DEVELOPMENT OF A MANUALLY OPERATED MANGO DICING MACHINE

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BY

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ABSTRACT

Pickling is one of the old methods of food preservation. Dicing is most important operation in mango pickle making process. Manual labour is mostly used in cottage and small scale mango pickle processing industry for dicing operation. The mangoes are available only for short period. Hence, hiring labour for short period is difficult due to labour scarcity and higher labour incurs higher cost. Also manual cutting is unhygienic and poses danger to operators. Therefore, a research project was undertaken to develop a manually operated mango dicing machine with a view to introducing for cottage level and small scale pickle industry in India.

The physical characteristics of two mango varieties namely length, breadth, thickness and weight were determined. These dimensions are very important in determining the size of blades, height of the blades particularly spacing blades and number of diced mangos expected from an average fruit. The spatial dimensions viz., length, breadth and thickness of mangos were determined. The data revealed that the mango of desikeri-1 variety has mean length (67.3± 4.6 mm), breadth (56.7± 3.5 mm) and thickness (49.9± 2.6 mm), while the mango of desikeri-2 variety has mean length (89.8 ± 7.8 mm), breadth (64.8 ± 3.3 mm) and thickness (58.7 ± 4.3 mm). The mean weight of desikeri-1variety was 108.031± 17.213 g and that of desikeri-2 variety was 186.083± 28.343 g.

The developed mango dicer simulates the traditional method of mango dicing, consisting of main frame, cutting blade assembly, lever mechanism, feeding and discharging hoppers. The performance of machine was evaluated in terms of capacity, dicing efficiency, breakage percentage, percentage of loss and size of diced mango. The dicer was tested using two mango varieties of 'desikeri'. The capacity, dicing efficiency, breakage percentage and percentage of loss pertaining to the mango dicing machine are 25.75 kg/h, 87.10 %, 1.74 % and 0.69 % respectively. The average size of diced mangos was 36.71±3.3 mm (L) x 33.34±3.0 mm (B) x 14.86±2.1 mm (t) for desikeri-1 variety and that of desileri-2 variety was 41.91± 4.7 mm (L) x 28.53±8.2 mm (B) x 16.79±2.4 mm (t). The mechanical cutting is faster to handle large quantities, hygienic and safe. This machine does not require any special skill to operate and no electrical power is required to operate. Hence, this machine is very useful for pickle industries having 200-250 kg per day capacity especially at off grid locations.

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CHAPTER I

INTRODUCTION

The mango (*Mangifera indica L*) is one of the most important tropical and subtropical fruit of the world and is popular both in the fresh and the processed form. It is a tropical fruit of the mango tree. Mangoes belong to the genus Mangifera which consists of about 30 species of tropical fruiting trees in the flowering plant family Anacardiaceae. The exact origin of the mango is unknown, but most believe that it is native to Southern and Southeast Asia owing to the wide range of genetic diversity in the region and fossil records dating back 25 to 30 million years. Mangoes retain a special significance in the culture of South Asia where they have been cultivated for millennia. It has been the national fruit of India, Bangladesh and Philippines. Reference to mangoes as the "food of the gods" can be found in the Hindu Vedas and the leaves are ritually used for floral decorations at Hindu marriages and religious ceremonies (http://en.wikipedia.org/wiki/mango visited on 30.12.2007)

It is the most delicious fruit of tropics and subtropics commercially grown in more than 80 countries. The leading mango producing countries of the world are India, China, Mexico, Pakistan, Indonesia, Thailand, Nigeria, Brazil, Philippines and Haiti. Less than 10% of total world production of mango is exported. The demand for mango in the world market is increasing day by day. It is reported that the markets for mangoes have increased in temperate countries because of social changes, promotion of fruit trade in developing countries and accessibility to international air cargo space. The expansion of mango trade has been possible because of successful post harvest management strategies to control diseases and insects (http://www.ikisan.com, visited on 03.09.2008)

Mango, the king of fruits because of its excellent flavor, attractive fragrance and beautiful shades of color, delicious taste and native value, is grown in India for over 400 years. More than 1,000 varieties exist today. It is grown in almost all the states. India shares about 56% of total mango production in the world. Its production has been increasing since independence, contributing 39.5% of the total fruit production of India. Andhra Pradesh tops in total production, whereas Uttar Pradesh tops area-wise. Andhra Pradesh, Uttar Pradesh, Bihar, Karnataka, Maharashtra, West Bengal and Gujarat together contribute for about 82% of total production in India. (Chadha, 2006)

In spite of India's dominant position in mango production, the performance of the fruits on export front is not so significant. India occupies fourth position in export of fresh mango in the world. India has been exporting mango to U.K. since 1925. Other major countries to which mango are exported are UAE, Kuwait, Saudi Arabia, Bahrain, Qatar, Bangladesh and mostly the Middle-East and Gulf countries. India produces more than fifty per cent of total mango production but its share in the international trade is confined to mere 0.40 per cent. On the other hand, Mexico shares almost 44.18 per cent followed by Brazil (10.84%) and Pakistan (10.04%). Out of 20 commercial varieties grown all over India, its export is confined to Alphonso and Kesar from Maharashtra and Gujarat respectively and Banganpalli and Suvarnrekha from Andhra Pradesh. Export from north India is almost negligible. Only Chausa from Utter Pradesh has export value (Pathak, 2003). Small countries like Venezuela, Brazil and Pakistan dominate in the world market. Venezuela, accounts for hardly one per cent of world's production of mango has a share of 12.17 per cent in export (Sastry, 1989).

Mango is perhaps one of the most important fruits of the world which can be utilized by the processing industry during the different stages of its growth, development, maturity and ripening. The products prepared both from ripe and green mangoes are highly popular in India and abroad. India dominated the world trade of processed mango products; even though hardly 1% of the total mango production in India is processed. Export of processed mango products is continuously increasing (http://www.ikisan.com, visited on 03.09.2008). Mangoes enter in to international market as fruit and processed food product. Mango is an important source of foreign exchange to India. Millions of tonnes of mangoes, lemons and green chilies are used in India to make different types of pickles where more than 50 varieties are available. Most of these pickles have ready market for millions of NRIs. Most of the manufacturers are small scale. Although export is not very big at present, potential is high (Bedekar, 2003).

Mango with many versatile properties has naturally found applications for processing into various products unparalleled by any other fruit. It is however estimated that only 0.22% of mangoes produced in the world is utilized for processing. Green mangoes are processed into traditional products like pickle, brine stock and chutney. Instant mango pickles, drum-dried green mango powder, production of raw mango beverage base are the new developments (Nanjundaswamy, 1991).

Ripe mangoes are processed into canned slices, pulp, beverages like RTS beverage, nectar and juice, dehydrated products like mango fruit bar, mango cereal flakes, mango powder, strained baby foods, etc. Mango slices in nectar, mango concentrate, mango aroma concentrate and mango pulp concentrate by evaporative technique by split process and by partial drying and cut back technique, mango aroma concentrate and identification of aroma compounds, aseptic bulk packing of pulp and concentrate, mango beverage in tetra pack, etc., are the recent developments (Nanjundaswamy, 1991).

The mango is an excellent nutritional source, containing many vitamins, minerals, and antioxidants, as well as enzymes such as magneferin and lactase which aid in digestion and intestinal health. It is also used in some parts of Southeast Asia and the Muslim world as a supplement for sexual potency. Table 1 shows food value per 100g of ripe mango flesh (http:/en.wikipedia.org/wiki/mango visited on 30.12.2007).

Table 1.1 Food Value per 100 g of Ripe Mango Flesh*

Description	Value
Calories	62.1-63.7
Moisture	78.9-82.8 g
Protein	0.36-0.40 g
Fat	0.30-0.53 g
Carbohydrates	16.20-17.18 g
Fiber	0.85-1.06 g
Ash	0.34-0.52 g
Calcium	6.1-12.8 mg
Phosphorus	5.5-17.9 mg
Iron	0.20-0.63 mg
Vitamin A (carotene)	0.135-1.872 mg
Thiamine	0.020-0.073 mg
Riboflavin	0.025-0.068 mg
Niacin	0.025-0.707 mg
Ascorbic Acid	7.8-172.0 mg
Tryptophan	3-6 mg
Methionine	4 mg
Lysine	32-37 mg

*Minimum and maximum levels of food constituents derived from various analyses made in Cuba, Central America, Africa and India.

Indians are fond of taste enrichers, which are regularly used along with the main course as well as snacks. Many taste enrichers are made from unripe mangoes and their shelf life is enhanced either by processing them or by using preservatives. Pickles, chutneys and many sweet preparations like murabba are made from unripe or semi-ripe mangoes. Apart from individual households, restaurants, eateries, roadside hotels, clubs, hostels, caterers etc. are the bulk consumers. There are some branded products available in the market but they are costly. Many Indian households make these items during the season. But this practice is gradually disappearing due to changing lifestyles, hassles of making these items and their availability throughout the year from market. There are many variants of these products and with certain change in the ingredients, taste differs. Hence, it is imperative to cater to the regional palate.

Mango pickle processing is one of the traditional activities in India. Products like pickle, chutney, murabba are consumed throughout the year. Indian pickles are classified as salt pickles or oil pickles. Every region has its own taste or liking and a care has to betaken to understand it and accordingly the recipe has to be finalized. Manufacturing process is very well standardized. In case of pickles, Pickles made from seedling mangoes containing 5-6% acidity were found to be of best quality. Generally the oil used is either mustard or gingerly oil. Salt-cured slices are drained, mixed with spices and oil, packed glass jars and are sealed properly. Extra oil is added to from a 1-2 cm layer over the pickle to prevent exposure to air. Microbial spoilage due to mould growth in salt pickles can be prevented by adding 200 ppm benzoic acid. Various recipes are available for preparation of pickles which are based on the regional preferences. Generally, the raw mango slices are treated with 10-20% of common salt, drained and mixed with partially ground spices like coriander, fenugreek, nigella, fennel, cumin seeds, turmeric powder and chili powder. The whole mixture is filled into the jars and covered with mustard oil (http://www.ikisan.com, visited on 03.09.2008).

Slicing and dicing are cutting processes for size reduction of fruits and vegetables. It involves pushing or forcing a thin, sharp knife to shear through the material. The result gives minimum deformation and rupture of the cell wall. Biological materials commonly subjected to cutting could be classified as: (1) Non-fibrous, liquid cell materials having uniform properties in all direction at the time of cutting, (2). Fibrous materials with high tensile strength fibrous oriented in a common direction with comparatively low strength materials bonding the fiber together (Owolarafe et al, 2007).

Currently mechanization is in increasing demand. Farmers and policy makers and developmental agencies now realize that for increasing production and productivity at reduced unit cost of production, free of arduous labour, agricultural mechanization is essential (Alam, 2001). In case of pickle industry, Raw-mango cutting and dicing machines from different manufactures have been designed for medium and large scale pickle industry. They consist of 3 machines, viz, slicers, de-coring conveyors and dryers. The slicers cut hard fruits into slices of uniform thickness and then put the slices on a conveyor, where the bitter core (seed) is removed manually, as this cannot be automated. After de-coring, the slices are automatically fed into the slicer where they are cut into uniform-sized cubes, ideal for quick and predictable pickling. Some entrepreneurs use these types of semi-automated or automated machines in their food processing plants.

In cottage level and small scale pickle production industry, adaptation of above type of automated machines is not economically viable and feasible. There should be machinery with appropriate technology, less power consumption, adaptable prices and suitable for such industries. A significant problem in developing mechanized equipment is the large number of varieties available and their different sizes and shapes. Especially, such industries at off grid locations or remote areas, requires manually operated machines such as hand held, hand operated or pedal operated etc. Because, following disadvantages as well as injuries are due to usage of household knives or similar equipments.

1. Pose danger to operator’s fingers by inflicting the injury, especially, when slicing with the tail end of the mango.
2. Produce cubes of the non-uniform size, shape.
3. Labour consuming and cumbersome in operation.
4. The capacity of these equipments is not enough to meet the requirement for pickle production at cottage level.

When we have qualified persons and proper machinery, we can make most indigenous products on large scale with saving of labour and energy. Large scale purchase of raw material will also be cheaper. This may enable extensive marketing in abroad also. Therefore, the scope of this project is to design, develop and evaluate manually operated mango dicing machine with a view to introducing for cottage level and small scale pickle industry. This will be ultimately beneficial to the growers and producers to sell their mango and mango based food product in international market or in domestic market to fetch higher prices of produce.

The specific objectives of this study are;

1. To study the physical characteristics of raw mango.
2. To design and develop a manually operated mango dicing machine.
3. To evaluate the performance of the machine.

If we look at the evaluation of almost any product of human endeavor we see what man is never satisfied with just the basic product that does the job adequately. We are, forever, looking to add 'value' to every design. So this design is also able to be modified according to the industry requirement later.

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with brief review of the relevant literature pertaining to various parameters involved in the present investigation. The main thrust is given on the mango dicing machines. The first section deals with information regarding mango crop and mango processing. The second section deals with engineering properties of mango. In the later section, various types of mango slicing/dicing machines are discussed.

2.1 Mango origin and distribution

The mango (plural mangoes or mangos) is a tropical fruit of the mango tree. The exact origins of the mango are unknown, but most believe that it is native to Southern and Southeast Asia owing to the wide range of genetic diversity in the region and fossil records dating back 25 to 30 million years. Mangoes retain a special significance in the culture of South Asia where they have been cultivated for millennia. The mango is a popular fruit with people around the world. India is by far the largest producer, with an area of 16,000 km^2 with an annual production of 10.8 million tonnes, which accounted for 57.18% of the total world production in 2005 (http://en.wikipedia.org/wiki/mango visited on 30.12.2007).

Until nineteenth century, mango was grown in community orchards for the consumption of local people and rarely for the trade but with the advent of grafting techniques for propagation, the mango began to be cultivated for the market necessitating a change from primitive to progressive cultivation. Phenomenal developments have taken place in its taxonomy, genetics, reproductive physiology, cultural practices, post harvest technology and international trade during the past half century. As a result, mango in India has become an important fruit of international trade.

The mango is now widely cultivated as a fruit tree in frost-free tropical and warmer subtropical climates throughout the Indian subcontinent, North, South and Central America, the Caribbean, south and central Africa, Australia and Southeast Asia. The mango is reputed to be the most commonly eaten fresh fruit worldwide. Mangos also readily naturalize in tropical climates. Some lowland forests in the Hawaiian Islands are dominated by introduced mangos, and it is a common backyard fruit tree in South Florida where it has also escaped from cultivation. Table 2.1 shows top 12 mango producers in the world in 2005. (http://en.wikipedia.org/wiki/mango visited on 30.12.2007).

