fruit maturity indices, such as shape and color, is helping farmers get higher quality fruits that fetch better market prices. As part of this initiative, the project has also trained, and is working with, extension workers and zonal and district agricultural officers in sensitizing the community to adopt better production techniques such as using improved mango varieties and optimum spacing of mango trees for optimal growth and easier harvesting. As a long term strategy, LIVES is also leading a farmer-based grafted seedlings supply system to avail improved trees to farmers. The ‘top-working’ technique is being used to produce improved and shorter mango trees that produce uniformly sized fruits

of superior quality and are easier (lessen chance of fruit damage) during harvest compared to cross-pollinated cultivars currently used by many farmers. To ensure farmers increase their incomes and improve mango marketing systems within and outside the zone, the LIVES project has partnered with organizations such as marketing and cooperatives offices at district and zonal levels, Gamogofa fruits and vegetables cooperatives union and local traders. The Ethiopian government has a plan to expand mango production by distributing high yielding Varieties for small scale farmers, especially in the Southern and Oromia region, by grafting mangos of known and high yielding varieties. In July 2006, it was announced that the Oromia regional government distributed 14,000 improved seeds of mango. The production of mango fruits for the past six years in Ethiopia was considered for the study which was found from CSA (2009), and is summarized in table 2.

With an increase in Ethiopian mango crop production and considering the current postharvest loss of mango fruits is at 26.3%, there is not only a need but also a potential for the fruit to be processed into various product types, consequently increasing the market potential of the mango fruit (Kader and Truneh, 2009). Industrial processing opportunities, to increase the market value of the initial fruit, may lead to the potential development of mango products like mango juice, fizzy drinks, canned fruits and pulp, fruit leather, dried pieces, jam and chutney. The availability of favorable weather, adequate water supply, suitable soil, abundant labour and the growing demand for Ethiopian fruits and vegetables as fresh and processed products for local and export markets encourage expansion of fruit and vegetable production in the country. CSA (2013) showed as mango is one of the second potential fruit crop produced in Ethiopia next to banana which is the first fruit crop produced in large quantity.

Table 2: Area, production and productivity of mango in regional states of Ethiopia

Regions	Area in hectare	Production in quintal	Productivity (quintal/hectare)
Tigray	118.20	-	-
Afar	-	-	-
Amhara	246.85	10,408.67	42.17
Oromia	3,789.47	284,065.79	74.96
Somali	33.52	3,776.26	112.66
Benishangul-Gumuz	652.56	51,411.10	78.78
S.N.N.P	3,375.89	343,910.27	101.87
Gambela	180.41	-	-
Harari	367.24	331.69	0.90
Total	8,764.14	693,903.78	411.34

Source: CSA, 2013, Agricultural Sample Survey Result

Mango pulps of different varieties were processed into mango jam according to guidelines described by FAO (2009). During cooking of fruit pulp, sugars, pectin, citric acid and sodium benzoate were added. The prepared jams were hot filled into presterilized (autoclaved at 121°C for 15 min) glass jars, closed and stored at ambient temperature (25±3°C). Jam is a fruit product prepared from fruit pulp by boiling with sufficient quantity of sugar and pectin to as moderately thick consistency. Jellies are differentiated from jam in that the fruit ingredients consist of the juice that is extracted from whole fruit and clarified by filtration or other means. The distinguishing characteristics of the product are a substantial amount of fruit ingredient used in the formulation (450 g/kg of jam) and high soluble solid content of the final product. Mangoes can be processed into puree from whole or peeled fruit. Because of the time and cost of peeling, this step is best avoided but with some varieties it may be necessary to avoid off flavors which may be present in the skin. The steam-softened skins allowed the fruit to be pulped by a power stirrer fitted with a saw-toothed propeller blade mounted 12.7 to 15.2 cm below a regular propeller blade. The pulp is removed from the seeds by a continuous centrifuge designed for use in passion fruit extraction.

The pulp material is then passed through a paddle pulper fitted with a 0.084 cm screen to remove fiber and small pieces of pulp. Mango puree can be frozen, canned or stored in barrels for later processing. In all these cases, heating is necessary to preserve the quality of

the mango puree. In one process, puree is pumped through a plate heat exchanger and heated to 90°C for 1 min and cooled to 35° C before being filled into 30 lb tins with polyethylene liners and frozen at -23.50 C. In another process, pulp is acidified to pH 3.5, pasteurized at 90°C, and hot-filled into 6 kg high-density bulk polyethylene containers that have been previously sterilized with boiling water (Khalid, 2009).

Most of the time Ethiopian farmers did not give attention to spacing. Orchards growth were not well spaced, some orchards are nearer to each other and the others are very far from one orchard to the others, according to the oldness of the trees age most of the farmers had no knowledge about spacing. Space plays significant role for all activities, absence of proper spacing create difficulties for production (Seid and Zeru, 2013). However, tree spacing appears to be an important consideration in mango production. Processing plays an important role in the conservation and effective utilization of fruits and vegetables. It converts perishable fresh products to more durable processed products in cases of sluggish markets or when there are profit- generating demands for processed products. It also helps in generating rural employment. Besides, processed fruits and vegetables are sources of foreign exchange earnings. Modern processing and packaging techniques make seasonal fruits and vegetables available all year round to almost all parts of the globe. Tropical fruit like mangoes can be enjoyed in temperate countries. The key challenges for developing a fruit processing sector in Ethiopia as indicated by James et.al (2008) include:

- ❖ Lack of technical knowledge in processing
- ❖ Low level of technical support for maintenance
- ❖ Low capital base from which to invest many low priced mango juice imports

Table 3: Capacity of fruits and vegetables processing plants in Ethiopia

Name of Processing Plant	Location	Ownership	Major Products	Production Capacity
Melge Wendo Food Processing Factory	Melge Wendo/ Southern Nations, Nationalities and	Private (foreign)	Tomato past (850g can) Peeled tomato Tomato	30 tons per day

	Peoples National Regional State		paste (410 g can)	
Gonder Food Processing Factory	Gonder/ Amhara National Regional state	Private (foreign)	Tomato paste (850 g can)	1,250 cans in a single shift per day
Merti Processing Factory	Merti/ Oromia National Regional State	State-owned	Tomato paste Orange marmalade	5,000 tones per year
Awash Winery	Addis Ababa	State-owned	- wine	10.9 million liter per year

❖ Source: Ethiopian Privatization Agency

2.2.1 Varieties of mango


There is thousands of mango varieties recognized through-out the world. The varietal differences are expected to affect the quality and storage stability of the fresh fruit and the processed products (Singh, 1960).

Kent Mango variety: Kent mango was first cultivated in Florida in 1944. It is a direct descendant of the Brooks cultivar, derived from the Sandersha seedling. The fruit is a regular oval shape, large 20 - 26 ounces, with plump cheeks, greenish-yellow color with red shoulder. Very rich and sweet with fiber-free flesh (slices clean to the pit - like butter when ripe!) It is a softer mango that really should not be put to the squeeze test. USDA estimates for production in Florida (and the whole of the USA) can be regularly viewed on www.nass.usda.gov/fl, which is updated from the 9th to the 12th of every month. The latest new season's Florida all orange forecast was released on 10 March 2011.



Figure 1: Kent (LFI, 2003) mango variety

Table 4: General description about kent mango variety

Name and Picture of Mango	Ripening Season	Plant characteristics	Flavor	Fruit Shape	Color	Comments
 Kent	July-August	Very large, vigorous grower which can attain heights of fifty to sixty feet if unmanaged	flesh is deep yellow, sweet, aromatic, juicy, tender	large, round shape	dark red	Fiberless It has an excellent flavor, large size, and very little fiber. Considered by many to be one of the best tasting Florida mangoes. Eat before fruit gets too ripe. The most rewarding attribute is a bountiful late season crop. Late season mango with good color and exceptional flavor, great for drying.

Neohera (NE₁) Mango variety: It is one of the most popular mangos in Ethiopia. The Mango cultivar was developed and grown for local market. The fruit is a regular oval, medium to large sized, 12 to 24 ounces, yellowish-orange with deep red to purple blush, thicker skinned, juicy but firm with medium fiber and it has high amount of stone/core/.



Figure 2: Neohera 1, NE1mango variety

2.2.2 Physicochemical properties of mango pulp

Mango pulp was analyzed for pulp content, Total Soluble Solids (TSS), acidity, pH, brix/acid ratio, reducing sugars and total sugars according to standard methods as described by AOAC (2005). Total Soluble Solids of pulp were estimated by using Abbe's Refractometer (ATAGO 3T) and the readings were corrected at 20°C whereas, pH was measured by digital pH meter (Orion 420 A+).

Physical properties: The major physical properties of fruits to be considered in characterizing mango varieties are their weight and the proportion of pulp, peel and stone of the fruit, peel color, texture and edible portion(Khalid,2009).

Chemical composition: The principle chemical composition constituents of mango fruit are carbohydrates, organic acids, proteins, poly-phenols, vitamins and minerals. Immature mango fruits are astringent acidic and rich in vitamin C, where as ripe mango are sweet, rich in vitamin A, moderate in vitamin C and high aromatic. Ali (2003) reported that the free sugars in the mango fruits mainly consist of glucose, sucrose, while xylose and arabinose have also been detected in similar quantities during different stages of fruit ripening. However, it has been reported that there is an increase in reducing sugars and total soluble solids, during storage period. The acidity of the fruit expressed in term of citric or malic acid, since they are the main accumulated free organic acids contributing to the acidity of the fruit besides tartaric, oxalic and glycolic (Nagy and Shaw, 1980).

Table 5: Physicochemical properties of mango varieties

Variety	Moisture (%)	TSS 0Brix	Ph	Acidity g/100g	Brix/Acid Ratio	Vitamin C (mg/100g)
Keitt	83.42	16.34	4.10	0.25	65.36	47.77
NE1	85.33	17.23	4.60	0.19	90.68	29.91

As reported by Binyam Teshome (2010)

2.3 Mango products

The variety of processed mango products is diverse, and variations exist from country to country and region to region. We can peel, slice, chop, dice, and puree mangos, which we are able to preserve by dehydration, canning, bottling, freezing, and pickling. We would recognize these mango products as dried fruits in trail mixes, or as canned fruit slices in syrup, or as nectars, juices or blends in tropical fruit punches, or as jams and jellies, or as mango chutney. Chutney is derived from salted green mango slices and constitutes the largest commercial volume of processed mango products. Mangoes are processed into many other products for home use and cottage industry (FAO, 1995). Such products include Nectars, which may be processed by mixing sugar and water with pulp and then heating and filling (Saeed and Khattab, 1974). Squash was produced by mixing ingredients (mango pulp, water, sugar and citric acid) together and heating by steam at 98°C and filling into sterilized cans, with immediate seaming (Saeed and Elmubarak, 1974). Ready to serve mango juice (RTS) Fruits juice beverage with 10 – 15% fruit pulp are becoming increasingly popular in comparison with aerated or synthetic beverage. Mango leather to produce mango leather, the Brix of mango pulp is raised to 25°Brix and acidity to 0.5% by adding sugar and citric acid, respectively.

The manufacture of mango puree is a good example of a highly mechanized process which requires less labor and offers other advantages, such as that the process makes use of fruit not suitable for other products, and the product can be used in other products such as jams, beverages, and dairy products as a flavoring ingredient, or as a fruit filling in pastries. Such product diversity expands the market potential for mango puree. Mango jam is a food product prepared from cooked fruit or vegetable pulps after removal of stones and seeds with addition of sugar, acid and pectin, to make slightly cohesive texture to the extent of total soluble solid not less than 60% and their natural appearance should not be retained. There are different types of jam which differ from each other in the raw material used, processing method, and additives, the jam can be classified into: jam, preserves, jellies and dietetic jellies, and according to texture it can be classified into solid, semi solid and liquid jam. The principle of the jam preserving to protect against microbial spoilage is increasing the percentage of the sugar and lower the pH.

2.4 Technology of fruit processing

The processing of fruits has two objectives. Firstly, to preserve by slowing down the natural processes of decay caused by microorganisms, enzymes in the food, or other factors such as heat, moisture and sunlight. The second objective is to convert them into different foods which are attractive and in demand by consumers. Food Processors should utilize their skills to develop recipes and create attractive products that consumers want to eat. Thereby successful Food Processors increase product sales and generate profits. Food Processors must select their products with caution. It is not enough to assume that processing can be a successful business simply because there are large quantities of cheap fruit available in the marketplace. There must be a good demand for the end product and this must be clearly identified before designing and investing in the business. The best types of products for small-scale production are those that have a high 'added value' as well as a good demand. A high added value means that cheap raw materials can be processed into relatively expensive products. It also means that this can be done at a small scale of processing, using equipment that is affordable (Fellows and Quaouich, 2004).

Fruits like mangos, pawpaw, guavas and bananas, can easily be dried. However, they should be harvested at the right stage and ripeness. Hard ripe stage in mangoes, pawpaw and bananas gives best results. Avoid overripe, under mature fruits in order to obtain good products. To prepare the fruits for drying, wash them thoroughly with clean water. Scrubbing with a brush might be necessary like in case of mango fruit with a lot of latex cover. The fruits are peeled if necessary and cut into smaller uniform pieces to ensure faster drying. Stainless steel knives are recommended for peeling and cutting of the slices or pieces. To avoid discoloration and excessive vitamin losses, treatment with anti-oxidants like citrus (lemon) juice is done. Fruits like pineapples may require pre-cooking to soften fibrous tissue hence hasten drying. Drying is done on trays, which should be made of wood, fabric, plastic or sisal material. This is because metal materials may affect the drying product negatively e.g. copper destroys vitamin C, iron rusts, aluminum discolors fruits and corrodes. Most fruits have natural acids and sugars which are preservatives therefore moisture contents of about 20% i.e. leathery and springy dry (not brittle) is good for storage. This is however dependent on the fruit or vegetable. After the correct stage of dryness is achieved the product should be removed from the dryer parked, and stored in a dry, dark store to avoid loss of vitamin A (GTZ, 2009).