Table-2.1: Top 12 mango producers in 2005

Country	Area (km^2)
India	16,000
China	4,336
Thailand	2,850
Indonesia	2,734
Mexico	1,738
Philippines	1,600
Pakistan	1,515
Nigeria	1,250
Guinea	820
Brazil	680
Vietnam	530
Bangladesh	510
World Total	38,702

(Source: http://en.wikipedia.org/wiki/mango visited on 30.12.2007)

The total world's production of mango which was about 23.12 million metric tonnes in 2000 (Anonymous, 2002a) increased to 26.10 million metric tonnes from an area of 3.8 million ha in 2002 (Anonymous, 2003). India is the largest mango producing country in the world. In India, the area under mango cultivation was 1.48 million ha and annual production of 10.5 million tonnes in 2000 that accounted nearly 43.22 per cent of the total world's production (Anonymous, 2002a). It has now increased to 1.52 million ha with an annual production of 13.00 million metric tonnes in 2002 which has a share of about 49.81 per cent of the total world's production (Anonymous, 2003).

India is the home of about 1,000 varieties. Most of them are the result of open pollination arisen as chance seedlings. However, only a few varieties are commercially cultivated throughout the India. Table 2.2 shows commercial mango varieties grown in different states. Konkan region of Maharashtra is a major mango producing region where world famous export quality Alphonso mango is grown predominantly. The agro climatic conditions of this region are most suitable for commercial production of high quality mango.

At present, only few cultivars such as Alphonso, Kesar, Pairi and newly developed hybrid Ratna and Sindhu are grown on commercial scale. Alphonso is the most popular and choicest cultivar grown extensively in this region which has a great demand in local as well as in foreign market. But the problems like spongy tissue and irregular and erratic bearing in Alphonso resulted in inconsistent yield patterns causing economical set back to the mango growers in the region.

Table-2.2: Commercial mango varieties grown in different states

State	Mango variety
Andhra Pradesh	Banganapalli, Suvarnarekha, Neelum and Totapuri
Bihar	Bombay Green, Chausa, Dashehari, Fazli, Gulabkhas, Kishen Bhog, Himsagar, Zardalu and Langra
Gujarat	Kesar, Alphonso, Rajapuri, Jamadar, Totapuri, Neelum, Dashehari and Langra
Haryana	Chausa, Dashehari, Langra and Fazli
Himachal Pradesh	Chausa, Dashehari and Langra
Karnataka	Alphonso, Totapuri, Banganapalli, Pairi, Neelum and Mulgoa
Madhya Pradesh	Alphonso, Bombay Green, Dashehari, Fazli, Langra and Neelum
Maharashtra	Alphonso, Kesar, Pairi,
Punjab	Chausa, Dashehari and Malda
Rajasthan	Bombay Green, Chausa, Dashehari and Langra
Tamil Nadu	Alphonso, Totapuri, Banganapalli and Neelum
Uttar Pradesh	Bombay Green, Chausa, Dashehari and Langra
West Bengal	Bombay Green, Fazli, Gulabkhas, Kishen Bhog, Himsagar and Langra

(Source: Chadha, 2006)

In India, Mango is available from March to mid-August. Table 2.3 shows state-wise mango availability in the year. The north Indian cultivars are alternate-bearer whereas south Indian ones are generally regular-bearer. About 20 varieties are grown commercially. They are Bombay Green, Chausa, Dashehari, Fazli, Gulabkhas, Kishen Bhog, Himsagar, Zardalu, Langra, Banganapalli, Suvarnarekha, Neelum and Totapuri, Kesar, Pairi and Mankurad.

Table-2.3: State-wise availability of mango in India

State	Months
Andhra Pradesh	March to mid August
Bihar	May-end to mid August
Gujarat	April to July
Haryana	June to August
Himachal Pradesh	Mid-June to mid-August
Karnataka	May to July
Madhya Pradesh	Mid-April to August
Maharashtra	April to July
Rajasthan	May to July
Tamil Nadu	April to August
Uttar Pradesh	Mid-May to August
West Bengal	May to August

(Source: Chadha, 2006)

2.2 Mango production:

In India, the major mango growing states are Andhra Pradesh having largest area of 2.97 lakh ha with highest production of 2.37 million tonnes followed by Uttar Pradesh (2.43 lakh ha and 1.91 million tonnes), Bihar (1.56 lakh ha and 1.87 million tonnes) and Maharashtra having 1.47 lakh ha area under cultivation with production of 0.5 million tonnes, respectively for the year 2000-2001 (Anonymous, 2002b).The mango production for the year 2003-2004 in the leading states increased to 4.04 million tonnes in Andhra, 1.90 million tonnes in U.P., 1.95 million tonnes in Bihar. Maharashtra ranked fourth in order of merit having a total production of 0.81 million tonnes (Shrinivasan, 2005).

Alphonso and Kesar mango varieties are considered among the best mangoes in India. Alphonso mango that is commonly exported is grown exclusively in the Konkan region of Maharashtra. It is named after Afonso De Albuquerque, who reputedly brought the drupe on his journeys to Goa. The locals took to calling this Aphoos in Konkani and in Maharashtra the pronunciation got further corrupted to Hapoos. This variety then was taken to the Konkan region of Maharashtra and other parts of India. Andhra Pradesh and Karnataka states in the south, Gujarat in western India, and Uttar Pradesh in the north are major producers of pickle-variety mangoes and specialize in making a variety of mango pickles. These pickles can be very spicy, and tend to have large regional differences in taste (http://en.wikipedia.org/wiki/mango visited on 30.12.2007).

2.3 Mango processing technologies

Mangoes 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, purée, juices, nectar and various dried products. Mangoes are processed into many other products for home use and by cottage industry.

The 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. 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. The lack of mechanized equipment for the peeling and slicing of ripe mangoes is a serious bottleneck for increasing the production of these products. The cost of processed mango products is also too expensive for the general population in the areas where most mangoes are grown. There is, however, 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 (http://www.fao.org/docrep, visited on 08.09.2008)

With the increasing awareness as well as demand for export and processing of mango, there is an urgent need for widening the scope of area under cultivation to greater number of varieties for export, processing and fresh domestic market. A very concentrated effort therefore, needs to be made to improve the situations so as to capture the international market. The standards should be prepared in a manner that they are harmonized with the international standards like Codex Standards. Institutions should be identified for regulating the implementation of the standards, both quality and human safety standards, and identified institutions should widely publicize the criterion by which they would accreditate various governmental and private agencies to monitor, regulate and implement the notified standards. Such accreditated agencies could be given product-wise, central responsibility for the implementation of these standards. Globalization of world trade due to WTO (World Trade Organization) and GATT (General Agreement on Trade and Terrifs) agreements have opened up immense opportunities for multifold increase in export of Indian products including fresh fruits. However, Indian exporters are presently facing growing competitions in foreign markets due to increasing consumer demands for high quality products along with stringent legislation relating to the product quality (Badhe, 2005).

2.4 Mango pickle

The process of preservation of food in common salt or in vinegar is called pickling. Spices and edible oil also may be added to the product (Lal *et al.*, 1986).

Pickles of various kinds are known throughout India and many part of the world. Some of the typical Indian pickles made from mango, lime, turnip, cabbage, cauliflower, etc., have become popular in several countries. There is wide and growing export market for these products which are associated with the well known Indian condiments. Pickles are good appetizers and add to the palatability of a meal. They aid to digestion by stimulating the flow of gastric juice. Very little scientific data is, however, available regarding their nutritive value. Different kinds of pickles contain varying amount of nutrients depending upon the raw material taken and the method of preparation followed (Lal *et al.*, 1986).

Different kinds of pickles are made in several Indian homes in fairly large quantities. Pickles are also manufactured on large scale and exported to other countries. In Indian pickles in oil, mustard, rape seed and sesame oils are generally used. Some pickles are made in lime juice. Pickles made to resemble imported pickles are made in vinegar. Onion pickle in clear spiced vinegar belongs to the latter category (Lal *et al*., 1986)

The method of preparation of mango pickle is different in different parts of India. These are by and large oil pickles. The ‘Avakai’ pickle of the Circars of Andhra Pradesh is a well-known mango pickle in oil. It is very pungent and hot to taste. Oil pickles are highly spiced. In north India, rapeseed is commonly used, but in the south, ginger oil is used. If handled carefully the pickle will keep in good condition for 1 to 2 years. There is considerable demand in other countries for mango pickles. Mangoes of high quality being almost a monopoly in India, it is desirable to standardize the method of pickling of mangoes to build up an extensive export market for the product (Lal *et al.*, 1986).

2.5 Mango usage as food

The fruit flesh of a ripe mango is very sweet, with a unique taste. The texture of the flesh varies markedly between different cultivars; some have quite a soft and pulpy texture similar to an over-ripe plum, while others have a firmer flesh much like that of a cantaloupe or avocado, and in some cultivars the flesh can contain fibrous material. Mangoes are very juicy; the sweet taste and high water content make them refreshing to eat. Ripe mangoes are extremely popular throughout Latin America. In Mexico, sliced mango is eaten with chili powder and/or salt. Street vendors sometimes sell whole mangoes on a stick, dipped in the chili-salt mixture. In the Philippines, unripe mango is eaten with bagoong. Dried strips of sweet, ripe mangoes have also gained popularity both inside and outside the country, with those produced in 'Cebu' making it to export markets around the world. Guimaras Island is also a major producer of mangoes in the Philippines, with a local variety that is reputed to be the sweetest among mango varieties (http://en.wikipedia.org/wiki/mango visited on 30.12.2007).

Mango is also used to make juices, both in ripe and unripe forms. Pieces of fruit can be mashed and used in ice cream; they can be substituted for peaches in a peach (now mango) pie; or blended with milk and ice to make thick milkshakes. In Thailand and other South East Asian countries, sweet glutinous rice is flavoured with coconut then served with sliced mango on top as a dessert. Dried unripe mango used as a spice and is known as "amchur" (sometimes spelled amchoor) in India and "ambi" in Urdu. "Aam" is a Hindi/Urdu word for mango. In Indonesia, green mango is sold by street vendors with sugar and salt and/or chili. Green mango may be used in the sour salad called *rujak* in Indonesia, and *rojak* in Malaysia and Singapore. In Guatemala, Ecuador, Nicaragua and Honduras, small, green mangoes are popular; they have a sharp, brisk flavour like a Granny Smith apple. Vendors sell slices of peeled green mango on the streets of these countries, often served with salt. In Hawaii it is common to pickle green mango slices. Ayurveda considers ripe mango sweet and heating, balancing all the three "doshas" (humors) and acts as an energizer (http://en.wikipedia.org/wiki/mango visited on 30.12.2007).

In India, ripe mango is often cut into thin layers, desiccated, folded, and then cut and sold as bars that are very chewy. These bars, known as amavat or halva in Hindi, are similar to dried guava fruit bars available in Colombia. In many parts of India, people eat squeezed mango juice (called Ras), the thickness of which depends on the type of mango, with variety of bread items and is part of the meal rather than a dessert. Many people like to eat unripe mangoes (which are extremely sour; much more than lemon) with salt and chili. The fruit is also widely used as a key ingredient in a variety of cereal products, in particular muesli and oat granola (http://en.wikipedia.org/ wiki/mango visited on 30.12.2007).

Mangoes are widely used in chutney, which in the West is often very sweet, but in the Indian subcontinent is usually made with sour, raw mangoes and hot chilis or limes. In other parts of South-east Asia, mangoes are very popular pickled with fish sauce and rice vinegar. Raw mangoes are used in making pickles and condiments due to its peculiar sweet and sour taste. This fresh mango pickle is from South India and is called “Maangaa Curry” or “Maangai Keeru” in Tamil. Dried and powdered raw mango is sometimes also used as a condiment in Indian cuisine (http://en.wikipedia.org/wiki/mango visited on 30.12.2007).

2.6 Engineering properties of biological materials

Engineering properties are useful and necessary in the design and operation of various equipments employed in the field of agricultural processing and also for designing and development of other farm machinery. In unit operations such as cleaning, grading, cutting, drying, milling etc., the properties of the biological material which play important role are physical, mechanical, electrical, optical, and thermal. Basic information of these properties is of great importance and help for the engineers, food scientist and processors towards efficient process and equipment development (Sahay and Singh, 2006).

2.6.1 Physical characteristics of mango fruits

Shape, size, volume, surface area, density, porosity, color and appearance are some of the physical characteristics which are important in many problems associated with design of a specific machine or analysis of the behavior of the product in handling of the material. Mechanical properties may be defined as those having to do with the behaviour of the material under applied forces. The mechanical properties such as hardness, compressive strength, impact and shear resistance affect various operations of the agricultural processing. Data on these properties are useful for application in designing equipment for food processing (Mohsenin, 1986)

2.6.1.1 Weight of the fruit

Roy *et al.* (1972) while evaluating some mango varieties for processing in to nectars, studied physico-chemical characteristics and reported that Dashehari, Langra, Chausa and Bombay green fruits recorded average weight of 150g, 210g, 216g and 150g, respectively.

Lodh *et al.* (1974) studied physico-chemical characteristics of eight important mango varieties and observed that the average fruit weight ranged from 209 g (Langra) to 622 g (Totapuri). Jindal *et al.* (1979) studied physico-chemical composition of Dashehari, Dashehari seeding and three other varieties and reported that Dashehari seedling fruits more weight 140 g, length 10.6 cm and diameter 5.3 cm over that of Dashehari fruit having weight 124 g, length 7.2 cm and diameter 5.0 cm respectively.

Joshi (1992) found maximum fruit weight in variety Fazil (351.25 g) followed by Pairi (344.50 g), Panchdharkalsa (265.80 g), Achalpur local (264g), Kesar and Neelum (220 g), Gramankeer (211g), Alphonso (190g), Dashehari (155.50g) and Amarapali (148 g), respectively. The least weight was recorded in the variety Buldhana Pairi that was 126.5g only. Verma and Singh (1999) during study of rheological properties of ‘Dashehari’ mango reported the weight of raw mango varied from 148 g to 309 g and the average weight of 233.8 g (S.D. is 39.70).

2.6.1.2 Size of the fruit (length/breath/ thickness)

Nanjundaswamy *et al.* (1966) while working on 13 important mango varieties reported that the average length of fruit varied from 7.6 cm to 11 cm while diameter of fruit ranged from 5.9 cm to 10 cm. Singh and Tripathi (1974) reported that average size of mango fruit varied from 7.36 x 4.82 cm (Rashu-E-Jahan) to 17 x 10.4 cm in Langra Bengal.

Kumbhar (1992) studied some engineering properties of Mallihabadi Safeda mango and mango stones. He observed that the average size of raw mango fruit was 7.3 cm (l) x 5.1 cm (w) x 5.3 cm (t). He reported that length of mango was about 40 per cent more than width and thickness. However, there was no much variation in width and thickness. Verma and Singh (1999) determined the physical properties of matured ‘Dashehari’ mango. The average size of mango was recorded as 133.30 mm in length, 63.61 mm in width and 58.20 mm in thickness. The length of mango was 46 per cent more than width and 44 per cent more than that of thickness.

2.7 Existing mango cutting machines

2.7.1 Raw mango cutting and dicing machines

Automatic raw-mango cutting and dicing machines have been designed by different machine manufactures for medium and large scale pickle industry. These machines can easily process one tonne of mangoes per hour. They consist of 3 machines, viz, slicers, de-coring conveyors and dryers. The slicers cut hard fruits into slices of uniform thickness and then put the slices on a conveyor, where the bitter core (seed) is removed manually, as this cannot be automated. After de-coring, the slices are automatically fed into the slicer where they are cut into uniform-sized cubes, ideal for quick and predictable pickling.

The machine uses 7 kW to 10 kW of 3-phase power and does not need any compressed air. All parts in contact with the fruit are made of rust-resistant steels or synthetic inert materials. Feeding of the mangoes is fully automatic, thus keeping the operator safely away from the knives. The machines can easily be cleaned by water hoses without trapping any fruit pieces. They confirm GMP standards for food industry. They are virtually noiseless and maintenance-free. (Retrieved from http://www.greatoffers4u.com/u/neubauplan/ visited on 30.12.2007)

2.7.2 Raw mango cutting machine

The raw mango cutting machines are designed user friendly especially for the pickle manufactures. Cutting size can be varied as desired. The production capacity is 100 kg per hour. Technical specification; overall dimensions are 1 m in length, 1 m in width, 2 m in height, weight 700 kg and approximate power requirement is 7 HP three phase. (Retrieved from http://www.vishwakarmaind.com visited on 12.01.2008)

2.7.3 Lab model mango slicer and cube cutter

Nehru and Kumaran (2004), has developed a lab model mango slicer and cube cutter for mechanizing the cutting operations in a pickle industry at Section of Agricultural Engineering, Indian Institute of Horticulture Research, Bangalore, India in 2004. In this machine, the cutting of mangoes into cubes was achieved in two stages. First the mango was cut into vertical slices by raw mango slicer and the slices were cut into cubes using raw mango cuber. The capacity and efficiency of the mango slicer and cube cutter are 500kg/h, 100kg/h and 80 percent, 86 percent, respectively.

2.8 Existing other cutting machines

2.8.1 Okra slicing device

Owolarafe *et al.* (2007), has designed, fabricated and tested a manually operated okra slicing device suitable for on-farm use at Department of Agricultural Engineering in collaboration with department of mechanical Engineering, Obafemi Awolowo University, Nigeria in 2007. The machine consists of the feeder, slicer and receiver. The machine was loaded with and shaft was turned clockwise by manually. It has been observed that the faster the speed of operation increases the rate of slicing. The plunger retains the okra fruits in the hopper and also presses them against the cutting disc. An appreciable force is needed to keep the okra fruits passed on the cutting discs during slicing operation. The machine has a slicing efficiency 77.4% and throughput of about 8.4kg per hour.

2.8.2 Motorized ginger slicer

Simonyan *et al.* (2003), has designed and developed a motorized reciprocating ginger slicer at college of Agriculture, Ahmadu Bello University, Nigeria in 2003. The machine consists of feeder unit, slicing mechanism, driving mechanism, frame and the housing. The reciprocating principle with fixed blades was adopted. The rhizomes, fed manually into the hopper, falls by gravity into the cylinder at the bottom dead centre of the piston. It is pushed horizontally to the stationary knives as the piston moves toward the top dead centre. The pushing from the rhizomes forces the sliced ginger through the blades. The slicing efficiency is 76.8% at 30% moisture content. The percentage of damage is 23.2% at 30% moisture content.

2.8.3 Banana slicers

Kacharu *et al.* (1995), developed power operated raw banana slicer at Central Institute of Agricultural Engineering, Bhopal, India. In this machine, three blades are mounted on the rotary cutter plate at 120 degree angle. Power is transmitted through belt and pulley. Single banana is put into the feeding chute which is pushed forward by wooden rod. When the cutter plate rotates, slices of required thickness are produced.

Sonawane, (1997), developed a power operated raw banana slicer with two separate feeder assemblies to make round and longitudinal (oblong) chips. The machine comprises of a feeder assembly, cutter assembly, and power transmission unit. The average effective capacity of developed banana slicer has been found to be 100kg/h at 360 rpm speed using three blade cutters.

2.8.4 Motorized cassava chipper

Balasubramanian *et al.* (1993), has designed, fabricated and tested a motorized cassava chipper at department of Agricultural Engineering, College of Agricultural Engineering, TamilNadu Agricultural University, India. The cassava chipping machine is a vertical feed type motorized unit. The various components of the chipper are frame assembly, power source, chipping disc and blades, chipping disc shaft, feed hopper with guides and chip outlet. The capacity of the chipper was 270 kg/h. The chip recovery was assessed at 92% for 1mm chips at 292 rpm.

2.8.5 Cube cutter/professional food dicer

Food cube cutter / dicer are with 8mm cutting knives and pusher for professional-presentation dice. This cube cutter is designed for professional chefs, caterers, and others who are familiar with professional cooking tools. Dimensions: 380 mm x 305 mm x 380 mm; weighs 3 kg. (http://www.comforthouse.com visited on 30th December 2007)

2.8.6 Lemon cutting machine

The machine is capable of cutting lemons ranging in size from 19 mm diameter to 65 mm diameter with the help of a spring loaded mechanism. A better grip on the lemon is also provided by this spring loaded mechanism which ensures uniformity in cutting. The machine is capable of cutting lemons ranging in size from 19 mm diameter to 65 mm diameter with the help of a spring loaded mechanism. A better grip on the lemon is also provided by this spring loaded mechanism which ensures uniformity in cutting. The cutting capacity of this machine is 160 lemons/ minute or 450 kg per hour. The selling price is Rs. 95,000.00. For packaging in smaller quantities, the lemon has to be cut into smaller pieces (12 to 16 pieces). (http://www.nif.org.in/ visited on 12.01.2008)

In cottage level and small scale pickle production industry, adaptation of above type of automated machines or power operated machines is not economically viable and feasible. There should be machinery with appropriate technology, less power consumption, adaptable prices and suitable for such industries. A significant problem in developing mechanized equipment is the large number of varieties available and their different sizes and shapes. Especially, such industries at off grid locations or remote areas, requires manually operated machines such as hand held, hand operated or pedal operated etc.

CHAPTER III

THEORETICAL CONSIDERATION

This chapter deals with the general design considerations, principles of sanitary (hygienic) design of the food processing machine/equipments, mechanics involved in the cutting of agricultural material and specialized cutting operations, design for strength and design procedures different machine elements.

3. 1 Design considerations

Design is a process concerned with generating ideas and suggesting ways to turn these ideas in to reality to satisfy some needs optimally under the relevant constraints (Lal, *et al.,* 2006).

3. 1. 1 Sanitary (hygienic) design of machine

In case of food plant equipments, sanitary (hygienic) design is of most importance than any other factors. The basic objective of the sanitary design of machine is that it must not contribute to the contamination of the product with regard to microbial or any other type of at any stage leading to its spoilage. In order to achieve this basic requirement of food plant equipment design several international standards have been evolved.

3. 1. 2 Design codes and standards

Use of codes and standards in the design has started in 1841 when Whittworth introduced first standard screw thread so as to have the interchangeability amongst various manufactures. Although the two terms are interchangeably used, code of practice i.e., a particular operating procedure or the recommended design whereas standard is used for particular sizes or compositions etc. In practice, adoption of the standard saves money ensuring the confirmation between various projects due to the reason that most of the engineering designs are routine and repetitive in nature (Phirke, 2004).

Equipment manufactures work to standards to produce the standardized designs and ranges for commonly used machines or elements such as pipes and pipe fittings, electric motors, pumps etc. Clearly, it is more economical to produce limited range of standard sizes rather than go to each job as a special work. The stock of spares is considerably reduced due to adoption of standards. For the designer, specifying particular standard equipment, automatically tells many dimensions or performances of a specific item. Besides this, the standards impose constraints on the designer. The nearest rounded computed size may not be optimum but may be economical due to standardization. The standard designs methods must, of their nature, be historical and do not necessarily incorporate the latest technique. However, this difficulty can be overcome by the revision of prevailing codes and standards to introduce new methodology or techniques (Phirke, 2004).

3. 1. 3 Basic principle of sanitary (hygienic) design

These are well expressed in the seven points of the USA document “Sanitary Design” (taken from *Food Processing* October 1964 and April 1965 and *Food Processing Catalog*, 1964/5)and quoted in the appendix (Shapton and Shapton, 1997).

1. All surfaces in contact with food must be inert to the food under the conditions of use and must not migrate to or be absorbed by the food.
2. All surfaces in contact with food must be smooth and non-porous so that tiny particles of food, bacteria or insect eggs are not caught in microscopic surface crevices and become difficult to dislodge, thus becoming a potential surface of contamination.
3. All surfaces in contact with food must be visible for inspection, or the equipment must be readily disassembled for inspection, or it must be demonstrated that routine cleaning procedures eliminate possibility of contamination from bacteria or insects.
4. All surfaces in contact with food must be readily accessible for manual cleaning, or if not readily accessible, then readily disassembled for manual cleaning, or if clean-in-place technique are used, it must be demonstrated that the results achieved without disassembly are equivalent of those obtained with disassembly and manual cleaning.
5. All interior surfaces in contact with food must be so arranged that the equipment is self emptying or self draining.
6. Equipment must be so designed as to protect the content from contamination.
7. The exterior or non-product contact surfaces should be arranged to prevent harboring of soils, bacteria, or pests in and on the equipment itself as well as in its contact with other equipment, floors, walls or hanging supports.

In addition to above seven points, four additional points are made in The Campden Technical Memorandum 289 (Shapton and Shapton, 1997).

1. In design, construction, installation and maintenance it is important to avoid dead space or other conditions which trap food, prevent effective cleaning and may allow microbial growth to take place.

2. The requirement of guarding machinery to insure safety in operation may easily conflict with sanitary (hygienic) requirements unless considerable care is taken in design, construction, installation and maintenance.

3. Noise suppression is important in providing acceptable working conditions, However, many noise reducing materials can give rise to microbiological or infestation problems unless care is taken in their selection, installation and maintenance.

4. It is important that the equipment itself is so designed, installed and maintained that it does not cause product contamination. Examples of possible contaminations are: lagging which may break up or insufficiently secured nut and blots. Such hazards should be designed out of the system.

The most common design faults which cause poor cleanability are: poor or nil accessibility, inadequate rounded corners (minimum radius should be 6.4mm), sharp angles and dead ends including poorly designed seals (Shapton and Shapton, 1997 and Joshi, 1985). Above points have been used in present study designing of machine components such as hoppers, cutting blades, cutting platform. Evan all these parts can be dismantled when cleaning is required.

3. 1. 4 Materials of construction

Campden Technical Manual 17 sets forth the qualities of these materials as follows (Shapton and Shapton, 1997).

1. Good sanitary (hygienic) design of equipment used in the manufacture of foods and beverages requires that all surfaces in contact with the product must be non-toxic, inert to the product under the condition of use, must not have constituents which migrate or absorbed by the product and, in addition, must be resistant to (i.e. be inert to) cleaning and disinfecting agents under normal (or expected) conditions of use.

2. Food contact surfaces should permit the easy removal of food residues and soils during cleaning so that microbial growth is prevented. Surfaces should be smooth,

hard continuous and free from cracks, crevices and pits. Ideally, materials should therefore be such that the original surface finish is maintained during the working life the equipment: furthermore, the material should not deform and should be resistant to denting, chipping, flaking and delamination.

3. Equipment surfaces not directly in contact with food, for example machinery framework and exterior cladding, should also be smooth to facilitate cleaning. In addition, they should be made of corrosion resistant material or protected against corrosion. Painting of equipment surfaces and precautions should be taken to insure they are not above exposed food materials.

Instead of above qualities of the materials, the following characteristics of the construction material should be paid attention while selection (Phirke, 2004 and Choudhury *et al.* 2003).

1. Mechanical properties such as strength, rigidity, elasticity, hardness, ductility, yield stress, fatigue and creep etc.
2. Effect of working temperature on properties of the material.
3. Corrosion resistance.
4. Special properties like thermal conductivity, electrical conductivity and magnetic properties.
5. Fabrication technique required like forming, casting, welding etc.
6. Commercial availability in the market.
7. Cost effectiveness against service life.

3. 1. 5 Equipment construction (fabrication)

As with other aspects of sanitary design, equipment fabrication is also having a vital role in food safety. The main important aims are to (Shapton and Shapton, 1997):

1. Give maximum protection to the product. This means, for example, that fastenings should not break or work lose with consequent product contamination.
2. Provide product contact surfaces adequate for the design function which will not contaminate the product and are readily cleanable.

3. Provide junctures which minimize ‘dead’ areas where chemical or microbial contamination may occur.

4. Give ready access for cleaning and maintenance. This means, for example, that removable panels should not require the use of tools.

The Campden Technical Manual 7 has given DOs and DON’Ts in equipment fabrication (Shapton and Shapton, 1997).

- Do use welded joints and Do grind and polish the welded joints to give a smooth finish so that debris does not lodge and microbial slime develop.
- Do radius corners. The optimum radius for cleaning is 20mm.
- Do have vertical and steep sides to minimize the lodging of products
- Do use the recommended design features
- Don’t uses overlap joints fixed by nuts and bolts or rivets because; the overlaps provide an area where product debris becomes trapped and encourage microorganisms to grow. The overlap area is impossible to clean and disinfect efficiently.

3. 2 Ergonomics and its applications in design

The working definition of ergonomics is “ the systematic application of knowledge about the psychological , physical, and social attributes of human being in the design and use of all things which affects a person’s working conditions: equipment and machinery, the work environment and layout, the job itself, training and the organization of work”

Anthropometric applications are mostly seen in (1). Workplace and layout designing where it needs either to avoid certain things and to assist smooth functioning with easy reach to facilitate comfortable work and to ensure safety, and (2). To dimension equipment and consumer commodities that need constant handling and can be used without discomfort. Design should be made fit to user’s body dimension. Measurements of body as a whole and in parts in standard and different adopted postures are required for various design conceptualizations. In order to satisfy most of the intended users, percentile variations of anthropometric data collected from a group of people are used (Singh, 2007).

3. 2. 1 Posture

Posture is the position of the body while performing work activities. Awkward posture is associated with an increased risk for injury. It is generally considered that the more a joint deviates from the neutral (natural) position, the greater the risk of injury. Posture issues can be created by work methods (bending and twisting the wrist to assemble a part) or work place dimensions (extended reach to obtain a part from a bin at a high location; kneeling in the storage bay of air plane because of confined space while handling luggage).

3. 2. 2 Force

Task forces can be viewed as the effect of an exertion on internal body tissues, or the physical characteristics associated with an object external to the body. Generally, the greater the force, the greater the degree of risk is. High force has been associated with risk of injury at the shoulder/neck, the lower back and the forearm/ wrist/ hand. The relationship between force and degree of injury risk is modified by other work risk factors.