Mangos are processed at two stages of maturity. Green fruit is used to make chutney, pickles, curries and dehydrated products. The green fruit should be freshly picked from the tree. Fruit that is bruised, damaged, or that has prematurely fallen to the ground should not be used. Ripe mangoes are processed as canned and frozen slices, puree, juices, nectar and various dried products. Mango processing within the home and cottage industries converts the fruit into many other products. Mango processing presents many problems as far as industrialization and market expansion is concerned. The trees are alternate bearing and the fruit has a short storage life; these factors make it difficult to process the crop in a continuous and regular way. The large number of varieties with their various attributes and deficiencies affects the quality and uniformity of processed products. Additionally, the lack of simple, reliable methods for determining the stage of maturity of varieties for processing also affects the quality of the finished products. Many of the processed products require peeled or peeled and sliced fruit. Within Ethiopia the lack of mechanized equipment for the peeling of ripe mangoes is a serious bottleneck for increasing the production of these products. A significant problem in developing mechanized equipment is the large number of varieties available and their different sizes and shapes. The cost of processed mango products is also too expensive for the general population in the areas where most mangoes are grown. However, there is a considerable export potential to developed countries but in these countries the processed mango products must compete with established processed fruits of high quality and relatively low cost (Dauthy, 1995).

Machinery required for the processing of fruit and juice packaging is available both local and imported. Local packaging machinery reportedly give poor quality output especially for fruit jam packaging which is considered to be highly sophisticated and hygienic hence it could not be done by using local machinery. However, pulp processing and jam production could be done on locally fabricated machinery

Table 6: Product specification of mango jam

No	Product Type	Product Specification					
		Ingredients	Fruit content	Color	Flavor	TSS and pH	Packaging material
1	Mango jam	Sugar, mango pulp, pectin, citric acid	45 parts per 100 parts of initial ingredients	light yellow	Clean and free from burnt caramelized & other flavors	TSS = 68°Brix pH = 3.0-3.2	Glass jar 450g unit

The quality criteria for jams and marmalades are decisively determined by the flavour, colour and consistency as well as state of preservation and distribution of fruits. These properties depend to a high degree on the quality of raw materials used, with special importance given to the proper selection of suitable fruits. The characteristic nature of the finished product is further determined by the addition of sugars, pectin and food grade acids

2.4.1 Fruit drying technology

The design and operation of dehydration equipment aim to minimize these changes by selection of appropriate drying conditions for individual food items. Heat under controlled conditions to remove the majority of water normally present in a food by evaporation. Drying causes deterioration of both the eating quality and the nutritional value of food. A range of technologies is used for fruit drying which include tray, tunnel dryers, freeze dryers. With the exception of tray dryers, none of these are appropriate, in terms of cost and output, for use by small and medium enterprises. Hot convective air dryers are generally used for drying piece-forms fruit and vegetables such as banana, mango and pineapple slices, and various tea leaves (Chua & Chou, 2003). Depending on the methods used to heat the air convective dryers are classified as solar, electric and fuel fired which consists of biomass, biogas or petroleum products

Fuel fired dryers: Situations where the control over drying conditions is sufficient using solar dryers, it is necessary to use fuel-fired dryers. There are large numbers of different types and the selection depends on the required throughput, types of fuel and level of investment that is available. The main limitation of fuel-fired dryers, in addition to higher capital and operating costs, are that they are more complex to build and maintain and therefore requires skilled labor for operation and maintenance.

Electric dryers: One option for drying fruits and vegetables is an installation of electric convective dryer. This option requires a regular electrical energy supply or the purchase of a generator. These dryers are available in size that ranges from units that handle 300 kg of fresh fruit per one day drying cycle up to units that handle one tone per drying cycle. The electrical energy requirement varies between 25 KVA to 50 KVA.

Solar dryers: The performance of the solar tunnel dryer is significantly dependent on the weather condition. Both the heat required for removing the moisture as well as the electricity necessary for driving the fans are generated by solar energy. The weather conditions have the biggest influence on the capacity product that can be dried within a certain time period. During the rainy season, which is not the best season for the utilization of any kind of solar dryer, the most efficient method of using the solar tunnel dryer is in combination with an artificial dryer. If the weather conditions are fine, the product can be dried as in the dry season, using only the solar tunnel dryer while under rainy conditions, the product will be pre-dried during the day time in the artificial dryer. This method is also suitable if the production has to be extended due to an increased request for high quality dried products.

Solar dryers can generally be classified into two broad categories active and passive. Passive solar dryers use only the natural movement of heated air and they can be constructed easily with inexpensive, locally available materials which make them appropriate at small level. In a direct passive dryer the food is directly exposed to the sun's rays.

Direct passive dryers are best for drying small batches of fruits and vegetables such as banana, pineapple, mango, potato, carrots and French beans. Active solar dryers are designed incorporating external means, like fans or pumps, for moving the solar energy in the form of heated air from the collector area to the drying body. The food is not exposed to the direct rays of sun which reduces the loss of color and vitamins. The collector can be large and thus heat greater quantities of air. There are a large number of different designs of solar driers. Small solar driers have been investigated at research institutions particularly in developing countries, for many years but their often low capacity and insignificant improvement to drying rates and product qualities have restricted their commercial use to only three of four

applications worldwide. Solar tunnel dryer becomes popular due to considerable reduction of drying time and significant improvement of product quality. Solar tunnel dryer have been used to dry fruits, vegetables, root crops, medicine preparation and fish. The utilization of solar energy as the only energy source offers the possibility to use the solar tunnel dryer at nearly any sunny location, even in remote areas without access to the mains electricity or in areas without reliable energy supply. The operational cost of the solar tunnel dryers in terms of energy amount to zero. The solar tunnel dryers basically consists three major components: the photovoltaic drive, the solar air heater and the drying compartment. The only part that may need replacing from time to time is the plastic cover. The life span of the plastic cover is mainly dependent on the location and care taken of the material. It has a life span in excess of 5 years.

2.5 Preparation of mango jam

After harvesting, mangoes are transported to the processing plant as soon as possible. Once at the plant, they should be processed immediately, or at least stored in the shade. Fruit quality deteriorates rapidly while waiting to be processed. To unload, either mangoes are off-loaded onto an inclined belt, or the gondolas are filled with water from overhead nozzles. If water is used, gates along the sides or undersides of the gondolas are opened, allowing the mangoes to flow out into water flumes. Mere rinsing of mangoes in water is not enough, because of mold filaments and other micro-organisms found in their cracks, wrinkles, folds and stem cavities are not easily dislodged. For thorough cleaning they should be washed in running water. For large scale, rotary washers are used. The process takes place using fruit processing machinery and during the process, preservatives are also added in order to avoid microbial growth and increasing shelf life. During the discussions with the industry experts and business stakeholders it was found that usually C grade (A grade is of export quality, B is consumed locally) fruit is used for the juicing or pulping purposes.

Preliminary plant design is suggested for small scale local mango fruit (Kent Variety) jam processing industry in Ethiopia. This was done with the consideration of the availability of the mango fruit with in the country throughout the year as well as the low price of the incoming raw mango fruits to the processing industry. However, from the sensory analysis, it was observed that most of the consumers' preference is towards Kent fruit jam having a higher sensory quality. As a beginning, the researcher believes that a small scale plant design shall be suggested for processing locally grown mango fruits as the product could be

relatively expensive. Moreover, with the same plant design if implemented with a lower capital investment, it would also be suitable for processing of the export standard Kent mango fruits whenever there is plenty supply because the fruit is very seasonal. The flow sheet (figure 1) clearly describes the process for making mango jam for small scale processing industry.

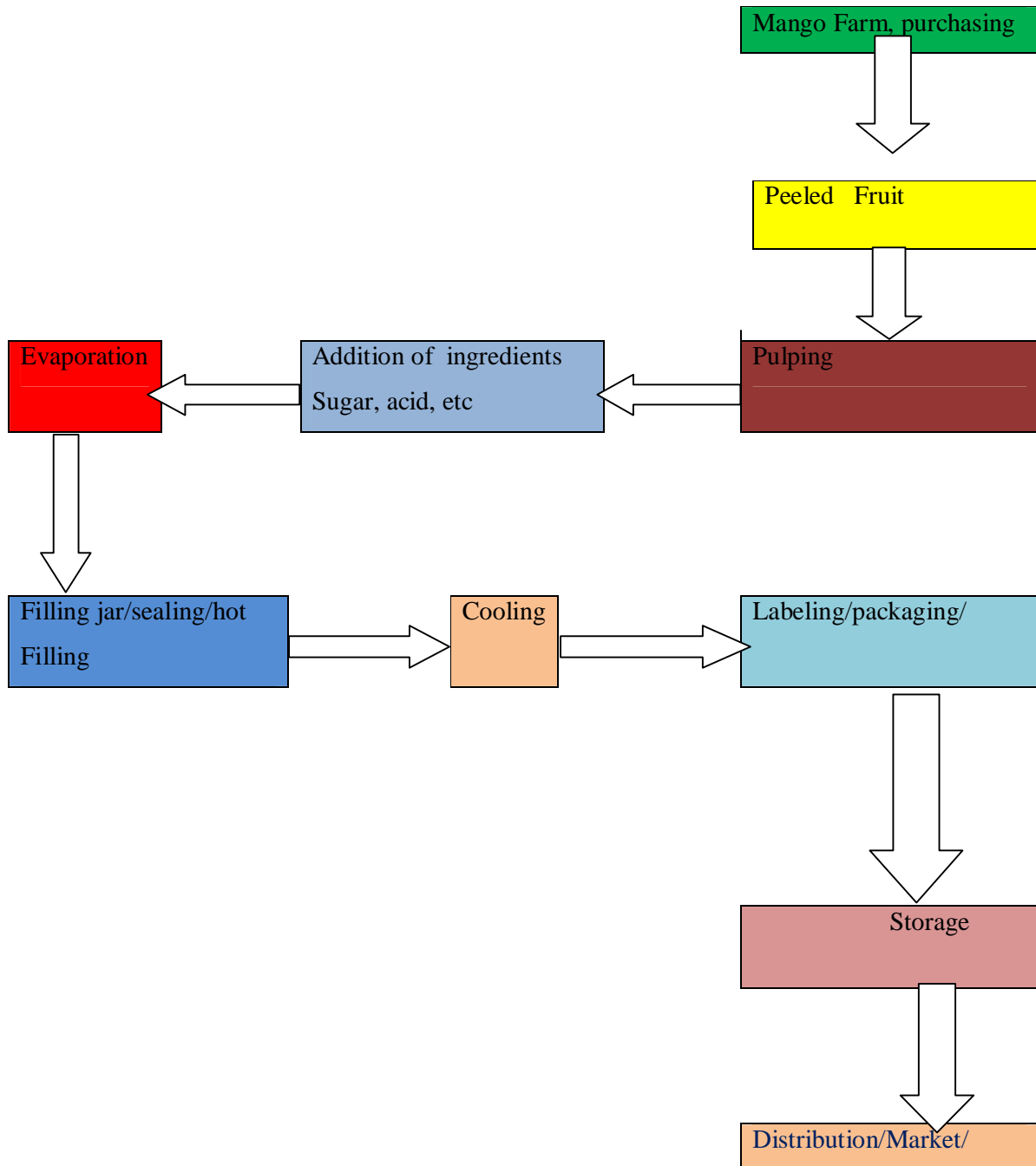


Figure 3: Commercial mango jam production flow sheet

2.5.1 Quality of raw materials

Factors affecting the quality of raw material are, variety, timing of harvest, harvesting methods transportation and storage condition of the fruit. The above mentioned constraints could be solved through the development of harvesting index to the fruits. Mango undergoes changes during maturation and ripening. As the fruit ripens, the 'eyes' change from pointed to flat, with a straight hollowness at the center; the fruit becomes enlarged, less firm and more aromatic. The shell colors of mango are generally used to determine the various stages of maturity. Red Spanish develops a reddish-brown, yellow or light orange color, while smooth cayenne produces a light yellow or golden yellow color when ripe. Fruits with no yellowing are not mature enough for optimum quality (Pantastico, 1975). Usually harvesting is initiated when a few mango fruits on the tree begin to ripen and fall. Optimum maturity stage lead to uniform ripening and better storage life of about 1 week at $35 \pm 0.1^{\circ}\text{C}$ and $65 \pm 1\%$. For industrial scale manufacturing of fruit juice, pulp is used which is available round the year; on the other hand, fresh fruits are also being used for 100% pure juice production. However, based on our discussions with industry experts, we understand that business viability could be a question mark when fruit jam business starts with fresh fruits processing..

2.5.2 Mango process utilization

Traditionally mango is consumed as fresh or processed. The raw fruits are utilized for products like chutney, pickle etc. Ripe fruits are used in making pulp, puree, nectar, squash, leather, slices, etc. Diversification of mango product is a good strategy to increase consumption in the main market of the world. Thus, mango is now consumed in the form of single strength or concentrated juice, dehydrated and/or sugared, canned in slices or bits. The variety traditionally employed to develop these products has been Cayenne Lisa. Among the new developments are dried chips, cocktail-type drinks, dried powdered, isotonic mixtures and wines. There are also new canned forms as whole fruit bars, flakes and cubes. Essentially a prime table fruit, mango pulp is perfectly suited for conversion to frozen juices, nectars, drinks, jams, fruit cheese, concentrates or to be had by itself or with cream as a superb dessert. It can also be used in puddings, bakery fillings, and fruit meals for children. Mango could be processed in to wide diversity of products. Alternative products from green, ripe and waste of mango crops. Green fruits are used to make chutney, pickles, slices and dehydrated products. Ripe mangoes are processed as canned and frozen slices, purée, juices, nectar, jam, jelly and various dried products.

Mango is an excellent source of vitamin A, C and K and provides dietary fiber, potassium; also mango is rich source of beta-carotene which is converted to vitamin A in the body. Vitamin A is essential nutrient required for normal growth, reproduction, vision and immune health, knowing that low fat diet rich in fruits and vegetable may reduce the risk of some types of cancer (Bhaskarachary, *et al.*, 1995). There are many types of products which can be made from mangoes; such products include Nectars, which may be processed by mixing sugar and water with pulp and then heating and filling (Saeed and Khattab, 1974).

In the large-scale production of jams, jellies and marmalades with cooking kettles two basic types exist for the concentration process: open system boiling and vacuum boiling. Cooking in an open kettle is now a day practiced only in a few, small companies. The great benefit of this cooking method consists in low cooking temperatures and short cooking times. Both criteria are decisive for an optimal finished product as regards to appearance, colour, flavour and vitamins, since the raw materials are exposed to only minimal stressing. Short cooking times and relatively large cooking batches also guarantee the economic efficiency of the process.

The pre-heated fruit/sugar mix is fed from the pre-heater by negative pressure into the kettle and reduced by boiling under vacuum with constant stirring. To prevent foaming, edible oils and fats such as mono- and diglycerides of edible fatty acids may be added. The pectin solution is then metered and further reduced by boiling under vacuum until the desired final soluble solids content is reached. Due to the low cooking temperatures, which may be as low as 65 °C, slow to medium rapid set pectins are applied in this process. Once the final soluble solids content is reached, the batch will be vented and acid is added. The temperature of the cooked material increases in this process, before discharging it should reach 80-85°C in order to guarantee germ-free filling. Sophisticated cooking systems with flavour recovery condense the volatile aroma components from the escaping steam and return them to the cooking batch before its discharge. The mango seed kernel is a rich source of carbohydrates, proteins, fat and tannins. The kernel fat (average 12 %) has potential use for preparing sweet meats, in soap manufacturing and as substitutes for cocoa butter. Mango seed kernels also contains 47-63 % starch, of which 19-22 % is amylose.