3. 3 Functionality of product

One of the most fundamental problems that every designer has to struggle with is to know that a good design is. He must design optimally and he must design to satisfy a need. Functionality of a product is a multi-faceted concept. We, in general, recognize four major dimensions of functionality: Need, Use, Method and Aesthetics. (Lal, *et al*., 2006).

3. 3. 1 Need

A design exists solely in response to a specified or a perceived need and, therefore, the satisfaction of that need is the most essential function of a design.

3. 3. 2 Use

The product that a designer develops is to be used by people. A well-designed product is one that can be used by people more comparably, more safely and with more efficiency.

3. 3. 3 Method

The method refers to the materials, tools, and processes used for the execution of the design. A design must reflect the process used for executing it. A bicycle wheel with its thin tensioned steel spokes is an apt example of a design that has exploited the material, tools and processes to the utmost, and does, therefore, passes the methods test beautifully. The great strength of steel in tension has been exploited to the extreme by pre-tensioning the spokes so that they are always in tension, even when the externally applied load acts in a way that would have caused compression if there was no pre-tensioning.

3. 3. 4 Aesthetics

A washing machine, even if it sits in the laundry room, must not just wash clean but most also look beautiful if it is to find customers. But what is concept of beauty? The source of our aesthetics, which is mainly concerned with what looks right from a functional point of view, is primarily the observation of nature. A building shape as an inverted pyramid would generally not look right because it appears to be unstable. It is interesting to note that balance, symmetric, unity, rhythm and form are words frequently used in evaluating any work aesthetically, and all of them have origins in nature and its preoccupation with function and efficiency.

3. 4 Size reduction

The general term 'size reduction' includes cutting, crushing and grinding and milling. The reduction in size is brought about by mechanical means without change in chemical properties of the material, and uniformity in size and shape of the individual grains or units of the end products is usually desired but seldom attained. Such process as cutting fruit or vegetables for canning, shredding sweet potatoes for drying, chopping corn fodder, grinding lime stone for fertilizer, grinding grains for livestock feed and milling flour are size reduction (Henderson and Perry, 1976). The size of agricultural products may be reduced by several ways, but mainly the following four methods are used in size reduction machines viz., compression or crushing, impact, shearing and cutting (Sahay and Singh, 2006).

Size reduction is the unit operation in which the average size of solid pieces of food is reduced by the application of grinding, compression or impact forces. Different methods of size reduction are classified according to the size range of particles produced (Fellows, 2005).

1. Chopping, cutting, slicing and dicing
2. Milling to powders or paste of increasing fineness
3. Emulsification and homogenization

The performance of a machine for reducing the size of the material is characterized by the capacity, the power required per unit of material reduced, the size and shape of the product before and after reduction, and the range in size and shape of the resultant product.

3. 4. 1 Crushing

When, an external force applied on a material excess of its strength, the material fails because of its rupture in many directions. The particles produced after crushing are irregular in shape and size. The type of material and method of force application affects the characteristics of new surfaces and particles. Food grain flour, grits and meal, ground feed for livestock are made by crushing process. Crushing is also used to extract oil from oilseeds and juice from sugarcane.

3. 4. 2 Impact

When, a material is subjected to sudden blow of force in excess of its strength, it fails, like cracking of the nut with the help of a hammer.

3. 4. 3 Shearing

It is a process of size reduction which combines cutting and crushing. The shearing unit consists of a knife and a bar. If the edge of knife or shearing edge is thin enough and sharp, the size reduction process nears to that of cutting, whereas a thick and dull shearing edge performs like a crusher. In a good shearing unit the knife is usually thick enough to overcome the shock resulting from material hitting. In an ideal shearing unit the clearance between the bar and knife should be small as practicable and knife as sharp and thin as possible.

3. 4. 4 Cutting

In this method, size reduction is accomplished by forcing a sharp and thin knife through the material. In the minimum deformation and rupture of the material results and the new surface created is more or less undamaged. An ideal cutting device is a knife of excellent sharpness and it should be thin as practicable. The size of the vegetable and fruits are reduced by cutting.

3. 4. 5 Theory of size reduction

In all types of size reduction there are three types of forces used to reduce the size of foods viz., compression force, impact force and shearing (or attrition) force. In most size reduction equipments, all three forces are present, but one is more often than others. When stress (force) is applied to a food the resulting internal strains are first absorbed, to cause deformation of the tissues. If the strain does not exceed a certain critical level named the elastic stress limit, the tissues return to their original shape when the stress is removed, and the stored energy is released as heat. However, when the strain within a localized area exceeds the elastic stress limit, the food is permanently deformed. If the stress continued, the strain reaches a yield point. Above the yield point the food begins to flow. Finally, the breaking stress is exceeded at the breaking point and the food fractures along a line of weakness. Part of the stored energy is then released as sound and heat. As little as 1% of applied energy may actually be used for size reduction. The amount of energy that is needed to fracture a food is determined by its hardness and tendency to crack (its friability) which in turn depends on the structure of the food.

Compression forces are used to fracture friable or crystalline foods; combined impact and shearing forces are necessary for fibrous foods, and shearing forces are used for fine grinding of softer foods (Fellows, 2005).

3. 4. 6 Size reduction equipment of fibrous food

Foodstuffs such as fruit and vegetable have a fibrous structure containing appreciable amount of liquid. Generally, impact and shearing forces applied through cutting edge are often used in the disintegration of fibrous materials. There are four main type of size reduction equipment, classified in order to decreasing particle size as follows (Fellows, 2005):

1. Slicing and flaking equipment
2. Dicing equipment
3. Shredding equipment
4. Pulping equipment

3. 4. 7 Dicing equipment

Dicing is the cutting of material in to cubes. For dicing, fruits and meat are sliced which produce slices of desired thickness. These slices are then cut in to strips by blades. The strips are fed to a second set of moving knives which operate at right angles to the first set and cut the strips in to cubes.

3. 5 Basic angles of knife motion

The knife and knife edge are often said to have a face and a back. The face is the surface most actively engaging the material in the cutting process. The back is the other surface creating the edge.

3. 5. 1 Edge angle

It is the angle between two cutting faces of the knife close to the front of edge.

3. 5.2 Rake angle

It is the angle in the XY-plane between the knife edge face and the normal to the direction of the knife travel. It is also called as chip angle.

3. 5. 3 Clearance angle

It is the angle in the XZ-plane between the back of knife edge and the knife travel.

3. 5. 4 Oblique angle

It is the angle between the edge normal in the XY-plane and the direction of motion of the knife.

3. 5. 5 Effect of chip (rake) angle and clearance angle

The effect of rake and clearance angle on the force requirement in cutting the fruits and vegetables have been studied and observed that reduction of cutting force by half has been found for an increase in chip angle from 15 to 50 degrees. It was suggested that for fruit and vegetables, chip angle should be in the range of 40 to 60 degrees and clearance angle is in the range of 10 to 15 degrees (Persson, 1987).

3. 5. 6 Knife sharpness

Cutting edge of the knife on the cutting machine must be sharp enough for good quality work and the efficient use of power. The power requirement increase sharply with decrease in the sharpness of cutting edge (Persson, 1987).

3. 6 Design for strength

Strength is a major factor in the design of machine members. To design a member or part of machine for strength, the two most important considerations are selection of material and selection of design stress or allowable stress or permissible stress that will be used to calculate the proportion of the part which will be sufficiently strong. Design stress is the limit which should not be crossed by the maximum induced stress, nominal or actual stress. It is the stress fixed by the designer and used by him in computing the proportions of a part for safe strength in service. The nominal or actual stress is that which is computed by relations. Working stress is that which actually occurs in the machine part under operating conditions. Working stress should never exceed the design stress (Sharma and Aggarwal, 1998).

The failure of a machine element can be prevented if the maximum induced stress due to external loading does not exceed the failure stress for the material. The failure stress for ductile materials is the yield point stress and for brittle materials it is the ultimate strength of the material. Hence, the failure of a machine part can be avoided if the maximum induced stress due to external loading is kept less than the yield point stress for ductile materials and less than ultimate strength for brittle materials. This is done by using a factor of safety: FS, (FS>1) on the failure stress. The stress which is obtained by using a factor of safety on the failure stress is termed as ‘allowable stress’, ‘design stress’ or the ‘working stress’ (Sharma and Aggarwal, 1998)

3. 6. 1 Design of L-iron structure

All parts of the machine are mounted on L-iron structure. The dimensions of L-iron structure were decided by considering, size of mangoes, ease operation, operator safety and anthropometric data of an average person. The thickness of L-iron was decided by calculation.

Assuming size of L- iron as w mm x w mm and thickness as t and it is very small

Cross sectional area of the one L- iron = wt + wt

= 2wt

Total cross sectional area of four L- irons = 4 x 2wt

= 8wt … (3.1)

To avoid compression failure of frame, following condition must be satisfied (Sharma and Aggarwal, 1998):

$$\sigma_{allowable} \geq \sigma_{working}$$

$$\frac{YPS}{FS} \geq \frac{P}{A}$$

$$A \geq \frac{P \times FS}{YPS}$$

$$8wt \geq \frac{P \times FS}{YPS}$$

$$t \geq \frac{P \times FS}{YPS \times 8w}$$

… (3.2)

Where;

YPS - Yield point stress for mild steel

FS - Factor of Safety

P - Total load on frame

A - Total cross sectional area

t - Thickness of L-iron

w - Width of L-iron

3. 6. 2. Design of shaft and axle

Shaft and axels are the machine members, mostly cylindrical in cross section, which supports the revolving parts of a machine, such as pulleys, gears, fly wheels, etc. An axle only supports a revolving part and may either be fixed relative to either supports or rotate or rotate together with the parts mounted on them. When the solid shaft is subjected to pure torsional load, the principle stress induced in the shaft will be the shear stress. The maximum shear stress induced in the shaft is given by relation (Sharma and Aggarwal, 1998);

The maximum shear stress induced in the shaft $= \frac{16M_t}{\pi d^3}$

… (3.3)

Where;

M_t - Torsional moment

d - Diameter of shaft

Shock and fatigue factor is taken in to account to take care of the nature of load. This factor should be applied to the computed torsional moment. The factor is designated as 'K_δ'. The value for suddenly applied loads with heavy shocks is in between 1.5 and 3. Therefore, designed torsional moment is $K_\delta M_t$.

When the solid shaft is subjected to pure bending load, the principle stresses induced in the shaft are tension and compression. The maximum stress induced is given by the relation (Sharma and Aggarwal, 1998);

The maximum normal stress induced in shaft $= \frac{32M_b}{\pi d^3}$

… (3.4)

Where;

M_b - Bending moment

d - Diameter of shaft

In this case also, the effect of shock and fatigue loads must be taken into consideration. The factor is designated as K_b. The value for suddenly applied load, heavy shock is in between 2 and 3. Therefore, designed bending moment is K_bM_b.

When solid shaft subjected to combined torsion and bending loads, the design is usually based on the maximum shear stress theory, as the shafts are usually made of ductile materials. Since under the combined loading, the shaft will depend upon; (a) ratio of torsional moment to bending moment, and (b) ratio of ultimate shear stress to ultimate tensile stress; it is suggested that the shaft size may be computed on the basis of both maximum shear stress and maximum normal stress theory and then, the larger size adopted (Sharma and Aggarwal, 1998).

The maximum shear stress, $(f_s)_{max,}$ is given as;

$$\left(f_s\right)_{\max} = \frac{16}{\pi d^3}\left[\sqrt{\left(K_b * M_b\right)^2 + \left(K_\delta * M_t\right)^2}\right] \quad \dots (3.5)$$

The maximum normal stress $(f_t)_{max}$ is given as:

$$\left(f_t\right)_{\max} = \frac{16}{\pi d^3}\left[\left(K_b * M_b\right) + \sqrt{\left(K_b * M_b\right)^2 + \left(K_\delta * M_t\right)^2}\right] \quad \dots$$

(3.6)

Where;

M_t - Torsional moment

M_b - Bending moment

K_δ - Shock and fatigue factor for torsional moment

K_b - Shock and fatigue factor for

d - Diameter of shaft

3. 6. 3 Design of bolted joints

Some machine parts must be so constructed that they may be readily connected or disconnected without damage to the machine or the fastening. This requirement may be for the purpose of holding or adjustment in assembly or service, repair, or replacement, or it may be for manufacturing or assembly reasons. These parts may be rigidly connected, or provision may be made for predetermined relative motion.

A screw fastening is composed of two elements viz. bolt and nut. The fastening should be located and placed so that they will be subjected to tensile and for shear loads and bending of the fastening should be reduced to a minimum. Bending of the fastening due to misalignment, tightening up loads, or external loads has been responsible for many failures (Sharma and Aggarwal, 1998). A through bolt is one of the common screw fasteners. It is a round bar with a head on one end and thread at other end to take a nut. It is passed through a drill holes in the two parts to be fastened together and clamps securely to each other as the nut is screwed on to the threaded end. A through bolt is also called simply a bolt.

When a bolt supports a load that acts perpendicular to the axis of the bolt, the bolt is under shear. The bolt can be under single or double shear. The maximum section under shear is at outside diameter.

Thus,

$$P = \frac{\pi d^2 \times f_s}{4} \quad \ldots (3.7)$$

Where:

P - Load

f_s - Allowable stress in shear

d - Diameter of bolt

$$f_s = \frac{f_{yps}}{FS} \quad \ldots (3.8)$$

Where:

P - Load

f_{yps} - Yield point stress in shear

FS - Factor of safety for impulsive load

The above relation is written for single shear. The bolt under double shear, the area to be taken is double. Bolts should not be perfectly subjected to shear.

3. 6 .4 Design of springs

A mechanical spring may be defined as an elastic body whose primary function is to deflect under load or absorb energy and which recovers its original shape when released after being distorted. The design of any spring must satisfy two requirements. Viz. the spring must carry the service load without the stress exceeding the safe value and the force deflection characteristics, i.e., spring rate must be satisfactory for the given application. Helical tension or extension is similar to helical compression spring (Sharma and Aggarwal, 1998).

The standard design procedure for helical tension spring is as follows:

1. From space limitation or other conditions, the pitch diameter D is selected or S is assumed.

2. Select the material and see the permissible stress and modulus of rigidity.

3. By knowing these data, the wire diameter can be found by following relation;

$$f_s = \frac{8PD}{\pi d^3}$$

… (3.9)

Where:

P - Load

D - Mean (pitch) diameter of coils

d - Diameter of spring wire

f_s - Shear stress induced in the wire of the spring

$$f_s = \frac{8PS}{\pi d^2} \quad \text{… (3.10)}$$

Where:

P - Load

d - Diameter of spring wire

f_s - Shear stress induced in the wire of the spring

S - Spring index

4. The stress factor K can be read from respective graphs. Then the more accurate value of diameter of spring wire is found by following relation.

$$f_s = K\frac{8PS}{\pi d^2}$$

… (3.11)

5. If the spring index S is directly assumed then D = S x d. Experience has shown that values of S from 6 to 10 will result in a reasonably balanced design in relation to stability, size and efficient use of material. For general industrial uses the spring index should be 8 to 10. Once S is known, then the value of K also is calculated. In this case the following equation involving S can be used for calculating the wire diameter.

$$K = \frac{4S - 1}{4S - 4} + \frac{0.615}{S} \quad \text{… (3.12)}$$

6. The necessary minimum diameter d having been calculated, the actual diameter d is taken as the nearest size from I.S. 1137-1959. This standard gives the basic thickness of sheet and diameter of wire in millimeters.

7. After standard wire has been determined, the number of active coils is calculated by use of following deflection equation.

$$\delta = \frac{8PD^3 z}{Md^4}$$

… (3.13)

Where:

P	- Load
D	- Mean (pitch) diameter of coils
d	- Diameter of spring wire
δ	- Deflection of spring
z	- Number of active coils
M	- Modulus of rigidity

If z becomes too small, the spring is too soft. According to the above equation the pitch diameter D must be decreased. This change will also slightly decrease d, and the calculations must be repeated. If z is too large, D must be increased.

8. When z is finally determined, the total number of coils z' can be determined from standard tables given in books or catalogs after selecting the end type.

9. Thus solid length and free length can be calculated using table. The spring having loops on both ends, the total number of active turns will be (z+1).

10. The pitch and helix angle of the coils can be calculated from following relations respectively.

$$p = \frac{free\ \ length - solid\ \ length}{z'} + d \quad \text{… (3.14)}$$

$$\alpha = \tan^{-1}\left(\frac{P}{\pi D}\right)$$

… (3.15)

Where:

p - Pitch

z' - Actual number of turns

d - Diameter of spring wire

α - The helix angle

P - Load

D - Mean (pitch) diameter of coils

3. 6. 5 Design of levers

A lever is a simple machine or mechanism which is used to get mechanical advantage, roughly speaking it a link or rigid rod moving about some fixed point or axis. A lever is meant to raise a load with less effort, or sometimes simply to facilitate the application of force in a desired direction. It is customary to call a rotating link a crank or handle, an oscillating link a lever or a beam, and the connecting rod. The fixed link is often enlarged and used as the supporting frame. The liver may be straight or curved. The advantage obtained by using a lever is called mechanical advantage and it is the ratio of load to effort, or it is also equal to the ratio of effort arm to the load arm. The perpendicular distance of the forces from the fulcrum are called the arms of the lever. The ratio is also called the leverage. The displacement of effort to displacement of load is called displacement ratio. Levers are of three types known as number 1, 2 and 3. In lever of type 1, the fulcrum is in between and the load and effort points are at the ends. In lever of type 2, the load point is in between and the effort and fulcrum points are at the ends, whereas in lever type 3, the effort point is in between and the load and fulcrum points are at the ends (Sharma and Aggarwal, 1998).

Designing a lever means, determining the physical dimensions of the lever when forces acting on the lever are specified. A lever is acted upon by two single forces or two sets of forces at effort and load points and by a reaction at the fulcrum. The forces acting on the effort and load points cause moments in the opposite directions. The effort arm and load arm are fixed either for requirements or from space considerations. Generally load acting on one arm is known and the effort to be applied to resist this load can be calculated by the principle of moments.

The reaction at the fulcrum point will depend upon that how effort and load are acting. The different ways in which effort and load can act are:

- When effort and load are parallel and their direction in same, then the resultant at the fulcrum point will be the sum of effort and load and direction of resultant will be same as effort and load.
- When effort and load are parallel and their direction is opposite to each other, then the resultant at the fulcrum point will be the difference of effort and load and direction of resultant will be the same as of effort or load whichever greater.
- When forces of effort and load are inclined to each other, then, the resultant at the fulcrum point can be obtained by parallelogram of forces and its magnitude will depend upon effort and load and the direction of the resultant will also depend upon the direction of effort and load.

Once the forces acting on the lever are known, the various dimensions of the lever can be obtained. In all types of levers when the load and effort are in a plane containing the lever arm, the section of lever arm is mainly subjected to bending moment. Hence section of the arm is estimated from the bending moment considerations.

For any kind of lever, the section at which maximum bending moment occurs can be determined by the following strength equation.

$$M_b = f \times Z \qquad \dots (3.16)$$

Where:

M_b - Maximum bending moment

f - Allowable stress of the material of lever

Z - Modulus section of lever

The modulus of section of the rectangular section is given by;

$$Z = \frac{1}{6} t w^2 \qquad \dots (3.17)$$

Where:

Z - Modulus of section

t - Thickness of rectangular section

w - Width of rectangular section

The modulus of section of the hollow rectangular section is given by;

$$Z = \frac{1}{12} t\left(w^3 - d^3\right)$$

… (3.18)

Where:

Z - Modulus of section

t - Thickness of rectangular section

w - Width of rectangular section

d - Diameter of the hole of the rectangular section

The modulus of section of the rectangular section is 1/6t w^2, where t is the thickness of the lever and w is the width of the lever. The width of the lever is generally 2 to 5 times the thickness of the lever. The ends of lever should be checked for shear force.

Hence,

$$M_b = \frac{1}{6} f\,tw^2$$

… (3.19)

Where:

M_b - Maximum bending moment

f – Allowable stress of material

Z – Modulus section of lever

t – Thickness of lever

w – Width of lever

Maximum shear stress induced in lever $= \frac{MSF}{t \times w}$

… (3.20)

Where:

MSF - Maximum Shear Force

t - Thickness of lever

w - Width of lever

The fulcrum pin is designed for bearing and bending considerations with a proper check for shear and sometimes deflection also. The general procedure is to design pin from bearing considerations and then to check it for shear. The permissible bearing pressure depends upon the amount of relative velocity between the pin and the lever and the frequency of motion. The sufficient length in bearing is usually obtained by providing bosses instead of choosing a thicker lever throughout. If the forces do not differ much, the same pin dimension for pin at fulcrum, load and effort joints may be adopted to reduce spares.

Normally, the suitable value of the ratio of length to diameter of pin is assumed and the dimension of the pin can be obtained. The value of this ratio may be taken from 1 to 1.3. Therefore, the length of the boss will be 1 to 1.3 times the diameter of pin. Diameter of boss is twice the pin diameter. To increase the life of the lever and reduce wear, it is customary to fit a phosphor bronze bush of thickness 3mm. To increase the life of the lever further, the dust proof lubrication arrangement should be provided. This help in reducing the wear to a minimum, thus resulting in very less replacement of bush. If the load or effort, are in plain containing lever arm but not normal to the axis of the lever then the lever arm is subjected to direct stress in addition to bending stress. It may be noted that the direct stress may be compressive or tensile, depending upon the direction of load.

3. 6. 6 Design of lever pin

The pins are used to joint lever by pin joints. Bending of the pin in the lever may take place in different ways. Size of the pin is determined by considering bending stress and bearing of the as per the relation given below. (Sharma and Aggarwal, 1998)

$$\frac{t}{d} = 0.634\left(\frac{f_b}{p^b}\right)^{1/2}$$

… (3.21)

Where;

f_b - Allowable bending stress

p^b - Allowable bending pressure

t - Thickness of the lever

d - Diameter of pin

By considering the bearing of the pin; size of the pin can be calculated as per relation given below (Sharma and Aggarwal, 1998)

F

$= d \times t \times p^b$ … (3.22)

Where;

F - Force

p^b - Allowable bending pressure

t - Thickness of the lever

From above relations, the value of t and d can be calculated. Generally, diameter of boss is taken as twice the diameter of the pin and length of the pin is normally 1.3 times the diameter of pin (Sharma and Aggarwal, 1998).

3. 6. 7 Design of welded joints

It is the art of joining metals by pressure after heating to a plastic or semi-molten state, or of joining the metals by fusion alone, or a welded joint is a combination of parts fastened together by means of weld. According to their purpose welded joints are subdivided into strong and tight-strong. Their functions are the same as those of riveted joints, i.e. to transmit load from one member to other in strong joint add to provide, besides for fluid and gas impermeability in tight-strong joints (Sharma and Aggarwal, 1998).

Welds are designed by keeping in mind the following assumptions: Load is distributed uniformly among the entire weld length and Stress is spread uniformly over its effective section. Butt jointed seams are designed for tension and compression. The thickness t of the thinner of the joined plates is taken as the design throat of the weld.

The transverse fillet welded joints are designed for tensile strength. For a single fillet lap joint and double fillet lap joint, the necessary length of weld in millimeter is given in following relations respectively.

For single fillet lap joint: $l = \dfrac{P}{0.7t \times f_t}$

… (3.23)

For double fillet lap joint : $l = \dfrac{P}{2 \times 0.7t \times f_t}$

… (3.24)

Where:

l - Length of the weld

P - Load

t - Size of the weld (Thickness of the plate)

f_t - Allowable stress for the weld metal in tension

3. 6. 8 Design of blade

When slenderness ratio (l/k) is less than 30 the effect of lateral deflections is negligible, and the member may be considered to be in simple compression. In machine design most of the members tend to be short columns. In mango dicing machine, blades are subjected to compressive load and buckling is the particular mode of failure. Therefore, blades are considered as short column. Rankine formula is used for short column (Sharma and Aggarwal, 1998 and Karwa, 1999).

$$F = \frac{f_c A}{1 + a\left(\frac{L}{k}\right)^2} \qquad \text{… (3.25)}$$

And $k = 0.289\ w$ … (3.26)

Where:

F – Crushing force in N

A – Cross sectional area in m^2

L – Length of column in m

σ_w – Allowable compressive stress in MN/ m^2

k – Radius of gyration

a – Constant, (1/5000 for stainless steel)

w- Width of the cross section in meters

3. 6. 9 Painting

Paint is a liquid material applied to a surface to form a hard, continuous film for protection or decoration. The most important function of modern paints is the protection against corrosion, the action of chemicals or wear. Without such protection, corrosion would be so extensive that most products of modern technology could not exist. Apart from those, another aspect of painting is that paints are used for coloring purposes. For better perception, different parts or sub systems of equipment are painted suitably (Khanna, 2005).

The choice of paint or paint system is determined by many factors, of which the followings are the most important:

- Mechanical climatological, physical and chemical requirements, depending on the application.
- Material surface which has to be treated.
- Appearance desired: color, glossy or matt finish, smoothness, surface effect etc.
- Method of application, determined, for example, by equipment available, form or material of surface to be painted.
- Cost, which depends amongst the things on the price of the paint, the method of application, the number of articles to be painted, machine and labor costs.

CHAPTER IV

DESIGN AND DEVELOPMENT

This chapter deals with the design and development aspects and constructional details of the mango dicing machine. Later part of the chapter includes all engineering drawing required for manufacturing of the machine.

4. 1 Design data

Designing of mango dicing machine requires the basic information such as expected capacity, operational method, end product details, users of machine, engineering properties of mango, engineering properties of constructional materials etc.

The manually operated mango dicing machine is to design and develop with a view to introducing for cottage level and small scale pickle industry. As this machine is manually operated, the expected capacity is mostly depend on the person who operates this machine, mango variety. This machine is targeting industries at off grid locations or remote areas which requires manually operated machines such as hand held, hand operated or pedal operated etc. Therefore, the machine was designed to operate by foot as man can exert nearly 800N by foot when compared to that of 400N by hand (Sharma and Aggarwal, 1998).

4.2 Details of mango dicing machine

The machine is used to produce mango cubes for pickle preparation. The operation is as follows. The first, mango fruit is placed on the wooden flank where there is spatial location for keeping mango fruit. Then, the mango fruit is sliced into two parts. The two parts are again placed in the respective locations in the wooden flank. The second stroke divides each sliced mango halves into four or six pieces according to the cutter used. There are two cutting arrangements which cut mango fruits in to four and six pieces at one stroke. The machine consists of following components.

- Main frame (L-Iron structure)
- Lever mechanism
    - Foot plate

- Foot lever
- Vertical and horizontal Levers
- Shafts
- Pins

- Cutter assembly
  - Cutting blades
  - Cutting blade fixing bracket
  - Cutting blade fixing plate
  - Bolts and nuts
- Feeding hopper
- Discharge hopper
- Springs
- Cutting platform

4.3 Main frame (L-iron structure)

Material of L-iron	= Mild steel (0.1- 0.2 % C)
Yield point stress of mild steel	= 355 MN/m^2
Maximum force, a man can exert by foot	= 800 N (Sharma and Aggarwal, 1998)
Factor of safety for impulsive load	= 12
Weight of the food mango on container	= 10 kg
Self weight of the mango dicer	= 50kg
Size of L-iron	= 37.5mm x 37.5mm x 3mm

All the components of the machine were mounted on main frame. The length, width and height of L-iron structure are 400mm, 350mm and 1200mm respectively. The dimensions of L-iron structure were decided by considering, sizes of mangoes, easy operation, operator safety and anthropometric data of an average person. The frame is fabricated by using 37.5mm x 37.5mm x 3mm L-angle iron. L-angle iron was made of mild steel containing 0.2 – 0.3 carbon percentage. The thickness of the L-iron was calculated by considering self weight of the machine, mango weight in feeding hopper and force exerted by the operator. The availability of material, available fabrication facilities, strength of material and cost of material were also taken into consideration while selecting suitable material. The parts of the main frame were joined by using electric arc welding facilities. The detailed engineering drawing of frame is shown in drawing number 01 of Fig.4.1. The design calculations of thickness are given in Appendix A.