2.5.3 Jam preservatives

Preservative such as sodium benzoate may be added @ 40 ppm to the jam. The principle of jam manufacture is the increase of solid material in the mix due to evaporation of water, a proportion of sucrose is converted to invert sugar and a gel is produced on cooling. It has been shown those separated component, sugar, pectin and acid all play a part in forming the gel, when the fruit is low in pectin, and high in acid, there for the deficiency was compensated by adding solution of such ingredients toward the end of boiling. Jelly manufacture involves boiling the fruit with water and then the extract is boiled with the sugar. The boiling point reached is about 169 °C (Pearson, 1970).

2.6 Legal requirements and food safety quality

Both national and international food safety & legal requirements applicable to the processed fruit based products were assessed. The Quality and Standard Authority of Ethiopia (QSAE) is the National Standard Body (NSB) of Ethiopia. Specific and general legislative requirements applicable to production of jam were obtained from QSAE. For international requirements Codex Alimentarius standards and additional specific requirements for the export food stuffs to European Union (EU) market were referred from Center for the Promotion of Export from Developing Countries (CPEDC).

Quality standards for jam: Quality should be emphasized at each step right from the beginning to the marketing of the product. Over the years, an image of high quality products should be cultivated.

- ❖ Jam shall contain a percentage of soluble solid in the range of 57 –M 68°Brix (Malcolum, 2005).
- ❖ The first named fruit in all mixed jam should contain amount to not less than 50% and not more than 75% of the fruit content (Kordylas, 1990).
- ❖ The second named fruit required to be present in 25% of the fruit content or less if more than two fruits mixed (Pearson, 1970).
- ❖ The content of toxic contaminants (heavy metals) in jam must be less than the following (Ward, 2000).

- Arsenic (As) 1.1 P.P.m. .

Copper (Cu) 3.0 P.P.m

- Lead (Pb) 2.5 P.P.m.

Zinc (Zn) 50 P.P.m

Failure of jelly

Jams, jellies and marmalades are discharged from the vacuum kettle by way of pumps or, even more sensitively, by gravity into heated filling troughs with agitators, from which they are fed into filling machines. The temperature of the cooking batch at the time of filling is 70-85 °C. The relatively high filling temperature and capping under vacuum with headspace sterilization guarantees germ-free filling and perfect stability during storage. Before closing the jars, suitable measures for the sterility of the product surface during the filling process are recommended. UV-radiation of the empty jars or the caps before filling is also indicated to protect against secondary infections. After filling and capping, the jars pass through a tunnel cooler and are sprinkled with cold water which lowers their temperature to 40-50°C. The rapid lowering of the temperature prevents caramelization and colour changes in the filled article and brings the product into a temperature range; in which gelation is initiated and an optimal gel texture may be slowly formed. After cooling and labeling, the products go into packaging. Before distribution, however, the jars should be stored until the product has thoroughly gelled.

Reasons of failure:

- ❖ Imbalance concentration relationship among sugar, pectin, acid, and raw material.
- ❖ Less quantity of pectin and this could be either is not adequately mixed with sugar or added at the beginning of the heat treatment.
- ❖ Total soluble solids have not being reached the final desired Brix degree.
- ❖ pH value above 3, but when the pH value is less than 3 this may lead to what called jam bleeding (Elsyaid, 2008)

2.7 Mangoes' nutritive value

Many studies on the mangoes were concentrated on their carotenoid (or β – carotene and pro-vitamin A) content. Mango is an excellent source of vitamin A, C and K and provides dietary fiber, potassium; also mango is rich source of beta-carotene which is converted to vitamin A in the body. Vitamin A is essential nutrient required for normal growth, reproduction, vision and immune health, knowing that low fat diet rich in fruits and vegetable may reduce the risk of some types of cancer (Bhaskarachary, *et al.*, 1995). Mangoes are rich sources of both vitamin A and C. (Ahmed Khalid, 2009).

Table 7: Range of some vitamins of fifty mango varieties.

Vitamin	Per 100 g fresh weight
A (β -carotene)	1000 – 6000 Iu
B1 (Thiamine)	35 – 63 μ g
B2 (Riboflavin)	37 -73 μ g
B (Folic acid)	3.6 μ g
C (Ascorbic acid)	0.0 – 160 μ g

As reported by Caygill et al. (1976)

2.8 Health benefits of mango products

Mango fruit is rich in pre-biotic dietary fiber, vitamins, minerals, and poly-phenolic flavonoid antioxidant compounds. According to new research study, mango fruit has been found to protect against colon, breast, leukemia and prostate cancers. Several trial studies suggest that polyphenolic anti-oxidant compounds in mango are known to offer protection against breast and colon cancers. Mango fruit is an excellent source of Vitamin-A and flavonoids like beta-carotene, alpha-carotene, and beta-cryptoxanthin. 100 g of fresh fruit provides 765 IU or 25% of recommended daily levels of vitamin-A. Together; these compounds have been known to have antioxidant properties and are essential for vision. Vitamin A is also required for maintaining healthy mucos and skin. Consumption of natural fruits rich in carotenes is known to protect from lung and oral cavity cancers. Fresh mango is a good source of potassium. 100 g fruit provides 156 mg of potassium while just 2 mg of sodium. Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure. It is also a very good source of vitamin-B6 (pyridoxine), vitamin-C and vitamin-E. Consumption of foods rich in vitamin C helps the body develop resistance against infectious agents and scavenge harmful oxygen-free radicals.

Vitamin B-6 or pyridoxine is required for GABA hormone production within the brain. It also controls homo cysteine levels within the blood, which may otherwise be harmful to blood vessels resulting in coronary artery disease (CAD), and stroke. Further, it composes moderate amounts of copper. Copper is a co-factor for many vital enzymes, including cytochrome c-oxidase and superoxide dismutase (other minerals function as co-factors for this enzyme are manganese and zinc). Copper is also required for the production of red blood cells. Additionally, mango peel is also rich in phytonutrients, such as the pigment

antioxidants like carotenoids and polyphenols. The amount of protein carbohydrates fat calories in 100 grams of mango Well, before proceeding further in the narrative of this fruit, let's look at the chemical composition of mango, though I only looked at him with one eye, before he began to write the article, but he has me interested. Energy value per 100 grams of mango (65 kcal), carbohydrates (15.2 g), proteins (0.5 g), fats (0.25 g) and nutritional value per 100 grams of mango.

Table 8: Vitamins and minerals in mango

Vitamins in mango	Minerals in mango
Vitamin A — 38 mcg	Iron — 130 mg
Vitamin B1 — 55 mcg	Potassium — 153 mg
Vitamin B2 — 56 mcg	Calcium — 10 mg
Vitamin B5 — 157 mcg	Magnesium — 8 mg
Vitamin B6 — 130 mcg	Manganese — 25 mcg
Vitamin B9 — 14 mcg	Copper — 104 mcg
Vitamin C — 27 mg	Sodium — 2 mg
Vitamin E — 1.1 mg	Phosphorus — 11 mg
Vitamin PP — 560 mcg	Zinc — 40 mcg

By-products of mango and medicinal uses: Mangos are an excellent source of Vitamins A and C, as well as Potassium, Beta-carotene, enzymes and anti-oxidants. Mangoes are high in fibre, but low in calories (approximately 110 per average sized mango) fat (only 1 g) and sodium. Mangoes are a good staple for your daily diet. It has a reputation (not necessarily scientifically proven) as an alternative or complementary medicine for a wide range of illnesses including beriberi, bronchial diseases, anxiety, insomnia, fatigue, depression, digestive problems heartburn, constipation, kidney stones. Mango kernel contains high amounts of fat and starch. The oil extracted from kernel is of good quality and could be used in cosmetic and soap industries. The kernel flour (starch) after mixing with wheat or maize flour is used in chapattis in India. About ten percent alcohol could be obtained from mango kernel by co-culture fermentation (Truneh, 2009).

2.9 Mango jam ingredients

Jams are always comprised of four main ingredients which determine their quality: fruits, Various types of sugar (such as refined sugar, glucose-fructose syrup etc.), Food acids (e.g. citric acid) and Pectin. The use of flavoring agents is not permitted. The only substances which are permissible as flavoring are vanilla, vanilla extracts and vanillin, as well as spirits, herbs and spices. Depending on the mandated minimum fruit content, a distinction is also made between extra jam and jam, and between extra jelly and jelly. Extra jam / jam an extra jam can be made from one or more types of fruit, whereby the fruit content must be at least 45 percent. The minimum fruit content for jams is 35 percent. Exceptions are made for fruits such as currants, rose hips and quinces. For these fruits, the minimum fruit content for extra jam is 35 percent, while it is 25 percent for jam. Extra jams and jams must also offer minimum sugar content. The legally mandated minimum sugar content for jams is at least 56 g per 100 g. Dietetic jams with a dietetic jam that is suitable for diabetics; the refined sugar component is replaced with fructose and/or other sugar substitutes and sweeteners. Belfrutta Diet Jam has nearly 50 percent fewer calories than a conventional extra jam. A jam may only be designated as “light” or “low calorie” if its calorie content has been reduced by at least 30 percent in comparison with a conventional jam.

Pectin content: the jam properties vary depending on the fruit or fruit combination used and their pectin content. The more pectin used, however, the weaker the flavor of the fruits used. The pectin content of any fruit may be tested by cooking for five to ten minutes, cooling and testing it using alcohol test. Citrus peel and apple pomace are the major raw materials used for the production of commercially acceptable pectin.

Preparation of Pectin:

The production of pectin solutions by way of a suitable system is the best possibility to add standardized pectin to the cooking process. If only slow-speed mixers are available, the pectin is mixed with about five times the amount of sugar and this mixture is dissolved in water with a temperature of at least 80°C. In this way, a 3-5 % pectin solution can be produced. If a dissolver with high-speed mixer is available (more than 1.500 rpm), pectin is added while the mixer is running and the water temperature is at least 80 °C, directly poured into the mixer flux and dissolved. Depending on the type of pectin, pectin solutions of 5-7 % may be produced. Nowadays, 7-10% pectin solutions can be produced, on modern injection

mixers. The concentration of jams, jellies and marmalades is done with the objective to create a finished product with a long shelf-life and with the required soluble solids content. During cooking, a sufficient exchange between sugars, liquid medium and fruits is achieved, which prevents water loss in the finished product during storage.

Acid content: Citric acid may be added to the low acid fruits; this enhances the flavor of jam, and helps the jam to gel (Kordylas, 1990)

Sugar content: The amount of sugar needed depends on the amount of pectin in fruit, but generally, the ratio of fruit to sugar for traditional jams (1:1). The sugar content is sometimes a little higher or lower depending on pectin and acid contents. Very acidic fruits such as black currant having good pectin content. These take an extra 50 to 100 g/kg of sugar to get a really juicy jam. Fruits such as strawberry, lower in pectin but also much sweeter can take the usual amount of sugar or possibly a little less (Kordylas, 1990).

2.10 Jam packaging

Packaging role include protection against insects and rodents, physical damage, chemical changes and contamination. For these reasons the product must be kept in good quality when a suitable package is used. Jam must be packaged in hermetic containers, which can be sealed completely against gas vapor, microorganisms and dirt. Since the natures of the material used in packaging were very effective to accomplish these purpose can of 3-piece type can be used. The glass jars, mainly are the soda lime silica-types which are constituted from the ratio of 74% silica, 9% lime, 16% soda, 1% alumina and these may result in strength and transparency of jars (Keddie, 1979).

2.11 Jam storage

Opened jam should be kept in the refrigerator at (40°F) or lower. "Regular" or pectin added, full sugar-cooked jams and jellies are best stored for one month in the refrigerator after opening. They may stay longer depending on specific product and how it is used. The expected shelf life will be shortened by keeping the container frequently open at room temperature for long periods of time during use. Examine the container regularly during storage for any signs of spoilage like moulds, yeast and off odors (including a fermented, "yeasty", or "alcohol" odor), once is opened. Discard the entire content of the container if these are detected (Ward, 2000). Lower-sugar or no sugar-added spreads may have a shorter

refrigerated shelf life than those made with the traditional amounts of sugar. Natural flavor changes in the fruit base are more noticeable without the sugar; for example: some lower sugar spreads their taste turn more tart or acidic over time. Light color spreads may also darken more quickly with less added sugar. Frozen jams have also been stored in the refrigerator after thawing and will retain good quality for 3 to 4 weeks (only) after opening. (Ward, 2000).

2.12 Microbiological determination of mango products

The shelf life of fruit products is limited primarily by microbial, enzymatic and chemical reactions that adversely affect their nutritional quality, color and flavor. Pasteurization requirements of freshly extracted juices are based on inactivation of heat resistant endogenous enzymes, whereas the requirements for reconstituted juices are based on destruction of microbial populations capable of causing spoilage (Graumilich et al., 1986). The main spoilage organisms in food products are yeast and molds, especially those which can be grown at low pH values i.e. below 4.6 pH and are those able to damage the product. Yeast pre dominates spoilage of acid fruit products because of their high acid tolerance and the ability of many of them to grow an-aerobically.

Yeast, molds and lactic acid bacteria have been implicated in spoilage of fruit products Harrigan, (1976). Accordingly, the pH of fruit products especially that range from 5.0 to less than 2.5 the types of microorganism that can spoil fruit products can be determined. Harrigan, (1998). Fruit products must be sterilized gently or must receive an equivalent process to prevent or delay pathogenic microorganisms. Washing of fruits with clean water can be used to remove the soil from the fruit and this may lower microbial load.

3 MATERIALS AND METHODS

3.1 Materials

1. Mango Fruit: Two mango varieties were selected namely Neohera (NE1) and Kent and kept 8°C for 7 days until the physicochemical analysis was conducted. High Methoxy Pectin (HMP) mango fruits of grade 150 were used for jam making experiments which were brought from Awash Melkassa Agricultural Research Center (AMARC).