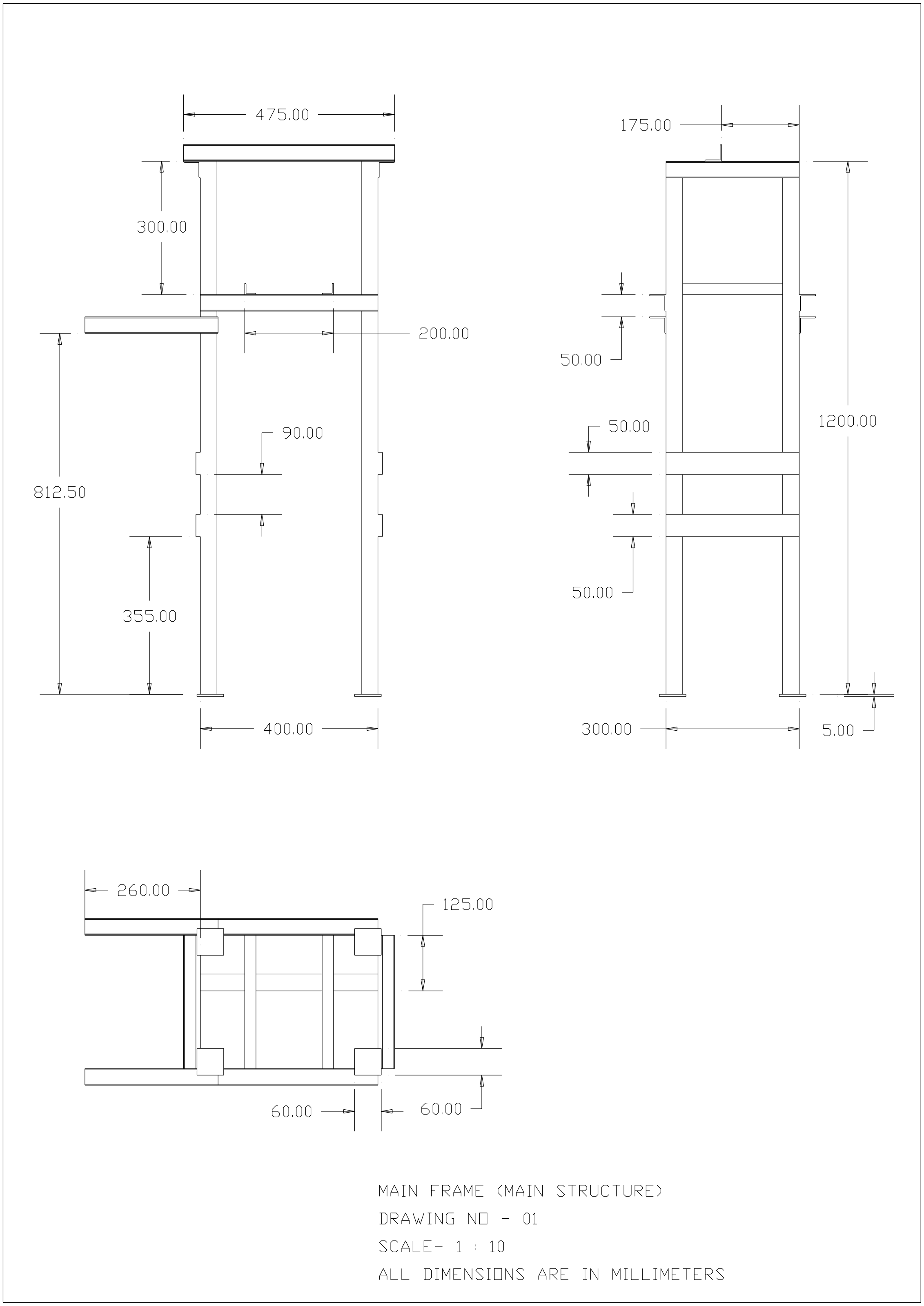


Fig. 4.1: Detailed drawing of main frame

4.4 Lever mechanism

Lever mechanism is used to get mechanical advantage that is with less effort, it is able to get more work done. The expected mechanical advantage from this mechanism is two. The mechanism consists of foot levers, other levers, pins, shafts, foot plate, and lever with bracket end. In this design, the lever of type 1 was used and in lever type 1, the fulcrum is in between and the load and effort points are at the ends.

4. 4. 1. Shafts

Material of shaft	= Mild Steel (0.2- 0.3 % C)
Maximum force, a man can exert by foot	= 800 N
Factor of safety	= 2
Ultimate tensile stress (f_{ut})	= 555 MN/m^2
Yield point stress (f_{yp})	= 480 MN/m^2
Shock and fatigue factor in bending (K_b)	= 2.5

There were three shafts used in whole lever mechanism as fulcrum points. The length and diameter of shafts are 420 mm and 22mm (appendix-A), respectively. The shafts were mounted to main frame. The two flat iron are welded to main frame and shafts were mounted on the holes of flat iron. To increase the life of the lever and flat iron and to reduce the wear, gun metal bushes of 1.5mm thickness have been used in the holes. The shafts are able to rotate their own axis. The diameter of the shafts was decided by considering only bending moments (appendix-A) on shafts as levers are freely rotating around shaft; there is no torsional effect on shafts. The relations used in these calculations were referred from Sharma and Aggarwal, 1998. The shafts are made up of mild steel bars with 0.2-0.3 percentage of carbon. The required dimensions were obtained by machining the shafts.

The detailed engineering drawing of shaft is shown in drawing number 03 of Fig.4.2. The design calculations pertaining to diameter of shafts are presented in Appendix A.

4. 4. 2 Foot lever, vertical and horizontal levers

Material of lever	= Mild Steel (0.2-0.3 % C)
Ultimate tensile stress (f_{ut})	= 555 MN/m^2

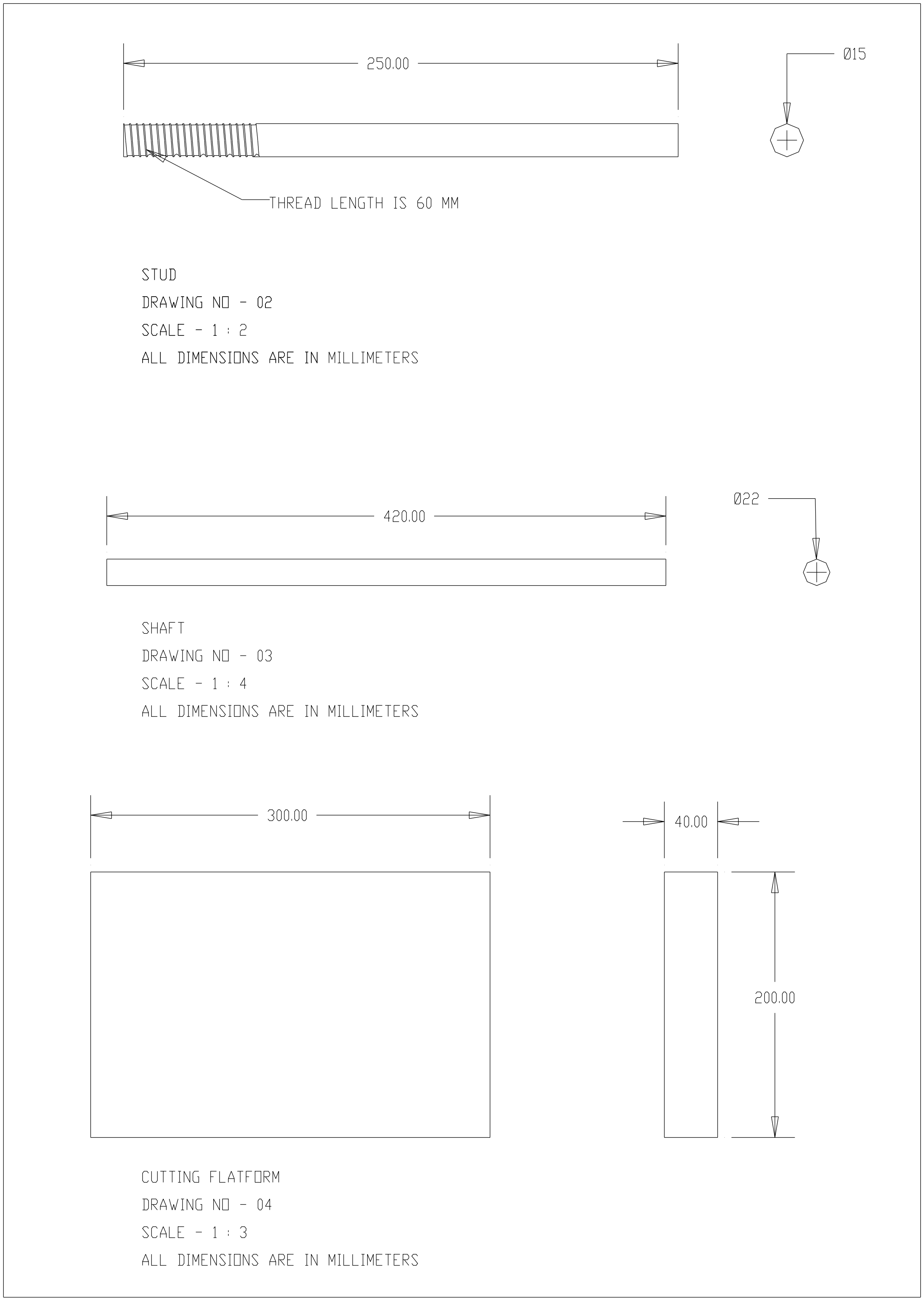


Fig. 4.2: Detailed drawing of stud, shaft and cutting platform

Yield point stress (f_{yp}) = 480 MN/m^2

Factor of safety = 2

Allowable bending stress = 69.375 MN/m^2

There were six livers used in lever mechanism. They have similar cross section and different length. These levers were designed for strength by considering bending moments and then checking for the maximum shear stress and bending stress induced with relations given in Sharma and Aggarwal, 1998. The width and thickness of the cross section of levers were decided as 50 and 8 mm (appendix-A), respectively. The lengths of levers were decided by taking into consideration of mechanical advantage of lever mechanism, size of the main frame and rigidity. The material selected for manufacturing levers were mild steel with 0.2-0.3 percentage carbon as this material is readily available, easy for machining and fair cost. The required dimensions were obtained by machining the flat iron bars.

The detailed engineering drawings of different levers are given in drawing number 05 of Fig. 4.3, drawing number 07 and 08 of Fig. 4.4 and drawing number 09 and 10 of Fig.4.5. The design calculations related to width and thickness of levers are presented in Appendix A.

4. 4. 3 Pins

Material of pin = Wrought iron

Allowable bending stress = 70 MN/m^2

Allowable bending pressure = 40 MN/m^2

Five lever pins were used in lever mechanism to join the levers each other. The levers can rotate freely the axis of pin. The pin size was designed as per the relations given in Sharma and Aggarwal, 1998. Thus, diameter of pin is taken as 10 mm (appendix-A). Length of the pin is normally 1.3 times the diameter of pin (Sharma and Aggarwal, 1998). Therefore the length of pin is taken as 20mm. The pins were made up of wrought iron as it is highly wear and tear resistance. The design calculations related to diameter and length of pins are presented in Appendix A.

4. 4. 4 Foot plate

Material of foot plate = Mild Steel (0.2 -0.3% C)

Ultimate tensile stress (f_{ut}) = 555 MN/m^2

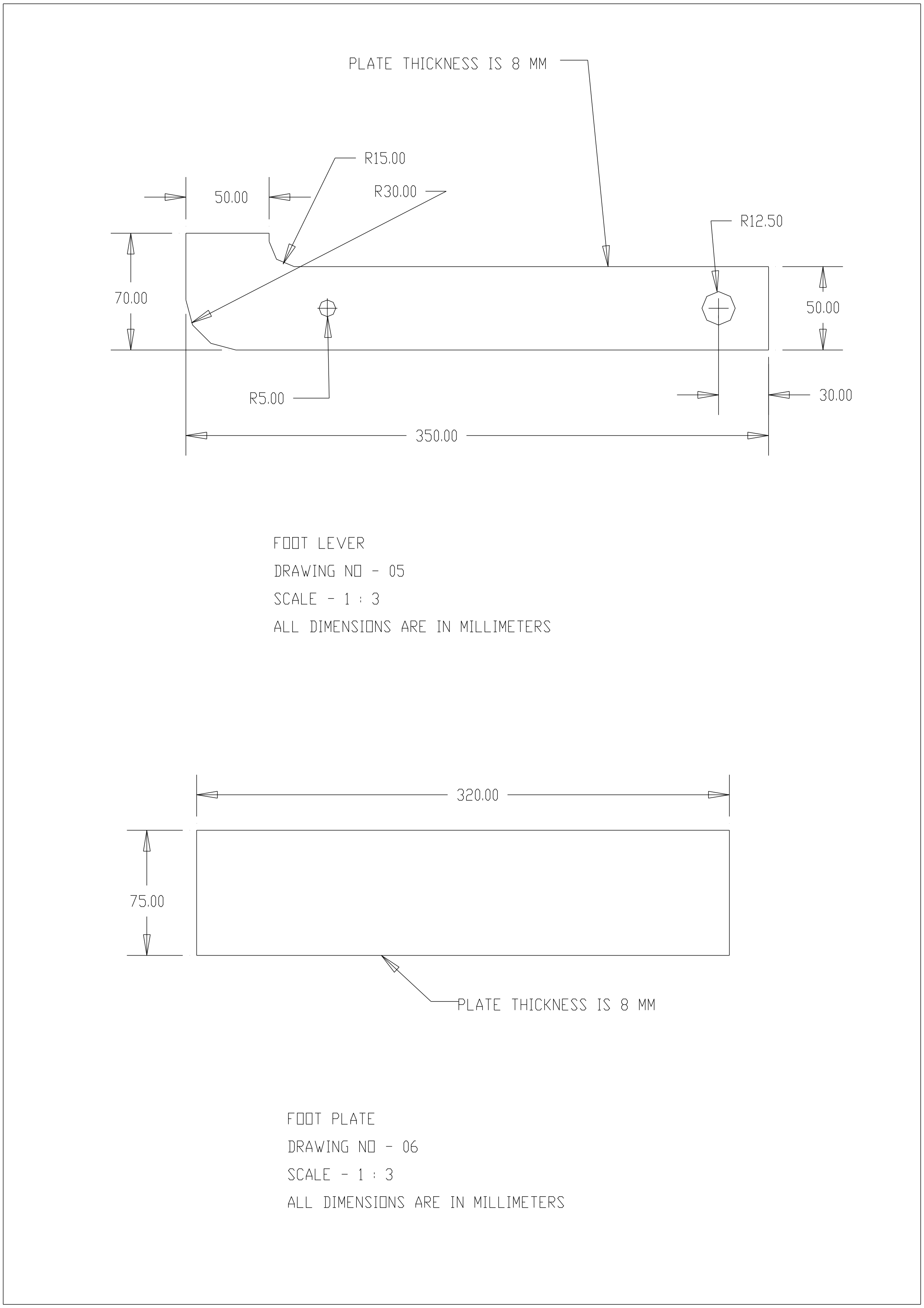
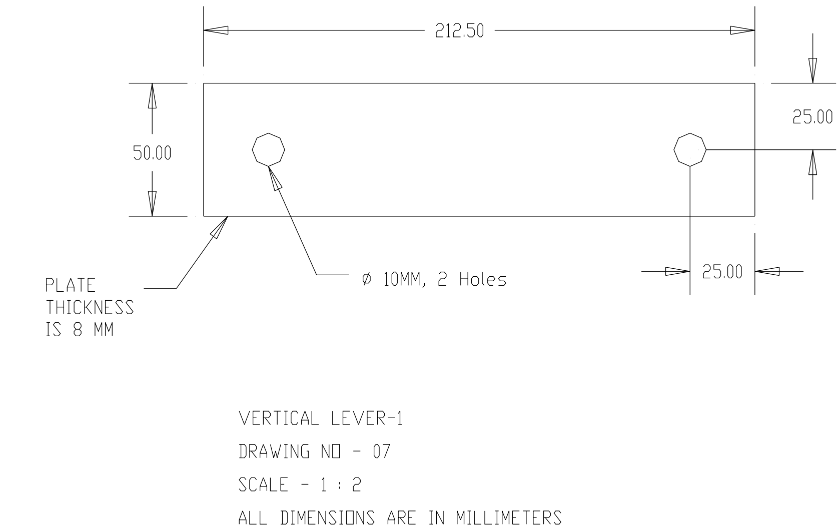