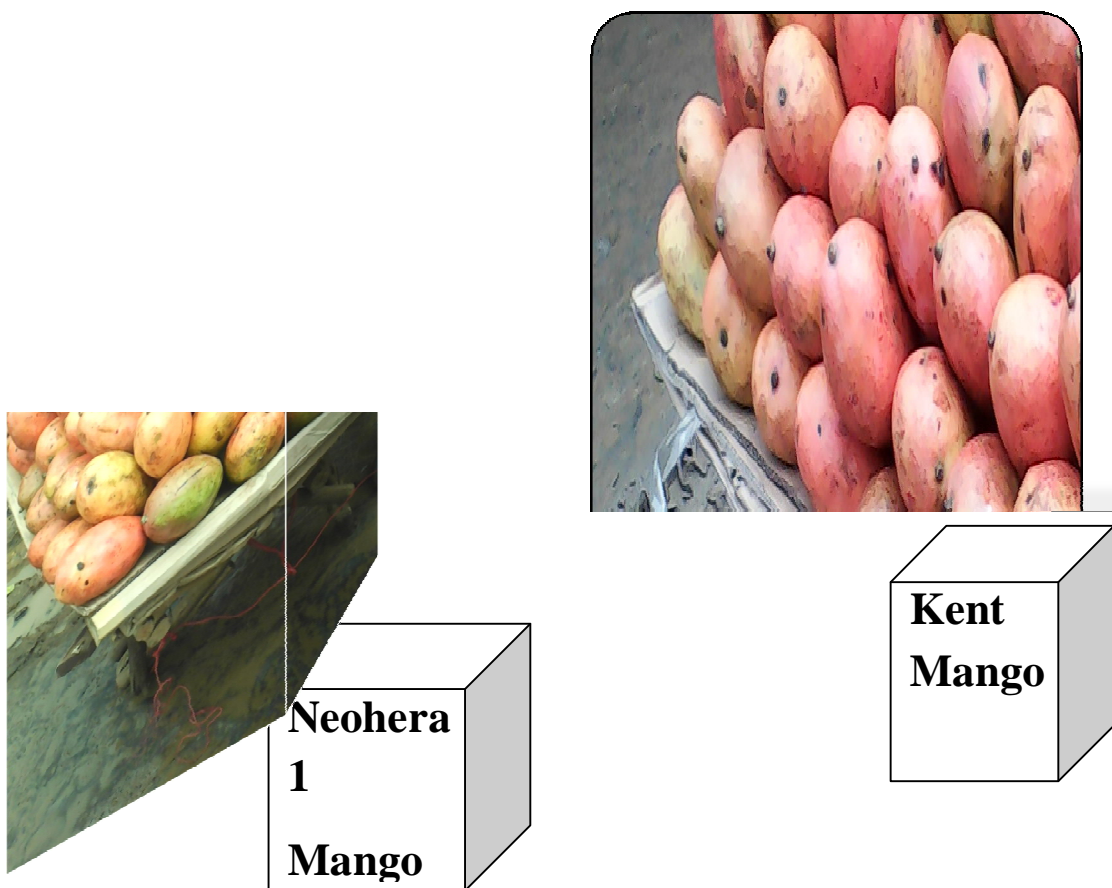


Figure 4: Selected mango varieties

2. Reagents, distilled water and other chemicals were supplied by Addis Ababa University, AAIT laboratory.

- Sugar and pectin were obtained from the local market
- Citric acid and sodium benzoate were supplied by Neway Chemical plc.

3. Apparatus:

Table 9: List of equipments

Thong	Presser	muffled furnace	jars with lids	Colorimeter
masher	glove	weight bottle	bottles	visco meter
strip road	funnel	erlenmeyer flask	mask	pH meter
oven	dryer	what-man filter paper	goggle	refracto meter
sieve	rack	beater or blender	bowl	tape meter
desiccators	strainer	wooden spoon	apron	stopper
stove	jars with lids	dishes	burette	measuring
thimble	cooking pot	saucer	knife	cylinder
cotton	razor blade	sterilizer		measuring cups
beaker	wiley mill	towel		weighing
scissor	silica crucible			balance
				thermometer

3.2 Methods

First, 10 kg of Kent and NE1 mango fruit varieties were taken from Awash Melkasa Agricultural Research Center (AMARC). The mangos were then brought to AAU, food engineering laboratory. The fruits were washed; steam bleached, peeled, sliced and pulped using an electric blender. The weights of pulp peel and stone were recorded by taking the average weight of 8 fruits of each variety. Accordingly, the mangos were weighed after the blemishes were cut away and were manually peeled with a stainless steel knife. They were cut and sliced in to pieces. These were removed to make fruit pulp ready for making the puree. The pulp was pureed in blender till becoming smooth. The pure mango was covered and put into a glass jar and refrigerated at 4⁰C. The puree mix was prepared with the appropriate proportion of mango puree, sugar, lemon juice and pectin. After the mango was pureed and mixed with lemon juice, sugar and pectin in duplicate samples for analysis so as to compare the effect of the ingredients on the physicochemical qualities. The sample was tested for the contents of the moisture, ash, pH, and microbiological examination, organoleptic quality (mean sensory scores) which were believed to be significant for the research.

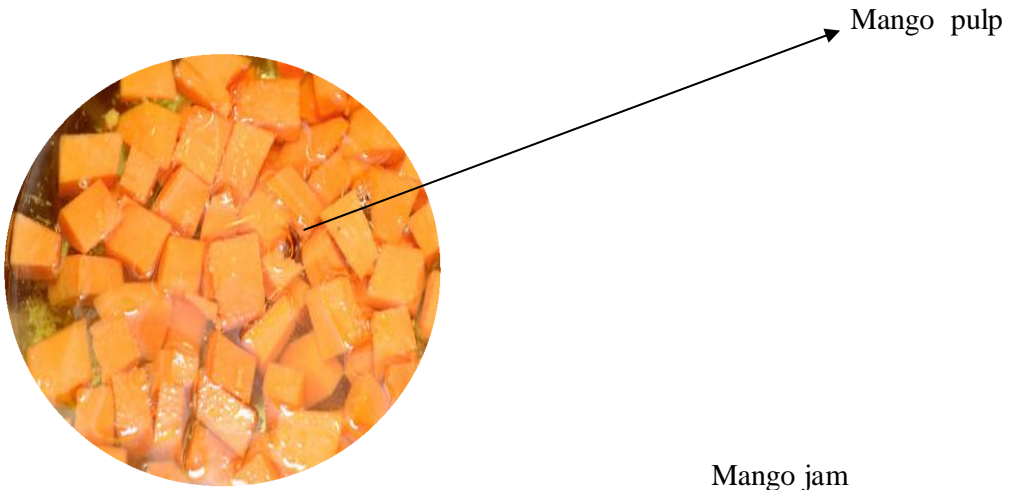
3.2.1 Selection criteria for mango

Mangos were selected for technical assessment for viability of product development from these fruit crops.

The selection criteria were:

- ❖ High added value either through agro-processing
- ❖ High market value
- ❖ Long term comparative advantage
- ❖ Social acceptance and support by government polices

3.2.2 Preparation of mango jam



Mango jam

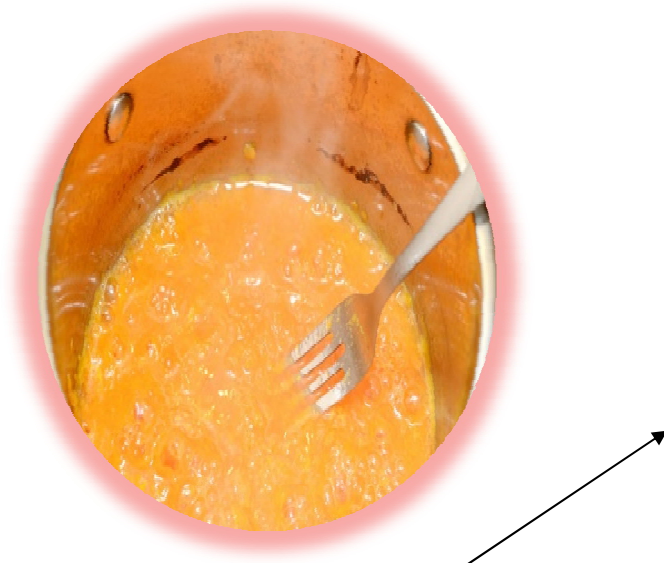


Figure 5: Prepared pulp and jam samples

The preparation flow sheet of mango jam is shown as follows:

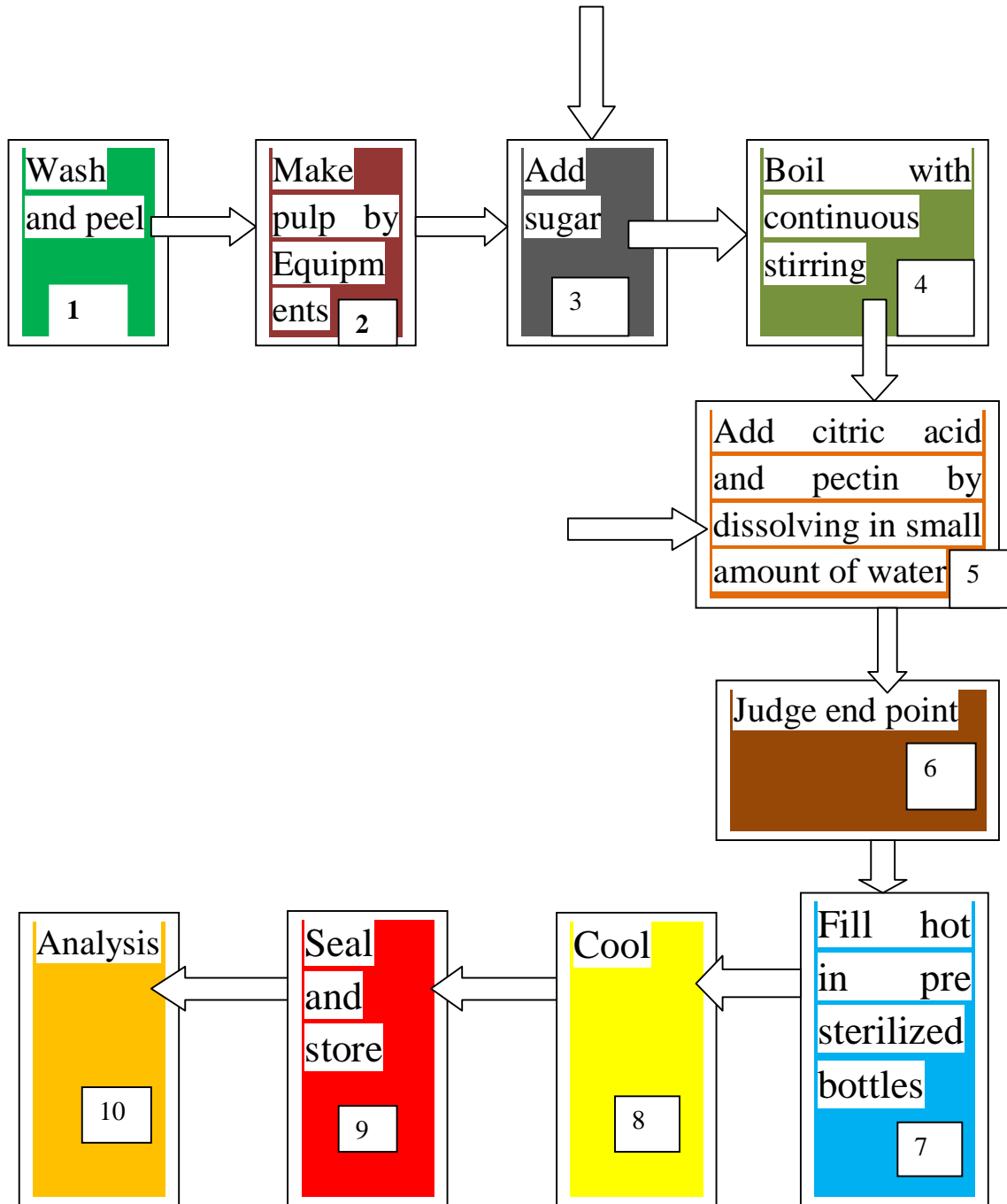


Figure 6: Mango jam preparation flow chart

3.2.4 Physicochemical analysis of mango pulp and jam

3.2.4.1 Physical analysis

Each sample of mango fruits was peeled. The peel, seed and pulp are separated and each fraction was then weighed using sensitive balance. Fruit volume was determined using rapeseeds displacement volumeter method according to Khalid (2009). However, this method was modified by using sesame seeds instead of the rapeseeds. Fruit dimensions; fruits thickness, length, width and diameter were measured by using tape meter.

Pulp viscosity (in centipoises) was measured by using U-tube viscometer at room temperature depending on the flow time, which calculated as follows:

$$\text{Flow time} = \frac{T-T_0}{T_0} \text{-----Equation 1}$$

Where:

T= Pulp flow time in s.

T₀=Distilled water flow time (s).pulp dilution 1:4 distilled water

Jam color was measured with AAIT laboratory; Color difference- meter (CDM) model CR-300 (Minlota camera CO. Ltd. Tokyo, Japan) Gardener color value measuring device has been used. Jams were prepared by diluting with distilled water to T.S.S. =1.

3.2.4.2 Chemical analysis

Mango pulp was analyzed for pulp content, Total Soluble Solids (TSS), acidity, pH, brix/acid ratio, reducing sugars and total sugars according to standard methods as described by AOAC (2005). Total Soluble Solids of pulp were estimated by using hand Refractometer (ATAGO 3T) and the readings were corrected at 20⁰C whereas, pH was measured by digital pH meter (Orion 420 A+).Mango varieties (Kent and NE1) were selected for jam preparation on the basis of physico-chemical/nutritional characteristics (high total soluble solids, brix/acid ratio, sugars and pH) desired for good jam making. Because of their varietal difference of mango Chemical conditions of mango jam must be analysis for mango jam development. During cooking of fruit pulp, sugars, pectin, citric acid and sodium benzoate were added. Thus all parameters were measured and analyzed both of the pulp and jam.