Fig. 4.3: Detailed drawing of foot lever and foot plate



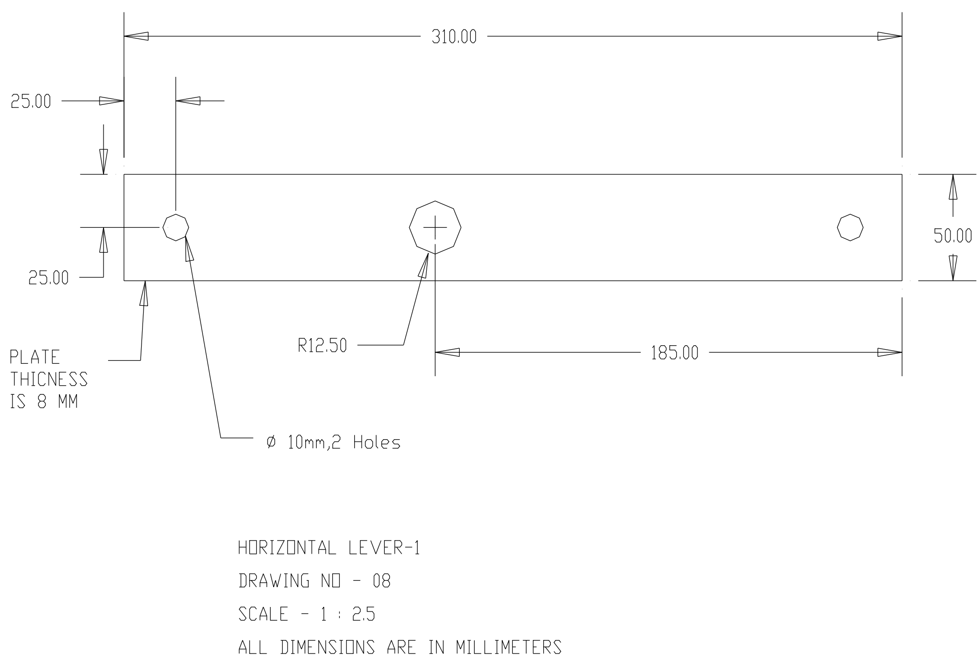


Fig. 4.4: Detailed drawing of vertical lever-1 and horizontal lever-1

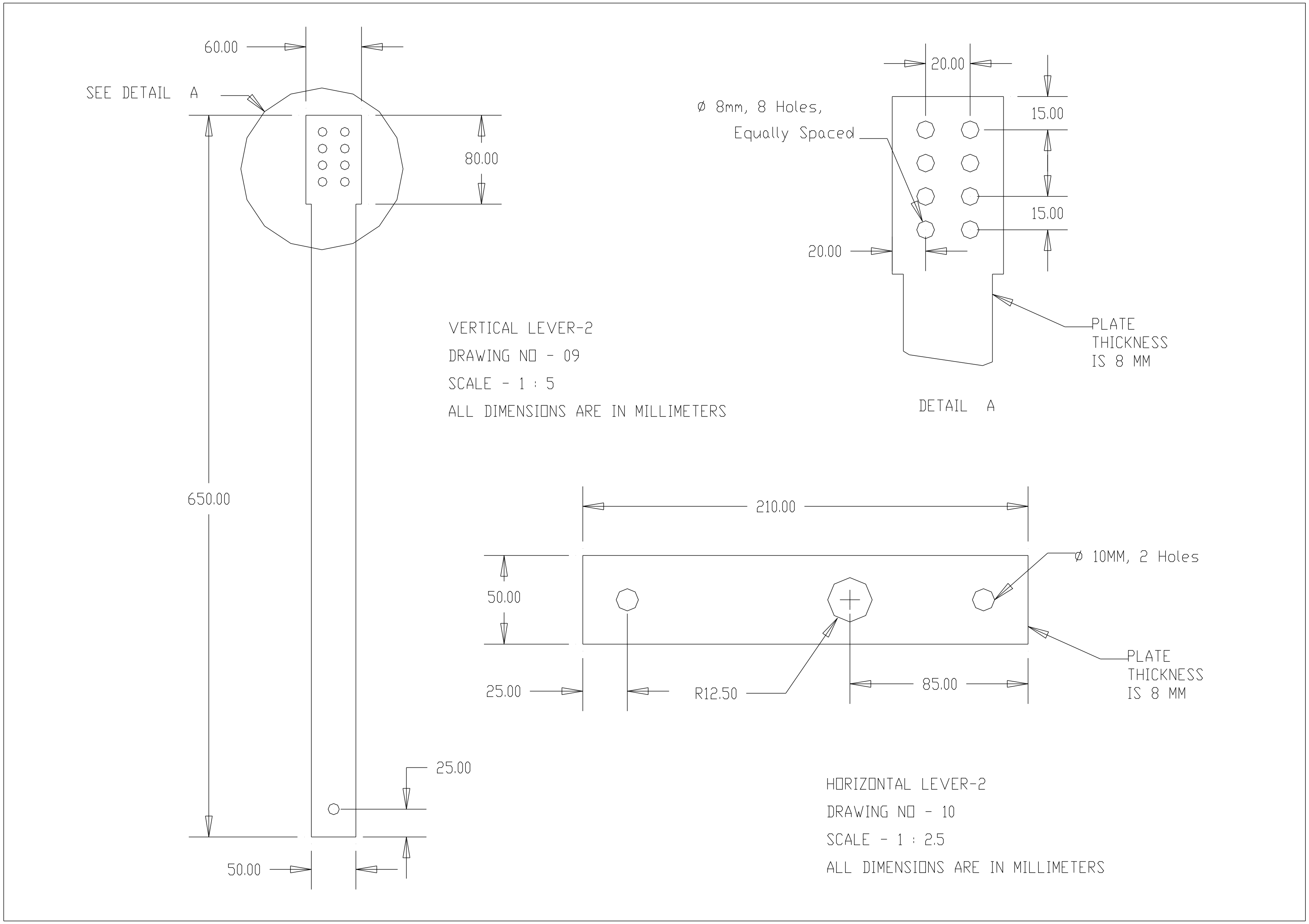


Fig. 4.5: Detailed drawing of vertical lever-2 and horizontal lever -2

Yield point stress (f_{yp})	= 480 MN/m^2
Factor of safety	= 2
Allowable bending stress	= 69.375 MN/m^2

The machine operator exerts his effort by foot on foot plate. This was made up of mild steel with 0.2-0.3 percentage of carbon. The foot plate was designed based on bending moment for strength and then checked for the maximum shear stress and bending stress induced in foot plate with relations given in Sharma and Aggarwal, 1998. The length and width of foot plate were predefined as 320mm and 75mm (appendix-A), respectively by considering operator's easiness. The thickness of the foot plate was selected as 5mm. If all the flat bars were same thickness, it is trouble-free and cheaper to purchase material as a lot. The detailed engineering drawing of foot plate is given in drawing number 06 of Fig.4.3. The design calculations related to thickness of foot plate are presented in Appendix A.

4. 5 Design of cutting mechanism

The cutting mechanism consists of cutting blades, cutting fixing bracket, sliding bracket, supporting plate, bolts, and guiding shafts. All parts of the cutting blades were fabricated by using stainless steel.

4. 5. 1 Design of blade

Material of blade	= Stainless Steel
Ultimate tensile stress (f_{ut})	= 980 MN/m^2
Yield point stress (f_{yp})	= 700 MN/m^2
Factor of safety	= 10
Allowable compressive stress	= 350 MN/m^2

The cutting blades were designed for cutting mango in to cubes. There were two cutting blade arrangement designed. One arrangement cuts mango into four cubes whereas other cuts mango into six cubes within two strokes. The blades were considered as short column with axial load. The Blades are subjected to compressive load and buckling is the particular mode of failure. Therefore, blades were designed by testing for buckling with Rankine formula available in Sharma and Aggarwal, 1998. The height and width were decided as per the mango sizes which were selected for testing of the machine. Thickness was calculated as 2 mm (appendix-A) and constructional material is stainless steel because blades are directly contact with the food material. The angle between two cutting surfaces was kept 15 degrees. Blades were joined to cutter bracket by welding technique. The detailed engineering drawings of cutting blades are given in drawing number 11 of Fig.4.6. The design calculations pertaining to thickness of blades are presented in Appendix A.

4. 5. 2 Bolts

Material of cutter bracket	= Mild steel (0.1 – 0.2 % C)
Ultimate tensile stress (f_{ut})	= 420 MN/m^2
Yield point stress (f_{yp})	= 355 MN/m^2
Factor of safety	= 4
Allowable shear stress	= 105 MN/m^2

The bolts were used for joining some parts of the mango dicing machine. They make way for assembling and dismantling machine components for replacement, repairing and cleaning as required. The cutter was jointed to lever mechanism through bolted joints, so that two cutters can be changed easily. When the bolts were designed, it was assumed that bolts fail only due to shear failure. The bolts were made up of mild steel containing 0.1 – 0.2 percentage of carbon. Standard bolts of diameter 8mm (appendix-A) was selected for all purpose of bolted joints in the machine. The head of the bolts were hexagonal and length is 40mm out of that 20mm screwed. The design calculations pertaining to thickness of bolts are presented in Appendix A.

4. 5. 3 Cutter bracket

Material of cutter bracket	= Stainless Steel
Ultimate tensile stress (f_{ut})	= 980 MN/m^2
Yield point stress (f_{yp})	= 700 MN/m^2
Factor of safety	= 4
Allowable shear stress	= 245 MN/m^2

Blades were joined to cutter bracket by welding technique. This was used to connect cutter to sliding bracket then lever mechanism. Cutter bracket comprises of guiding plate so that cutter is easily joined. The forces pass through these brackets. Therefore, cutter was designed by assuming shear failure. There were five holes made in bracket to join cutter to

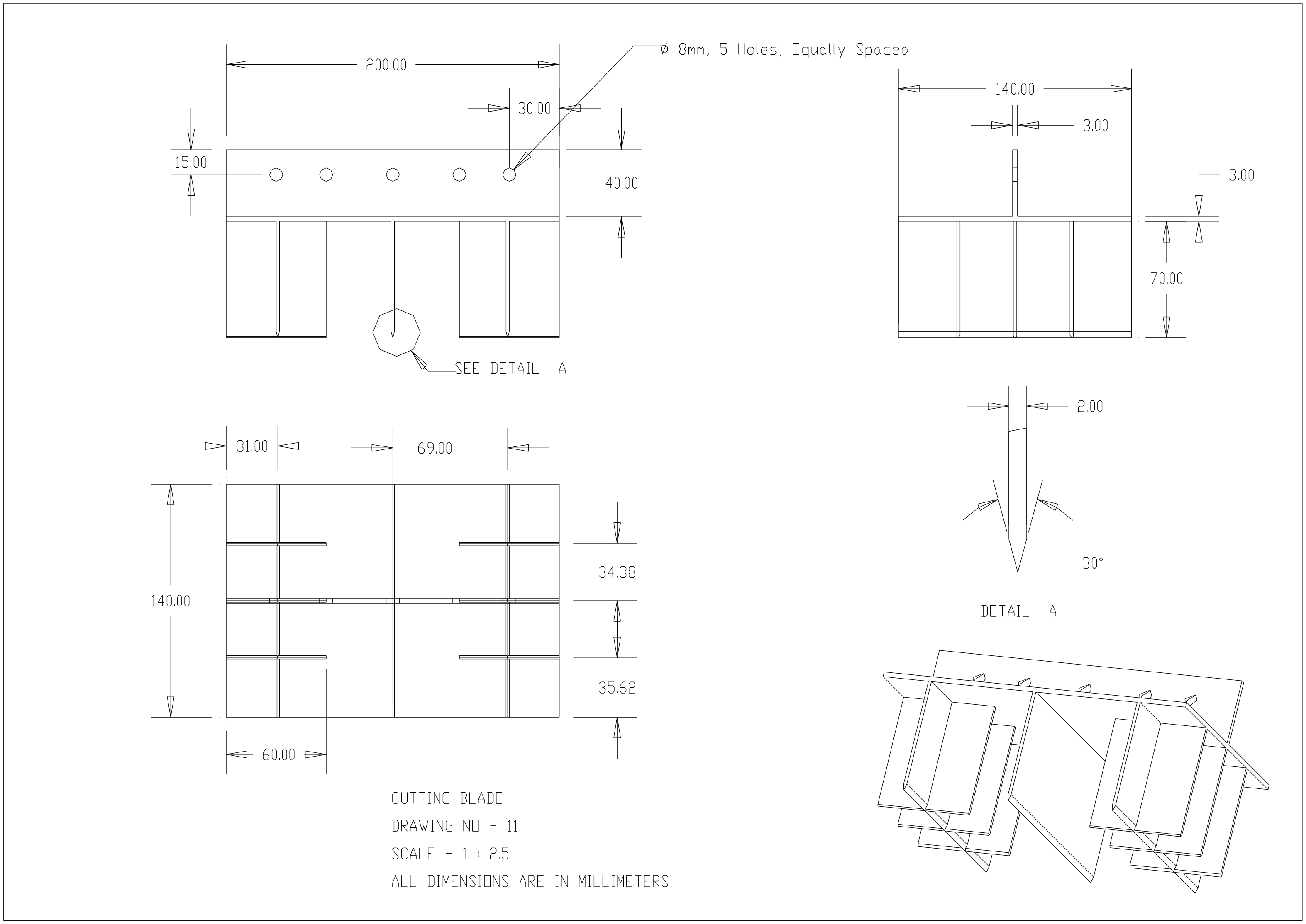


Fig. 4.6: Detailed drawing of cutting blade

sliding unit which cutter goes up and down while operation. This was made up of stainless steel as this part is also indirectly contacted foods.

The detailed engineering drawings of cutting blades bracket part are given in drawing number 11 of Fig.4.6. The design calculations of cutting blade bracket are presented in Appendix A.

4. 5. 4 Cutting blade fixing bracket

Material of cutting blade fixing bracket -01, 02	= Mild Steel (0.1-0.2 % C)
Ultimate tensile stress (f_{ut})	= 420 MN/m^2
Yield point stress (f_{yp})	= 355 MN/m^2
Factor of safety	= 4
Allowable shear stress	= 105 MN/m^2

Cutter was joined to this sliding bracket by using blots. This moves up and down in two guiding shaft according to the movement of lever mechanism. This bracket comprises of two rings and two small plates with hole. The small plates were welded to end of this bracket so that lever mechanism was bolted to this. The diameter of holes in the plate is 8mm and prepared by drilling. The two rings were also welded to main bracket as shown in Fig.4.8. The sliding bracket was designed by considering shear failure and then checked for bending stress. The constructional material of sliding bracket is mild steel with 0.1-0.2 percentage of carbon.