Moisture content: The moisture content of the pulp was assessed according to the A.O.A.C. method (1984). Five grams of the prepared pulp were spreaded in the bottom of aluminum dish (55mm diameter and 40 mm thickness). The dish and its contents were accurately weighed, placed in an air oven Gallenkamp, model (ov-160) at 65°C and left to dry for 24 hours. After drying to a constant weight, the covered dish was transferred to desiccator to cool and then it was accurately re-weighed. The percentage of moisture content was calculated using the following formula for the triplicate samples of each variety:

Calculation:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_0} \text{ ----- Equation 2}$$

Where:

W₁=the original weight of dish plus sample, g

W₂= the weight of dish plus sample after drying, g

W₀=the original weight of the sample, g

Ash content: Ash was determined according to the method of A.O.A.C. (1970) Triplicate samples 5g were accurately weighed into relatively broad crucibles that have been pre ignited, cooled in desiccator and weighed. The crucible and its content were ignited in a muffle furnace at 550°C until light grey ash of constant weight was obtained.

$$\text{Ash content (\%)} = \frac{W_1 - W_2}{W_0} \text{ ----- Equation 3}$$

Where:

W₁=the weight of the crucible plus sample after ignition, g

W₂=the weight of empty crucible, g

W₀= the weight of the sample (5g).

pH value: The pH of the pulp (or jam) was measured with glass electrode pH meter (Model; HANNA instruments 8521) at ambient temperature. Lower sugar content requires for proper gelation a lower pH-value. Higher pH-values are feasible with higher sugar content. If the sugar content remains constant, gels with lower pH values will be firmer and more brittle; the

same applies if the pH stays the same and the amount of sugar increases. The optimal soluble solids content for jams is 60-65 % (Oakenfull, 1984). Replacing part of the sucrose with glucose syrup or the use of the optimal type of pectin may prevent the formation of brittle gels and the crystallization of sugar and dextrose.

Total Soluble Solids (T.S.S.): T.S.S. of mango pulp (or jam) was measured with hand refractometer at (20°C); it was expressed as (%) or degree Brix A.O.A.C., (1984). Total soluble solids (TSS) and total titratable acidity (TTA) for fruit pulps and jams were measured to obtain the required acid to sugar ratio for quality jam. Pectin content of the fruit pulps, mango and lemon extract were also determined. Shelf life of jams stored at room temperature was monitored for six months by determining moisture content, TSS, TTA, and microbiological changes. Sensory evaluation of the jams was performed to assess consumers' preference among the produced jams. Jams formulated without addition of pectin were inferior in quality. Time of storage did not have significant influence ($p > 0.05$) on the TSS in all fruit jams formulations. In general, fruit jams treated with commercial pectin (CPT), lemon extract (LEP) and *A. digitata* L. powder (APP) maintained the recommended level of TSS above 65%, pH (3.0 to 3.5) and pectin (0.5%), which was the case with all formulated jams (FAO, 2009) throughout the storage time. The ratio of acid, sugar and pectin might have contributed to the stability of the jam during storage time.

Total titratable acidity: The total titerable acidity was calculated according to the method described by (Board, 1988). Ten grams of mango pulp (or jam) were weighed into a 250ml beaker, diluted with 150ml of distilled water, then filtered, 10ml of the filtrate were titrated against (0.1N) NaOH to pH 8.0 using phenolphthalein as an indicator and it was calculated as follows

$$\text{Total acidity (mg/100g)} = \frac{\text{Titre (ml)} \times \text{N (NaOH)} \times \text{dilution} \times \text{equivalent weight} \times 100}{\text{Weight of the sample taken} \times \text{volume taken} \times 1000}$$

----- Equation 4

Standard method for titration

Ten ml of a mixed solution (25ml for mango jam) of Fehling (A) and (B) were pipetted into a conical flask. A burette was filled with the clarified sugar solution and running the whole volume required to reduce the Fehling's solutions so that, 0.5-1.0ml was still required to complete the titration. The content of the flask was mixed and then heated to boiling for

2minutes; Three drops of methylene blue indicator were added. Then the titration continued till color completely disappeared. The optimum gel set normally obtained in the pH range of 2.8 to 3.3 for high methoxy- pectin. If the acid value is too high (pH-value under 2.8) the gel elasticity will be increased and the gels become firm and brittle. If the acid value is low (pH-value above 3.3) the gel structures become very soft. When exceeding a certain pH limit, gelation is no longer possible. The presence of buffer salts in fruits, e.g. salts of citric and malic acid, suppresses the impact of pH modification by added fruit acids, part of the effective acid value is compensated. To get into the desired pH-value, the acid dosage must be raised. On the other hand, if the pH-value in fruits is too low, it can be increased in order to prevent pre-gelation (Oakenfull and Scott, 1984). Citric acid is a sharp-tasting acid present in the juice of lemons and other sour fruits. The total titerable acidity was calculated according to the method described by (Board, 1988). Ten grams of mango pulp (or jam) were weighed into a 250ml beaker, diluted with 150ml of distilled water, then filtered, 10ml of the filtrate were titrated against (0.1N) NaOH to pH 8.0 using phenolphthalein as an indicator.

Sugars: Total sugars were assessed according to Lane and Eynon titrometric method, described by (A.O.A, C., 1984). Twenty-five grams of the mango pulp (3g mango jam) under investigation were filtered through what man filter paper (No.4) and then beaker, diluted with 150ml of distilled water, then filtered, transferred to a 250ml volumetric flask. A 100ml of distilled water was carefully added and then neutralized with (1.0N) NaOH to a pH 7.5-8.0. About 2ml of lead acetate were added and the flask was then shaken, and left to stand for 10minutes, then 2g of sodium oxalate were added to remove the excess of lead. Distilled water was again added to make up the volume to mark (250ml), and the solution was filtered. A 50ml of the filtrate were pipetted into 250ml volumetric flask. To the new mixture 50g citric acid and 50ml distilled water were slowly added. The content of the flask was boiled gently for 10minutes to invert the sucrose, and then cooled; few drops of phenolphthalein indicator were added. In order to neutralize the mixture, a 20% NaOH solution continuously added till the color turned pink. Immediately, (1.0N) HCl was added till the color of the solution disappeared, and the volume was made to mark before titration.

Reducing sugars: For most fruits, the reducing sugars were very low, so that filtrate can be used directly for titration according to (A.O.A.C, 1984) using the following equation:

$$\text{Total sugars\%} = \frac{\text{mg/100ml} \times \text{dilution} \times 100}{1000 \times \text{weight taken}} \text{----- Equation 5}$$

$$\text{mg total} \frac{\text{sugars}}{100\text{ml}} = \frac{\text{factor} \times 100}{\text{Titer}} \text{----- Equation 6}$$

The factor is obtained from glucose table (Pearson, 1970). Sugars are one of the main constituents of jams, jellies and marmalades and influence the shelf life of these products decisively through the soluble solids content. At the same time they provide taste, flavor, consistency and coloring. For jam production, mostly refined sugar or white sugar (sucrose) is used. During cooking, sucrose is partially inverted. This intended chemical reaction (splitting of sucrose into glucose and fructose by binding water) is influenced by: the pH-value, temperature and time of boiling. The formation of invert sugar prevents the crystallization of the sucrose in the finished product. On the other hand, a complete inversion of sucrose may lead to crystallization of the glucose in the product.

Total pectin content: The method used depends on the extraction of pectin by using HCl at three different concentrations 1N, 0.5N and 0.05N, with the use of two different extraction temperatures 50°C, 80°C, after extraction the pectin can be precipitated as a calcium pectates using CaCl₂ 2N. 50g of the pulp under investigation were weighed into 300ml conical flask, A 100ml of HCl solution (1N,0.5N and 0.05N) were added, then heated at 50,80°C (on which the extraction time depend), then the extracted pectin was filtered through filter paper, A 50ml of CaCl₂ 2N was added and allowed to stand for 2 hours to form a calcium pectates as a precipitate ,then the precipitate was separated from the solution by centrifugal forces and washed with hot distilled water to remove the chloride, and then the precipitate was dried at 60°C for 5 hours, the total pectin content can be calculated as follows:

$$\text{Total pectin (\%)} = W_1 - W_2 \text{----- Equation 7}$$

Where W₁=the weight of calcium pectates

W₂=the weight of added calcium.

3.2.5 Microbial load determination

The microbial load of both jam and fruit bar was under the limit at the end of 120 days. Hence, the prepared jam and fruit bar was safe and fit for consumption.

Total viable count: One ml of aliquots from suitable dilution was transferred aseptically into sterile Petri dishes; to each dilution 10-15ml of melted and cooled 42°C plate count agar was added. The inoculums were mixed with media and allowed to solidify; the plates were then incubated at 37°C for 48hours. A colony counter (Quebec colony counter) was used to count the viable bacteria.

Yeast and mould enumeration: From suitable dilution of sample, 0.1g chloroamphenicol per one liter of medium to inhibit bacterial growth, Samples were spread all over the plates using a sterile bent glass rod. Plates were then incubated at 25-28°C for 48hours Colony forming units (CFU) were counted using a colony counter and the results were presented as CFU/g.

3.2.6 Sensory evaluation

Sensory evaluation of prepared mango jams and imported mango jams was conducted. The sensory evaluation was conducted 4 week after the jam was prepared. The prepared jams were kept refrigerated for 4 weeks at 12°C and at room temperature for 24 hours before sensory evaluation were carried out in triplicate for colour, taste, flavour and overall acceptability by a panel judges at intervals of 0, 30, 60, 90 and 120 days. The sensory evaluation was carried out using semi trained sensory panels consisting of students and staff from the faculty of technology AAU. Each panelist received samples numbered with three digit random numbers and presented according to a randomized complete block design. Bread was used as carrier since jam is normally consumed with bread. A nine point Hedonic test scales was used to analysis the sensor evaluation.

The panel members were selected on the basis of their ability to discriminate and scale a broad range of different attributes of mango and mango products. Samples were presented in succession and panelists were asked to rate evaluation variables according to 9-point Hedonic scale.

3.2.7 Experimental design and data analysis

The data obtained for each parameter was subjected to statistical analysis using Statistica 6.0 software. All the experiments were conducted in triplicate and thus data were mean of three replications. The Analysis of Variance (ANOVA) was applied to determine the level of significance. The least significant differences among means at $p < 0.05$ were further compared through Duncan Multiple Range test (DMRt). In Statistical analysis Least Significant Difference test (LSD test), was used to separate the means, (Peterson ,1985).

4 RESULTS AND DISCUSSION

4.1 Results of the physicochemical analysis of mango pulps

4.1.1 Physical properties of mango fruit pulp

The physical properties of the two mango varieties Neohera (NE1) and Kent were used in this study and the results obtained for the two varieties were compared to show the varietal differences and compared with previous studies.

Table 10: The physical properties of the Kent and NE1 mango varieties and their jams

Fruit variety	Weight (g)	Pulp (%)	Peel (%)	Stone (%)	Length (in)	Width (in)	Thickness (in)	Diameter (in)	Viscosity (cp)	Color (visually)
NE1 fruit	345.3 ^y	61.1 ^x	20.6 ^z	18.3 ^z	5.8 ^z	4.8 ^x	2.8 ^y (±0.02)	7.7 ^x	3000 ^x (±2.16)	Yellow red
Kent fruit	414.5 ^z	72.9 ^y	18.8 ^y	8.3 ^y	6.5 ^y	5.0 ^x	3.7 ^y	9.51 ^y	2554 ^y (±4.25)	Yellow green
Type of jam	Amount									
	Jam (ml)	Sugar(g kg ⁻¹)		pectin (g kg ⁻¹)		citric acid(ml)				
NE1 jam	540	818		31.3		19		4517 ^x (±2.16)	yellow	
Kent Jam	980	657		49.5		27.9		3781 ^y (±4.25)	Red yellow	

Where g=gram. cp=centipoises 1in= 2.54 cm 1kg=1000g

- ❖ All values are mean of three replications.
- ❖ Values are average of 8 Fruits Means followed by same letters do not differ significantly (p<0.05)
- ❖ Any two values having different super script letters in each column differ significantly (P≤0.05).

Table 10 Shows the physical properties of mango fruit, Kent fruits showed the maximum average weight 414.52gm and Neohera (NE1) fruits showed the minimum average weight 345.30gm showing significant (P≤0.05) difference among the average weight of the fruits of these varieties. The difference in average weight may be attributed to varietal differences.

The average weight of mango fruits is reported to be in the range of 243-741gm Czhrniciw, (1969). The values of average weight obtained in this study are within the range. The value obtained in one fruits were found to be different values obtained by different researchers reported by Khalid, (2009) this may be due to the difference in production area and other environmental factors. Percentage of the pulp weight was found as 72.9% for Kent and 61.1% for Neohera(NE1) showing significant ($P \leq 0.01$) difference among the pulp percentage of these varieties .The percent of pulp for some mango varieties were reported to be in the range of 69.00-81.86% Czhrniciw, (1969). Gowda *et al.* (1994) reported the pulp percentage of two mango varieties to be in the range of 57-68.7%. The percentage of the peel weight was found to be 18.8% for Kent and 20.6% for Neohera(NE1) respectively showing significant ($P \leq 0.01$) difference between kent peel and the NE1varieties .

Percentage of the stone weight ranged from 8.3% for kent, 18.3% for Neohera(NE1) showing significant ($P \leq 0.01$) difference among the percentage of the stone of these varieties. The percentage of stone of some mango varieties was found in the range of 9.18-16.6% Czhrniciw, (1969). Mohamed, (1994) reported the range of stone of nine mango varieties to be 13.9-17.2%.The dimensions of these two mango varieties were found to be length 6.50in for Kent fruits, and 5.8in for NE1 fruits showing significant ($P \leq 0.01$) differences among the length of these varieties .The width ranged from 4.80in for NE1, and 5.00in for Kent showing no significant differences among the width of these varieties.

However, the Thickness ranged from 2.80in for NE1 and 3.70in for Kent showing significant ($P \leq 0.05$) differences among the thickness of these varieties. While the fruit Diameter ranged from 7.7in for NE1to 9.51 for Kent showing significant ($P \leq 0.05$) difference between Diameter of the two mango varieties, the results of Dimensions obtained in this study are in general within the range of the results obtained by (Saeed, 1974) for mango fruit.The Viscosity in centipoises (cp) of mango pulps ranged from (2554cp) for Kent pulp to (3000cp) for NE1 pulp showing significant ($P \leq 0.01$) difference among the viscosity of these varieties ,These differences in viscosity may be mainly due to differences in pectin content of the two mango varieties .

4.1.2 Chemical composition of mango pulp

The results showed the chemical composition of fruit pulps. Table 11 shows the chemical composition of the two mango varieties for the fresh mango pulp. The moisture content was found to be 76.5% for Kent and 81.25% for Neohera (NE1) pulps showing significant ($P \leq 0.05$) difference between Kent moisture content and the Neohera (NE1) mango varieties. Anon, (1990) has reported the moisture content to be in the range of 76.00-86.00 %, values of 72.10-85.50% were reported by Caygill *et al.*, (1976) for different mango varieties. Values of 79.1-86.1% were reported by Singh, (1960b). The moisture content obtained in this study was within these ranges. The amount of water present in the mango sample was considered to be equal to the loss of weight after drying the sample to constant weight at a temperature of 100°C according to Method AOAC (2003).

The ash content of thirty three mango varieties ranged between 0.26-1.16 percent as reported by Singh, (1960b). The ash content of these mango varieties was within the range. Crude fiber percentage was found to be 0.4% for kent and 2.00% for Neohera showing significant ($P \leq 0.01$) differences among the fiber content of these mango varieties. The organic matter is burned off at low temperature and the inorganic materials remaining are cooled and weighed. Heating is carried out in stages, first to derive the water, then to char the product thoroughly and finally to ash at 550°C in a muffle furnace (AOAC, 1984). The amount of water present in the mango sample was considered to be equal to the loss of weight after drying the sample to constant weight at a given temperature. The differences in crude fiber content may be due to varietal differences. The values of crude fiber content obtained in this study similar with the values (0.3-2.38) reported by Caygill *et al.*, (1976) for some mango varieties. The pH of the pulp of the two mango varieties was found to be 3.51 for kent and 3.78 for Neohera (NE1) showing significant ($P \leq 0.01$) differences among the pH of these mango varieties, The pH values of (4.50) is considered as the demarking line between acid and non-acid foods (Cruess, 1948).

The acidity was found to be (0.56 mg/100g) for kent and (0.15mg/100g) for Neohera (NE1) showing significant ($P \leq 0.01$) differences among the acidity of these mango varieties. The T.S.S was found to be 17 °Brix for kent and 16°Brix for Neohera (NE1) showing significant ($P \leq 0.05$) difference among the T.S.S of these mango varieties, Values obtained in this study were slightly lower than the values obtained by Saeed, (1974) for kent T.S.S, this may be due to the difference in production area, values of T.S.S obtained for NE1 were similar to those obtained by Mohamed, (1994). As can be seen in table 11 the total sugars in the two mango

varieties were found to be 9.5% for kent and 10.58% for Neohera(NE1) showing significant ($P \leq 0.05$) difference among the two mango varieties. The Values of reducing sugars for these samples were found to be 2.54% for kent and for 2.59% showing significant ($P \leq 0.01$) differences among the reducing sugars of these mango varieties. Gowda and Ramanjaneya, (1995) reported values of 9.3-15.3% total sugars and 3.0-9.8% reducing sugars of eleven varieties of Indian mangoes. The results obtained in this study were within the range reducing sugars this may be attributed to the difference in production area but the similar result obtained by Mohamed, (1994). The sugars in mango fruit include sucrose, fructose and glucose as reported by (Chan and Kwok, 1975).

Table 11: Chemical properties of Kent and Neohera mango variety pulps

Variety	Moisture (%)	Ash (%)	Fiber (%)	pH	T.S.S °Brix	Acidity (citric) (mg/100g)	Reducing Sugars (%)	Total Sugars (%)
Neohera (NE1) pulp	81.25 ^x (±1.31)	0.80 ^x (±0.15)	2.00 ^z (±0.05)	3.78 ^z (±0.00)	16.00 ^z (±0.00)	0.15 ^z (±0.00)	2.59 ^y (±0.03)	10.85 ^x (±0.35)
Kent pulp	76.5 ^y (±1.00)	0.56 ^x (±0.01)	0.40 ^z (±0.11)	3.51 ^z (±0.01)	17.0 ^z (±0.00)	0.56 ^y (±0.03)	2.54 ^x (±0.08)	9.5 ^y (±0.32)

- ❖ All values are mean of three replications.
- ❖ Means followed by same letters do not differ significantly ($p < 0.05$)
- ❖ Any two values having different super script letters in each column differ significantly ($P \leq 0.05$).
- ❖ Values obtained on wet basis.

Table 12 Shows the values of total pectin percent extracted by hydrochloric acid at two different concentrations , column one represent the extraction of pectic substances by using hydrochloric acid 1N at 50°C for 10 minutes ,the values obtained by this level 0.85% for Kent, and 1.50% for Neohera(NE1) showing significant ($P \leq 0.01$) differences among total pectin content of these mango varieties at this level of hydrochloric acid, column two represents the extraction of pectic substances using hydrochloric acid 0.5N at 50°C for 15 minutes ,the values obtained by this level 0.56% for kent and 1.0% for Neohera(NE1) showing significant ($P \leq 0.01$) difference among the two mango varieties ,while the extraction of pectic substances using hydrochloric acid 0.05N at 80°C for 30 minutes gave 0.45% for kent and 1.32 % for Neohera(NE1) showing high significant ($P \leq 0.01$) difference between total pectin content of the two mango varieties.

There is a slight reduction in the yield of pectin and this may be due to the increase of temperature which may break down the pectic substances. Nwanekezi *et al.*, (1994) found that mangoes have the highest pectin content (1.80%) among some tropical fruits. The total pectin of some apple cultivars reported by Strandzhev *et al.*, (1974) was in the range of 0.68-1.16%. Elmubarak *et al.*, (1977) obtained pectin values of 4.29% for lime peels, 4.48% for orange peels and 2.17% for grape fruit peels. The pectin content of Indian guava, cultivar named Allahabad Safeda gave 0.78- 0.88% by Ahmed *et al.*, (1998), The pectin content in this study was lower than the values obtained by Elmubarak *et al.*, (1977), these variations were attributed to differences among species of the fruits (mango and citrus fruits). The variation can be attributed to differences in growing conditions and the degree of ripening which may be lower in the raw material used by them.(Protopectin have not been reduced to the acid soluble pectin by enzyme action).

Table 12: Total pectin extracted from mango pulps using HCl

Variety	(1N)	(0.5N)	(0.05N)
Neohera(NE1)	1.50 ^x (± 0.03)	1.0 ^x (± 0.10)	1.32 ^{xy} (± 0.03)
Kent	0.85 ^{yx} (± 0.05)	0.56 ^y (± 0.05)	0.45 ^y (± 0.03)

- ❖ All values are mean of three replications.
- ❖ Means followed by same letters do not differ significantly ($p < 0.05$)
- ❖ Where the first letter for the varietal effect and the second for HCl conc. effect.
- ❖ Any two values having different super script letters in each row and column differ significantly ($P \leq 0.05$).

4.2 Physicochemical properties of mango jams

The physico-chemical analysis for the mango jam (including: pH, moisture content, and viscosity) was undertaken at AAU Chemical Engineering laboratory. The pH was measured using pH meter. The TSS was measured by refractometer, titrable acidity was determined by titration method, °Brix /acidity ratio was calculated.

Determination of viscosity of the Mango puree: The viscosity of the puree was measured by Vibro viscometer (SV-10, JAPAN), (2001) model which works between 0.3 and 10,000 mPa.s at different temperatures during the heating process on continuous mixing. Mango puree sample was poured into the cup until viscosity surface reaches between the level gauges. The level gauge indicates between 35 and 45ml. The cup was then attached on the table along the guides, gently lowering the sensor plates above the sample surface and the viscosity was measured.

Table 13 shows the physicochemical properties of the two mango jams. The maximum T.S.S. was reported for Kent jam 68.50°Brix, followed by Neohera(NE1) jam 65.2°Brix. These results showed significant ($P \leq 0.05$) differences among the T.S.S of these mango jams, The T.S.S. in jams was reported to be in the range of 57-68°Brix (Malcolm, 2005). Neohera(NE1) jam showed the maximum pH 3.2 followed by kent jam 3.15 showing significant ($P \leq 0.01$) differences among the pH of these mango jams. Kent jam contains the maximum acidity as citric acid 0.60mg/100g and Neohera(NE1) jam contains acidity of 0.5mg/100g showing significant ($P \leq 0.01$) difference between the two mango variety jams. The acidity in jams was reported to be in the range of (0.6-0.8) Anon,(1990) , The minor variation of acidity may be due to the low and high acidity of the raw mango.

As can be seen in table 13 Neohera (NE1) jam contains the maximum total sugars 67.9% and Kent jam contains 56.25% showing significant (≤ 0.01) difference between the two mango jams. Total sugars in jams were reported to be in the range of 53.0-68.0% Pearson, (1970). The results obtained in this study were within this range. The reducing sugars showed their maximum value Neohera(NE1) in jam 32.54% and Kent jam 21.52% showing significant ($P \leq 0.01$) difference between the two mango varieties, The reducing sugars in jams were reported to be in the range of 22.0-40.0% Pearson, 1970), the results obtained in this study were within the range. Neohera(NE1) jam contain the maximum color degree 2.00 and kent

jam contains the minimum color degree 1.55. Showing significant ($P \leq 0.01$) difference between the two mango jams, the variation of color may be due to varietal differences.

Table 13: Physicochemical properties of kent and NE1 mango jams

Source Of Jam	T.S.S (%)	pH	Acidity (mg/100g)	Reducing Sugars (%)	Total Sugars (%)	Color(*) (degree)
NE1	65.2 ^y (±0.00)	3.2 ^z (±0.00)	0.50 ^y (±0.03)	32.54 ^x (±0.0)	67.9 ^x (±0.11)	2.00 ^x (±0.0)
Kent	68.50 ^z (±0.1)	3.15 ^y (±0.1)	0.60 ^y (±0.01)	21.52 ^y (±0.5)	56.25 ^y (±0.3)	1.55 ^y (±0.1)

* Color measured as a degree orange color

- ❖ Any two values having different super script letters in each column differ significantly ($P \leq 0.05$).
- ❖ Values are means of triplicate analysis.



Figure 7: Kent and NE1mango jam

4.3 Changes in chemical properties of mango jams during storage period

Table 14 Shows change in total soluble solids (T.S.S) of mango jams during storage .The T.S.S of all mango jams significantly ($P \leq 0.05$) increased at the end of the storage period (120days). Such trend may be attributed to certain degree of hydrolysis of insoluble solids to become soluble with time. The variety neohera(NE1) remained the highest in T.S.S 65.00°Brix, while Kent jams stored at refrigerator temperature remained the lowest in T.S.S 64.45 °Brix.

Table 14: Change in total soluble solid of mango jams during 120 storage days

Source of jam	0 day	60 days	120 days
Neohera(NE1)	65.00 ^{yz} (±0.00)	66.00 ^y (±0.00)	66.07 ^{yx} (±0.00)
Kent	63.40 ^{zy} (±0.00)	64.2 ^{zx} (±0.00)	64.24 ^{zx} (±0.00)
k. refrigerated	63.40 ^{zx} (±0.00)	63.41 ^{dx} (±0.00)	63.34 ^{zy} (±0.00)
k.deep freedzed	64.4 ^{zx} (±0.00)	63.37 ^{dx} (±0.00)	63.44 ^{dx} (±0.00)

- ❖ Values are means of triplicate analysis.
- ❖ Any two values having different super script letters in each row and column differ significantly ($P \leq 0.05$).
- ❖ Where the first letter for the varietal effect and the second for storage effect.
- ❖ K. refrigerated: kent jam stored at refrigerator temperature.
- ❖ K. deep freedzed: kent jam stored at freezing temperature.

The result of pH values of mango jams stored for 120days are reported in table 15. All samples of jams have shown significant ($P \leq 0.05$) decrease in pH values from 3.07-2.57 for kent refrigerated, and 3.07-3.00 deep freedzed kent and 3.03-2.8 for neohera(NE1) at the end of storage period (120days). The pH of jams formulated with (CPT), (LEP) and (APP) throughout the storage time was within the required range of 3.0 to 3.5 (FAO, 1997)

Table 15: Changes in pH of mango jams during 120 storage days

Source of jam	0 day	60 days	120 days
Neohera(NE1)	3.03 ^{zx} (± 0.00)	3.00 ^{yx} (± 0.00)	2.80 ^y (± 0.01)
Kent	3.07 ^{yx} (± 0.00)	3.04 ^{zy} (± 0.00)	2.90 ^{dz} (± 0.02)
k. refrigerated	3.07 ^{yx} (± 0.00)	3.00 ^{zy} (± 0.00)	2.57 ^z (± 0.02)
k.deep freed	3.07 ^{yx} (± 0.00)	3.03 ^{yx} (± 0.00)	3.00 ^y (± 0.00)

- ❖ Values are means of triplicate analysis.
- ❖ Any two values having different super script letters in each row and column differ significantly ($P \leq 0.05$).
- ❖ Where the first letter for the varietal effect and the second for storage effect
- ❖ K. refrigerated: Kent jam stored at refrigerator temperature.
- ❖ K. deep freed : Kent jam stored at freezing temperature.

The acidity (expressed as citric acid mg/100g) of mango jams are shown in table 16. For NE1 jam stored at room temperature there is a significant increase ($P \leq 0.05$) at the end of storage period. But for kent refrigerated and deep freed the acidity remained unchanged and this may be attributed to the low temperature at which the jams are stored (affect chemical reaction rates) the acidity of kent&NE1 significantly ($P \leq 0.05$) increased at the end of storage period (120days).The slight increase in acidity of mango jams might be partially due to the production of acids with increase in storage period.

Table 16: Changes in acidity (%)of mango during 120storage days

Source of jam	0 day	60 days	120 days
Neohera(NE1)	0.34 ^{yz} (± 0.04)	0.44 ^{yx} (± 0.04)	0.65 ^{yx} (± 0.04)
Kent	0.56 ^y (± 0.00)	0.56 ^y (± 0.00)	0.7 ^{yx} (± 0.04)
K. refrigerated	0.56 ^{yx} (± 0.00)	0.56 ^{yx} (± 0.00)	0.6 ^{yx} (± 0.04)
K. deep freed	0.56 ^{yx} (± 0.00)	0.56 ^{yx} (± 0.00)	0.56 ^{yx} (± 0.00)

- ❖ Values are means of triplicate analysis.
- ❖ Any two values having different super script letters in each row and column differ significantly ($P \leq 0.05$).
- ❖ Where the first letter for the varietal effect and the second for storage effect.
- ❖ Changes in acidity expressed as citric acid mg/100g
- ❖ k.refrigerated: kent jam stored at refrigerator temperature
- ❖ k.deep freed : kent jam stored at freezing temperature

Table 17 Values obtained for kent jams indicate that there was no significant difference among Kent jams total sugars during storage period (this may be due to the raw mango used, was not fully ripe) , for Neohera(NE1) there is a significant ($P \leq 0.05$) decrease in total sugars during storage period, Neohera(NE1) jams remained the maximum total sugars 67.7 % and Kent remained the lowest in total sugars 56.03% , The decrease in total sugars may be due to the inversion of sucrose into invert sugars during storage period.

Table 17: Change in total sugar (%) of mango jams during 120 days

Source of jam	0 day	60 days	120 days
Neohera(NE1)	67.7 ^x (± 0.01)	66.04 ^{xy} (± 0.2)	65.02 ^x (± 0.00)
Kent	56.03 ^{yx} (± 0.14)	55.37 ^{yx} (± 0.77)	54.75 ^{yx} (± 0.77)
K. refrigerated	56.03 ^{yx} (± 0.14)	55.43 ^{yx} (± 1.72)	55.38 ^{yx} (± 0.77)
K.deep freezed	56.03 ^{yx} (± 0.14)	56.67 ^{yx} (± 0.85)	56.05 ^{yx} (± 0.48)

- ❖ Values are means of triplicate analysis.
- ❖ Any two values having different super script letters in each row and column differ significantly ($P \leq 0.05$).
- ❖ Where the first letter for the varietal effect and the second for storage effect.
- ❖ K.refrigerated: Kent jam stored at refrigerator temperature.
- ❖ K.deep freezed: Kent jam stored at freezing temperature.

Table 18 data obtained indicated that a fluctuating trend was observed in values of reducing sugars during storage of these jams. As can be seen in table 18; the reducing sugars were found to be 33.00% for Neohera(NE1) jam at the end of storage period which is higher than the values obtained from the Kent variety. It was recorded the lowest levels of reducing sugars 23.43% at the end of storage period, these variations may be attributed to varietal differences.

Table 18: Change in reducing sugars (%) of mango jams during 120 days

Source of jam	0 day	60 days	120 days
Neohera(NE1)	32.52 ^{xy} (± 0.00)	34.50 ^x (± 0.63)	33.00 ^{xy} (± 0.57)
Kent	20.83 ^y (± 0.36)	21.22 ^{zy} (± 0.17)	23.43 ^{yx} (± 0.00)
K. refrigerated	20.83 ^{yx} (± 0.36)	21.43 ^{zx} (± 0.38)	21.63 ^{zx} (± 0.18)
K. deep freezed	20.83 ^{yx} (± 0.36)	20.45 ^{zx} (± 0.41)	20.44 ^{dx} (± 0.16)

- ❖ Values are means of triplicate analysis.
- ❖ Any two values having different super script letters in each row and column differ significantly ($P \leq 0.05$).
- ❖ Where the first letter for the varietal effect and the second for storage effect.
- ❖ K. refrigerated: kent jam stored at refrigerator temperature.

4.4. Microbial analysis results

The microbiological analysis was conducted at EHNRI for two samples selected from the final Products of both mango varieties which were treated at 60⁰C temperature and 0.6g/cm² puree load. They were selected on the basis that microorganisms grow as the drying temperature was lower and the puree load was greater in relation to the other developed products. Enumeration of total bacteria 1 ml of sample was transferred with a sterile pipette to the tube containing 9 ml of normal saline to make 10⁻¹ dilution. In such a way, dilution up to 10⁻⁷ was made. 0.1ml of each dilution was evenly spread on the nutrient agar medium and incubated at 37⁰C for 24 hours. Quantitative analysis for the presence or absence of specific microorganisms was done by plating on selective media. Estimation of bacterial load was performed by standard method. The microbiological condition of safety and hygiene were then assayed by comparing the obtained results with the limit of Ethiopian standard, known as the recommended microbiological standard for fruit jam in the country.

4.4.1 Effect of storage time on total microbiological growth

Data regarding changes in to microbial analysis of jams prepared from two in mango varieties, no detectable yeast and mold was observed during 120 days storage period. The microbial quality of jams at different time of storage is shown in the table below. Jam formulated without addition of pectin (WP) had a significant higher number of microorganism than all other jams formulated using pectin ($p < 0.05$). The fruit jams that were formulated without addition of pectin had low pectin content that lead to their poor gel formation and its consequent separation that increased the water activity of the product, which could have influenced the growth of microorganism on the 4th month of storage. However, there was no significant microbial growth in other formulations and no coliform growth in all jams throughout the storage time. This clearly shows that when mango fruits are used to prepare jam, it is important to balance the pectin, sugar and acid. The results show that jams formulated with additional pectin could be stored for four months at room temperature without spoilage.

Tables 19, 20 and 21 shows the microbiological examination of mango jams during the entire study: With respect to the occurrence of bacteria, yeast and molds types of microorganisms in mango jams stored for four months (120 days), both varieties showed presence of normal level of 2.5×10 CFU/g, the result showed that there are no yeast and molds growth at (0day and 60days storage). The value mentioned previously is the highest during the entire study, and this could be attributed to the raw mango used, being of high microbial load or under processing; these low numbers were eliminated and vanished out during the next months of storage, because the pH value was unsuitable for microbial survival. Jackson *et al.*, (2003) noticed that the removal of decayed or damaged fruits or trimming of mold portion of fruits can reduce microorganism's number or toxins in fruit products. Microbiological analysis of mango jams after four months storage showed the occurrence of a negligible numbers of yeast and molds in all jams, and this may be attributed to the low pH and high sugar concentration resistance of yeast and molds. Such reduction in bacterial count of the investigated mango jams was mainly due to the heat treatment and subsequently, the possible reduction in water activity. Results obtained in this study were complied with the standards being conducted by Ethiopian Standard Agency (ESA) for microbial level of food.

Table 19: Microbiological examination of mango jams at first day

Source of jam	Total viable count CFU/G dilutions			Yeast and mould CFU/G dilutions		
	-1	-2	-3	-1	-2	-3
Neohera(NE1)	23	2	14	No growth		
Kent	16	10	0	No growth		

❖ All values are mean of three replications.

❖ The lowest sum of rank, the best acceptability.

Table 20: Microbiological examination of mango jam after 2 months storage

Source of jam	Total viable count CFU/G dilutions			Yeast and mould CFU/G dilutions		
	-1	-2	-3	-1	-2	-3
Neohera(NE1)	10	1	0	No growth		
Kent	10	0	0	No growth		
K.refrigerated	12	1	0	No growth		
K.deep freezed	1	2	0	No growth		

❖ Values are means of triplicate analysis

❖ K.refrigerated: Kent jam stored at refrigerator temperature.

❖ K.deep freezed : Kent jam stored at freezing temperature.

Kent jam was judged superior in flavor. Neohera(NE1) jam was judged superior in color and consistency than kent, while these two jams reported the same preference by panelists in taste and overall acceptability.

Table 21: Microbiological examination of mango jams after three months

Source of jam	Total viable count CFU/G dilutions			Yeast and mould CFU/G dilutions		
	-1	-2	-3	-1	-2	-3
Neohera(NE1)	0	4	1	11	12	14
Kent	12	6	11	2	3	5
K. refrigerated	11	3	1	5	7	0
K. deep freezed	2	0	1	0	2	2

- ❖ Values are means of triplicate analysis.
- ❖ K. refrigerated: kent jam stored at refrigerator temperature.
- ❖ K. deep freezed: Kent jam stored at freezing temperature.

4.5 Sensory analysis results

The sensory evaluation was carried out using untrained and semi-trained sensory panels consisting of students and staff from the AAU. The panel consisted of seven members including male and female members of the institute. All evaluation sessions were held in the laboratory of food engineering in Addis Ababa University Institute of Technology, AAIT. The sensory evaluation of mango jam was carried out after 3 days of the jam manufacturing. The mango jam samples were stored at 5°C and were taken out 3h before serving. Color, taste, odor, flavor, aroma, texture, degree of spread ability and overall acceptability of mango jam samples were evaluated following nine point hedonic scale (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely).

The panelists were briefed how to use sensory evaluation forms and terminologies of sensory attributes. All samples were presented before the panelists at room temperature under normal lighting conditions in 50 mL cups coded with random, two-digit numbers. Bread pieces and spoons were provided to the panelists. Drinking water was provided for oral rinsing. At each session, the panelists evaluated 3–6 samples. The average values of the sensory scores (color, taste, odor, spread ability, and overall acceptability) were used in the analysis. Mean sensory

scores for jam formulated from local (NE1) mango and imported (Kent) mango jam is shown in table 22 which indicates jam formulated from local mango had scored similar sensory score. Each panelist received samples numbered with two digit random numbers and presented according to a randomized complete block design. Bread was used as carrier since jam is normally consumed with bread. Statistical analysis was done using Statistical Package for Social Scientists (SPSS version 13.0). The quality and desirability of a food product is determined by its interaction with the sensory organs of human beings, e.g., vision, taste, smell, feel and hearing. For this reason the sensory properties of new or improved foods are usually tested by human beings to ensure that they have acceptable and desirable properties before they are launched onto the market. Even so, individuals' perceptions of sensory attributes are often fairly subjective, being influenced by such factors as current trends, nutritional education, climate, age, health, and social, cultural and religious patterns. To minimize the effects of such factors a number of procedures have been developed to obtain statistically relevant information.

The perceived flavor of a food product depends on the type and concentration of flavor constituents within it, the nature of the food matrix, as well as how quickly the flavor molecules can move from the food to the sensors in the mouth and nose. Some compounds may be lost during processing, which reduces the intensity of flavor or reveals other flavor/aroma compounds. Volatile aroma compounds are also produced by the action of heat, ionizing radiation, and oxidation or enzyme activity on proteins, fats and carbohydrates. The colors of foods are the result of the presence of natural pigments or of added dyes. These pigments are organic in their nature and generally considered to embrace the pigments already formed in the foods as well as those which can be formed on heating, storage or processing. Many naturally occurring pigments, flavor, aroma are destroyed by heat processing, chemically altered by changes in pH or oxidized during storage.

On the other hand, addition of pectin had no significant ($p > 0.05$) effect on the color of the jams produced. Spread ability of the jam on the bread was significantly different ($p < 0.05$) between NE1 and Kent jams formulated without pectin (WP). However, spread ability of NE1 jam with lemon extract (LEP) was significantly ($p < 0.05$) poor compared to other formulations with added pectin. This was probably due to the spongy and brittle characteristics observed by panelists that could have occurred probably during heating (over heating) and resulted into jam with low moisture content compared to other jams. The flavor of a food is determined by the way that certain molecules in the food interact with receptors

in the mouth (taste) and nose (smell) of human beings. Table 22 shows sensory evaluation of mango jams at zero time storage (fresh). There are no significant ($P \leq 0.05$) differences in color, flavor, and taste and over all acceptability among the two samples of jams, while the sample Kent was reported excellent in consistency, taste and overall acceptability compared to the rest of samples and recorded the best preference by panelists. Neohera (NE1) jam was judged superior in flavor and color than Kent.

Table 22: Mean sensory scores of mango jams

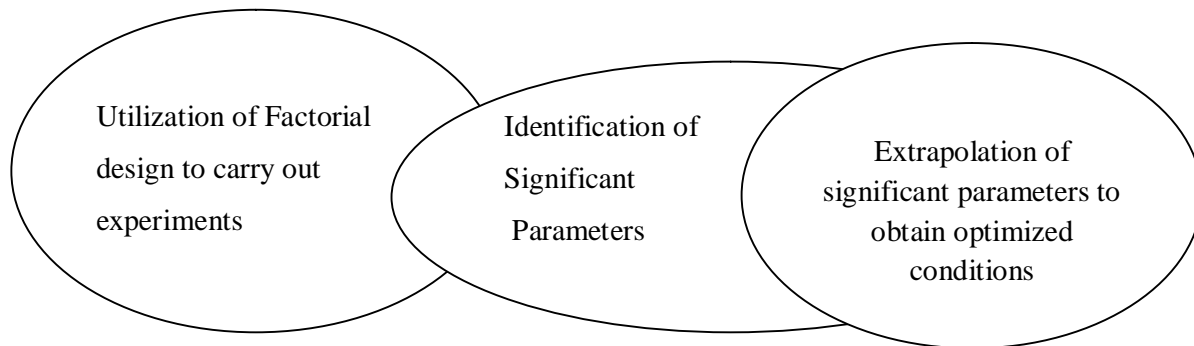
Source of Jam	Color	Flavor	Consistency	Taste	Overall Acceptability
Neohera(NE1)	8.7 ^x	8.84 ^x	8.4 ^y	7.87 ^x	7.87 ^x
Kent	8.6 ^x	8.33 ^x	8.62 ^x	8.42 ^x	8.24 ^x
Mano(commercial)	8.33 ^x	7.69 ^x	6.69 ^x	7.87 ^x	7.87 ^x

- ❖ Any two values having different super script letters in each column differ significantly ($P \leq 0.05$).
- ❖ The highest sum of rank, the best acceptability

Generally, the sample judged Kent as the excellent in overall acceptance followed by commercial and Neohera(NE1). The consistency of commercial was the lowest in consistency by panelists.

5 OPTIMIZATION OF JAM PRODUCTION

5.1 process optimization using factorial design



5.1.1 Factorial Design of Experiment

Experimental conditions in the 2^2 factorial design

Experiment

No.	pH	Sugar
1	5.5	6%
2	5.5	4%
3	5.5	6%
4	5.5	4%
5	4.5	6%
6	4.5	4%
7	4.5	6%
8	4.5	4%

Optimized production of Kent mango can be carried out using the following conditions, at 30°C in 9 days:

- pH: 4
- Sugar: 4%
- 61.2 g kent mango can be produced per 100 g mango pulp, and if scaled up properly, the yield can be increased by 73.2% with a cost reduction of 43.2%.
- Kent jam with sensory acceptability and texture comparable to neohera can be developed using kent Mango and supplementing it at a conc. of 25%.

5.1.3 Statistical analyses

Analysis of variance (ANOVA) was applied using a factorial design with two factors including storage temperature (ambient and refrigerated) and storage time (0, 1, 2, 3 and 4 months). The effect of each factor on the response variable (TSS, pH, TA, RS, vitamin C, FRAP, TMA, TPC) as well as the effects of interactions between the different factors were tested. Significance was accepted at $P < 0.05$ using Minitab Statistical Software (Version 16.0, 2008; Minitab Statistical Software, Minitab Inc., Enterprise Drive State College, PA). All experiments were run in triplicate. Data were subjected to analysis of variance (ANOVA) using Microsoft Excel 2000 (Microsoft Corp., Washington, USA). The statistical model was used to optimize the factors levels for highest acceptability, to produce Kent mango jam. Jam produced under the optimum conditions for sensory score was again subjected to evaluation of sensory values and the results were compared with the RSM predictions

A second order polynomial of the following forms was fitted to the data of all the responses

$$Y = \beta_0 + \sum_{i=1}^4 \beta_i x_i + \sum_{i=1}^4 \beta_{ii} x_i^2 \text{ -----equation 10}$$

Where

Y-response

x^1 - defatted Kent

x^2 - defatted neohera

5.1.4 Analysis of variance for sensory responses

Analysis of variance shows that the coefficient of determination, R^2 , was higher than 0.80 except that of aroma suggesting more than 80% variability could be explained by the predictive models. They were significant at $p < 0.01$ except aroma. Lack of fit was no significant for colour and appearance, body and texture and aroma. However, it was significant for taste and overall acceptability. Considering R^2 , F value and subjective evaluation of the responses. The responses were colour and appearance, taste, body and texture, aroma and overall acceptability. The variables were standardized to simplify computation and to deduce the relative effect of variables on the responses. The magnitude of the coefficient in second order polynomial shows the effect of that variable on the response.

Regression of coefficients and their significance

The sign and the magnitude of the coefficient indicate the effect of the variable on the response. Negative sign of a coefficient at linear level indicates decrease in response with an increase in level of the variable whereas at interactive level, level of one variable could be increased while that of other decreased to get the same response. In case of quadratic term, negative sign of a variable indicates the minimum is at centre point and increases with increase or decrease towards the α level of the variable. Positive sign indicates maximum response at centre point. Defatted kent jam affected all the responses significantly ($P < 0.001$) at linear as well as at quadratic level. The effect was negative suggesting that with increase in the level of defatted kent jam decreased colour and appearance, taste, body and texture and overall acceptability. Neohera did not have significant effect on colour and appearance of its jam. However, it affected taste ($P < 0.01$), body and texture ($P < 0.05$), and overall acceptability ($P < 0.05$) at quadratic level. This shows the concentration of neohera at centre point would give minimum sensory score. It affected taste significantly at linear level. The effect was positive.

5.2 Optimization of ingredient

All the responses were optimized using multiple response optimization software. The software is used to optimize individual response as well as compromise optima considering more responses. To get compromise optima, the software takes into account individual optimum conditions and tries to get the compromise optimum. However, it is always not possible to get compromise optima since the optimum conditions of the individual responses vary widely. The compromise optimum conditions could not be obtained as the individual optimum conditions vary widely. Therefore, optimum conditions of overall acceptability were considered as it was sum total of all quality attributes.

5.2.1 Effect of ingredients on sensory properties of mango jam

Sensory score of color and appearance, taste, body and texture, aroma and overall acceptability range shows that an acceptable mango jam could be developed using all ingredients, combination of defatted kent and neohera. It was found that in general minimum sensory score was of the product made with a combination of defatted kent and neohera as 38.4 and 3.0 g per 100 g mango pulp and maximum at 21.64 and 3.0 g per 100 g mango pulp, respectively. However, defatted kent and neohera showed maximum overall acceptability in the range 25 to 30g per 100g of mango pulp. kent in the range 2-2.5 g per 100 g of mango pulp gave the maximum response. Thus, defatted kent and neohera are important ingredients in preparation of mango jam.

5.3 Development of mango jam using response surface methodology (RSM)

The Response surface methodology (RSM) consists of a group of empirical techniques used for the evaluation of relationship between clusters of controlled experimental factors and measured response. The RSM was employed to optimize the process ingredients like mango pulp, sugar, pectin and citric acid in the mango jam preparation. The ranges of these four ingredients are given in chapter three. The statistical software package “Minitab 16” was used to analyze the experimental data. All variables were taken at a central coded value of zero. Experiments were performed according to the central composite design (CCD) in the RSM. Upon the completion of experiments, the average maximum sensory evaluation of mango jam for color, taste, aroma and texture was taken as the response (Y). A multiple regression analysis of the data was carried out for obtaining an empirical model that relates the response measured to the independent variables.

The mango jam was developed as per the standard procedure using RSM. A combination of ingredients was used to obtain taste and consistency to individual treatment with a view to increase the levels of both sugar and pectin. The optimum level of single treatment was used as center value for the RSM experiments. The level of sugar ranged between 70.86 to 99.14 gm and pectin level was in the range of 3.4 to 4.76 gm /100 gm of jam. The different variables and their levels, central composite design arrangement for preparation format of mango jam were given in Table 24. A central composite rotatable design was used in selecting the levels of parameters in the experiments and to investigate the effect of independent variables on the response. The independent variables were defatted kent and neohera. Response surface methodology (RSM) can be used to model and optimise any response affected by levels of one or more quantitative factors. The optimum conditions for the best sensory score of the four outputs were obtained using Response optimizer in Minitab 16. An experimental run was conducted by taking the operating parameters that yielded best sensory value. The jam produced was tested with the panelists and the scores were compared with the predicted value. The overall scores were 8.90 for color and taste, 9.00 for aroma and texture.

The present investigation deals with the production of kent mango jam using aloe pulp, sugar, pectin and citric acid. Response Surface Methodology design was used to test the relative importance of sensory outputs the optimum condition for the best sensory score is Kent pulp. The quality of the jam depends on the proportion of the mixture which can be tested by sensory analysis. In product development and optimization, Response surface methodology (RSM) is used to model and optimize the response affected by levels of one or more quantitative factors.

5.4 Optimization of mango jams production for sensory analysis

Numeric and graphic optimizations were carried out for the process parameters of the mango fruit jam. The desired goals for each variable and response were chosen. The limit for each variable was narrowed down to obtain an optimal region. Each goal was chosen to be is: at target and is to maximize based on the sensory score of the developed product. Software has generated one optimum conditions of independent variables with the predicted values of responses, in the target of sugar= 85gm/100 gm and carrageenan concentration at maximum level=3.40gm/100 gm for achieving the maximum scores of taste=8.37 and consistency=8.58. From the set of constraints and given outputs, contour plots of relevant and statistically significant responses were generated. The optimum processing conditions could be drawn from shaded area and specific goals were achieved. For example, the graphical data determines the following criteria and goals: sugar = 85 gm/100 gm, taste score=8.37 and consistency score=8.58. The optimized jam was developed by using above ingredients for assessment of nutritional composition and shelf stability.

The mango jam was prepared using the derived optimum formulation conditions to check the validity of the second order polynomial model. The actual values, i.e. experimental values for taste and consistency score were determined and compared with the predicted values of the second order polynomial model. The actual values of taste and consistency scores, i.e. 8.40 and 8.62 were found to be in close agreement with the predicted values of these scores, i.e. 8.37 and 8.58 and they were also within the acceptable limits indicating the suitability of the model in predicting quality attributes of mango jam. Nutritional composition and antioxidant activity of the mango jam in comparison with other commercial jams. The result showed that the mango jam was significantly superior to the commercial jams in terms of nutritional value and antioxidant activity ($p < 0.05$). The mango jam exhibited more amounts of vitamins C when compared to similar commercially available products.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Ethiopia with its diverse agro-ecology is very suitable for the production of high quality mango both for domestic and export markets. However, the country average mango productivity is below the international average. To improve high yielding, better quality, disease resistant and adaptable mango varieties for different agro-ecologies and year round harvest need to be identified through research in addition, there is no recommended spacing, fertilizer rate, irrigation interval for mango production. Mango is one of the second potential fruit crop produced in Ethiopia next to banana which is the first fruit crop produced in large quantity and produced mainly in-west and east of Oromia, SNNPR, Benishangul and Amhara national regional states.

Currently, mango sub-sector is a good entry point for introduces technologies, create employment and reduces poverty among the communities and that the market for mangoes in Ethiopia is significant. Most mango trees in some area are developed from seedlings and are inferior in productivity and quality. Therefore, these less productive and low quality mango trees need to be replaced into improved varieties through top-working. Generally, mango growers in the country have knowledge gaps and need to be solved to boost mango jam production in the country. In order to increase the production of mango jam, many actions have to be taken. Distribution of pest and disease resistance and early maturing varieties is another method to increase production potential. Facilities like road, canal and transportation system should be improved for further dimension and to reduce the loss.

Currently in Ethiopia there is no fruit processing industry involved in mango jam development Process. Most fruit processing industries are interested in production of juices and similar types of products. However, fruit mango jam production can easily be implemented taking advantage of utilizing fruit normally not selected for juice making, freezing or other processes. In the country, the production of mango jam is almost unknown and if this project were to be implemented, it will be very attractive and profitable. Besides, the application of this kind of simple processing technology has designed and developed the process for the production of mango jam at a small scale level within home and village.

From the interpretation of the results obtained in this study the following points can be concluded:

* Variety Kent jam was found to contain the maximum level of extractable pulp, (T.S.S.) and Acidity, While Neohera (NE1) jam was found to contain the maximum level of moisture content ,total sugars and reducing sugars.

* After 4 months, storage of mango jams variety Neohera (NE1) was found to contain the maximum total and reducing sugars, the maximum (T.S.S.), and acidity were recorded by Kent.

* Neohera(NE1) jam was found superior in color & flavor where as Kent jam was found superior in taste and overall acceptability .

* At the end of storage period 4months, all mango jams were found free from microorganisms.

* Refrigerator ($5\pm 2^{\circ}\text{C}$) and deep freezing (-18°C) temperatures decrease the production rate of organic acids in mango jams during storage period.

*Mango jam is a product made by boiling fruit pulp Jam having a good set, should have a proper proportion of sugar, acid and pectin.

*The RSM is an innovative approach to model a system with the collection of statistical techniques where in interactions between multiple processes variables can be identified with a fewer experimental trials. The RSM experimental design is an efficient approach to deal with a large number of variables and there are several reports on application of RSM for the evaluation of sensory analysis.

6.2 Recommendations

The mango properties during processing have to be monitored and measured. So that if there is any problem developed it can be quickly detected, and the process will be adjusted to compensate for it. The final mango fruit jam product has to be also analyzed and characterized to ensure that it retains its desirable properties up to the time when it is consumed, meets the appropriate high quality requirements, and that it is safe for consumption. By mixing different proportions of various types of fruits, fruit jam can be developed to nutritionally enrich the final product and attract customers' attention. The fruit jam products are being targeted at consumers' requirement with increased awareness towards health food choices. Consequently fruit jam is being marketed as luxury health food products in Europe. Once the technology is applied and implemented for mango fruit processing industry, it can also be used for processing of different types of fruit jam at different seasons of the year whenever the fruit types are abundant. From the results obtained in this study, the following point's can be recommended:

- *Organize a design review workshop on mango jam and Organize cooperatives to focus on mangoes
- * Production of mango jam from Neohera (NE1) variety due to the high sugar
- * Variety Kent may be used in future for jam processing due to its high pulp content, excellent processing and storage characteristics.
- * Kent jam should be processed with the addition of suitable food colorant.
- * To minimize undesired changes in consistency of mango jams during storage, to be stored at room temperature ($25\pm 5^{\circ}\text{C}$).
- Import new commercial highly important varieties of mango for jam production and test them at the Awash Melkasa Agricultural Research Center, targeting both table and processing types
- Further researches are needed on Development of other Ethiopian mango varieties for jam making.

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APPENDICES

Appendix-1 Safety Precautions during jam preparation

Electricity and fire safety	Kitchen hygiene
<ul style="list-style-type: none"> • Do not use frayed cords. • Pull plug out by holding the plug not the cord. • Turn power off after use. • Use dry hands, not wet hands. • Keep cords away from hot appliances. • Keep children away from fire place. • Fire must be made in the usual place of cooking. • Do not over make fire by placing more firewood stove and fire use. • Always turn handles in No handles over edge of stove. • Always stay close by when cooking the jam. <p>Do not leave boiling jam unattended.</p> <ul style="list-style-type: none"> • Use correct pot-holders, not wet or trailing tea towels. • Lid must not be placed on the cooking jam • use proper handling of muffled furnace. 	<p>Clean Kitchen</p> <ul style="list-style-type: none"> • Wipe surfaces over when there is split water. • Use clean equipment. • Always wash equipment well after use. • Wash dishcloths and tea-towels often, so that only clean ones are in use. • Use bleach and disinfectant to make sure that dishcloths and mops are clean. <p>Clean Cook</p> <ul style="list-style-type: none"> • Always wear an apron. • Wash hands before handling food and after going to the toilet. • Do not sneeze over prepared mango; cover mouth with handkerchief when sneezing; wash hands afterwards. • Keep hair clean, tied back from the face. • Cover cuts and wounds. <p>Hygienic handling</p> <p>Fruits are highly perishable and affected by different microbial contaminates from production to consumption</p> <ul style="list-style-type: none"> • Wash hands, knives and boards after using them to chop mangoes. • Do not use chipped plastic or china ware. • Do not lick your finger when handling mangoes. • If you taste jam from a spoon, always wash it after use Do not return a used spoon to pot.

Appendix 2 - Laboratory Analysis Method, reagent and apparatus required

The Physico-Chemical analysis of the mango jam was conducted in the AAIT Laboratory.

1. Determination of Acid Value: 25ml of Toluene and 25ml of ethanol was mixed in a 250ml beaker. The resulting mixture was added to 2g of oil in a 250ml conical flask and few drops of phenolphthalein were added to the mixture. The mixture was titrated with 0.1M NaOH to the end point with consistent shaking for which a dark pink colour was observed and the volume of 0.1M NaOH (V_0) was noted. The Acid value was calculated as:

$$\text{The Acid value} = \frac{V \times C \times 40}{M}$$

Where

V =Volume of sodium hydroxide (ml)

C=Concentration of sodium hydroxide,

40 =Molecular weight of sodium hydroxide,

M= sample weight

2. pH Determination

Method: potentiometric method

Apparatus pH meter: Model pH 330i Manufactured by WTW Pty Ltd, capable of reading to the nearest 0.01

Procedure pH meter calibration: calibrate the temperature electrode of pH meter against the temperature measured by the good quality mercury thermometer. Then calibrate the meter against the pH buffer solutions obtained from the manufacturer. All calibration standard procedures follow the manufacturer's instructions.

Appendix 3: Sensory test form

Difference-from-control test

Name: -----Date: ----- Test: -----Type of sample: -----

Introduction

1. Taste the sample method “Control” test
2. Taste the sample method with the three digit code
3. Assess the overall sensory difference between the two samples using the scale below.
4. Mark the scale to indicate the size of the overall difference.

	Scale	Mark to indicate difference
No difference	1	-----
	2	-----
	3	-----
	4	-----
	5	-----
Extremely difference	6	-----

Remember that a duplicate control is the sample some time.

Comments: -----

DECLARATION

I hereby declare that the work reported in the M.Sc. thesis entitled “**Jam Development from Selected Varieties of Mango**” submitted to Addis Ababa Institute of Technology, Addis Ababa, Ethiopia, is an authentic record of my work carried out under the supervision of Ato Adamu Zegeye. I have not submitted this work elsewhere for any other degree or diploma, and that all sources of materials used for the study have been duly acknowledged. I am fully responsible for the contents of my master’s degree thesis.

Nega Endayehu Berhan

Signature _____ Date _____

Date of submission: 24/10/2016

Place: Addis Ababa, Ethiopia

This thesis has been submitted for the examination with our approval as university

Confirmed By Advisor:

Name

Signature

Date

Mr. Adamu Zegeye