The detailed engineering drawings of cutting blade fixing brackets 01 and 02 are given in drawing number 12 and 13 of Fig.4.7 and Fig.4.8 respectively. The design calculations of cutting blade fixing bracket are presented in Appendix A.

4. 6 Springs

Material of spring	= High carbon steel (0.7-0.8% C)
Ultimate tensile stress (f_{ut})	= 1420 MN/m^2
Yield point stress (f_{yp})	= 1170 MN/m^2
Modulus of rigidity	= 84 GN/ m^2
The force causing deflection of spring	= 857 N

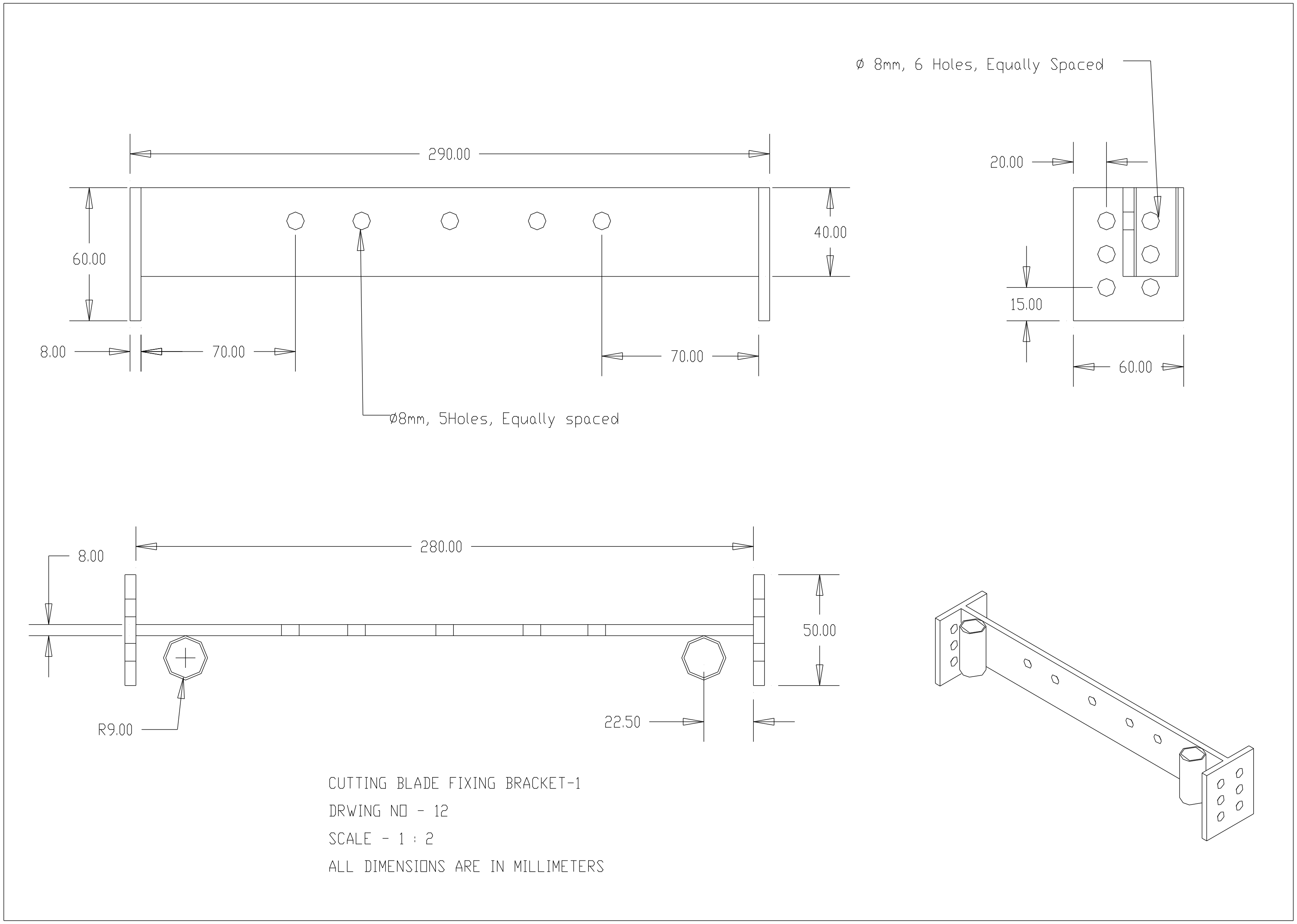


Fig. 4.7: Detailed drawing of cutting blade fixing bracket-1

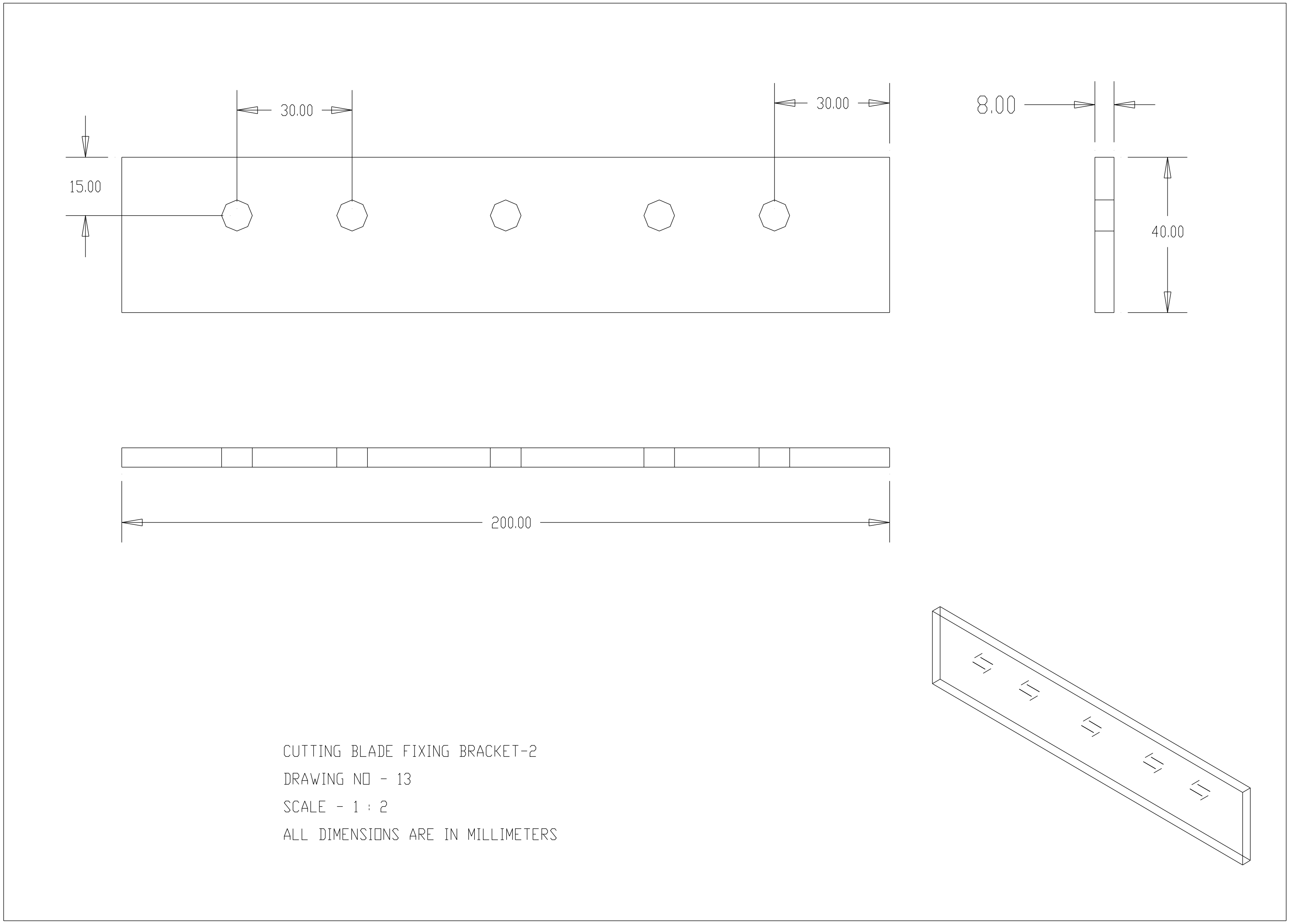


Fig. 4.8: Detailed drawing of cutting blade fixing bracket-2

Spring index	= 6
Factor of safety	= 2
Maximum deflection	= 50 mm
Allowable shear stress	= 710 MN/ m^2

Spring is used to bring lever mechanism back its normal position. However, spring is subjected to sudden force when operator presses the foot lever. Therefore, the force considered in the spring design is same to that of force acting on it when operator presses the foot lever. It is assumed that this force is enough to bring lever mechanism back to its normal position. The diameter of spring wire is 5mm and mean coil diameter is 30mm. the number of active coils are 30 (appendix-A). Both ends of spring have loops. The design calculations of spring are presented in Appendix A.

4.7 Cutting platform

Material of cutting platform	= Wooden (Douglas fir, air dry)
Ultimate tensile stress (f_{ut})	= 58 MN/m^2
Yield point stress (f_{yp})	= 52 MN/m^2
Factor of safety	= 2
Allowable bending stress	= 3.5 MN/m^2
Allowable shear stress	= 29 MN/m^2

The wooden flank is used to keep mango for dicing. Wooden was selected as there is no or little harm to blade when it touches on wooden flank. The wooden flank was designed for maximum bending moment and checked for shear stress. The length and width was predefined as 300mm and 200mm (appendix-A), respectively. Thickness was calculated by using existing equations given in Sharma and Aggarwal, 1998, and selected as 40 mm.

The detailed engineering drawings of cutting platform are given in drawing number 04 of Fig.4.2. The design calculations of cutting platform are presented in Appendix A.

4. 8 Discharging hopper

The discharge hopper is used to discharge diced mango cubes in to vessel near to the machine. The operator can easily throw mango cubes in to vessel without any unnecessary movement. The discharge hopper was designed by taking into consideration of angle of repose. This was done by trial and error method by using the diced mango cubes of respective variety which was used for designing and testing. The slope of the hopper is 54 degrees with horizontal plane. The detailed engineering drawings with dimensions of discharging hopper are shown in drawing number 14 of Fig. 4.9.

4. 9 Feeding hopper

The feeding hopper is used to store some mango while operating machine. The operator can easily pick and place the mango on wooden flank without any unnecessary movement. The feeding hopper was fabricated by using stainless steel as it touches the mango directly for hygienic condition. The length, width and height of the hopper are 300mm, 200mm and 100mm respectively. The thickness of stainless steel plate was selected as 3mm so that electric arc welding is possible. The detailed engineering drawings with dimensions of feeding hopper are shown in drawing number 15 of Fig.4.10.

4. 10 Welded joints

The welded joints were used where assembling, dismantling were not required. The main frame, feeding hopper and discharging hopper were joined by welded joints. The welded joints have more rigidity even than bolted joints. It was assumed that thickness of weld is same as that of the plate. Length of weld was calculated by relation given in Sharma and Aggarwal, 1998. The design calculations of welded joints are presented in Appendix A.

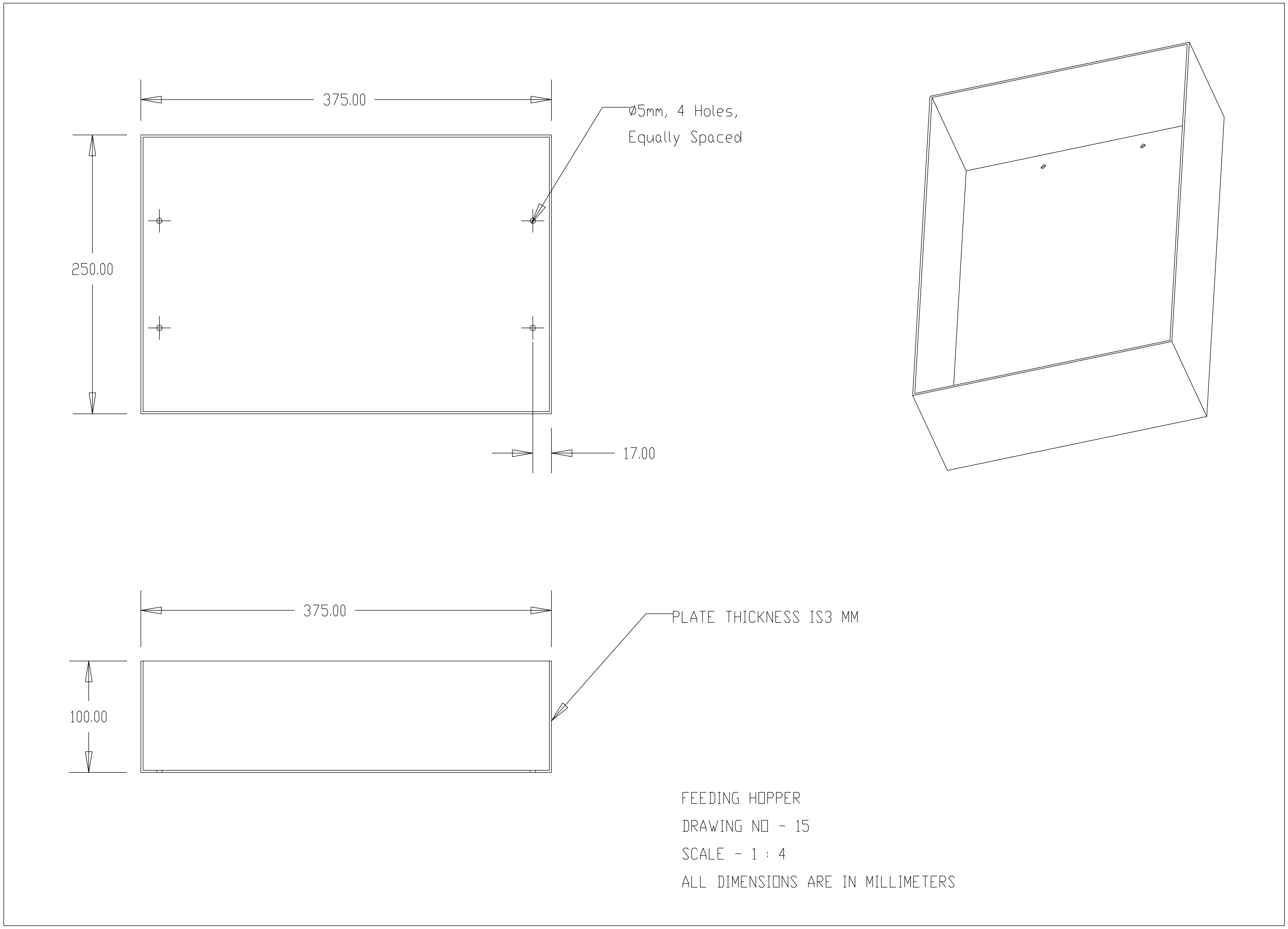


Fig. 4.9: Detailed drawing of feeding hopper

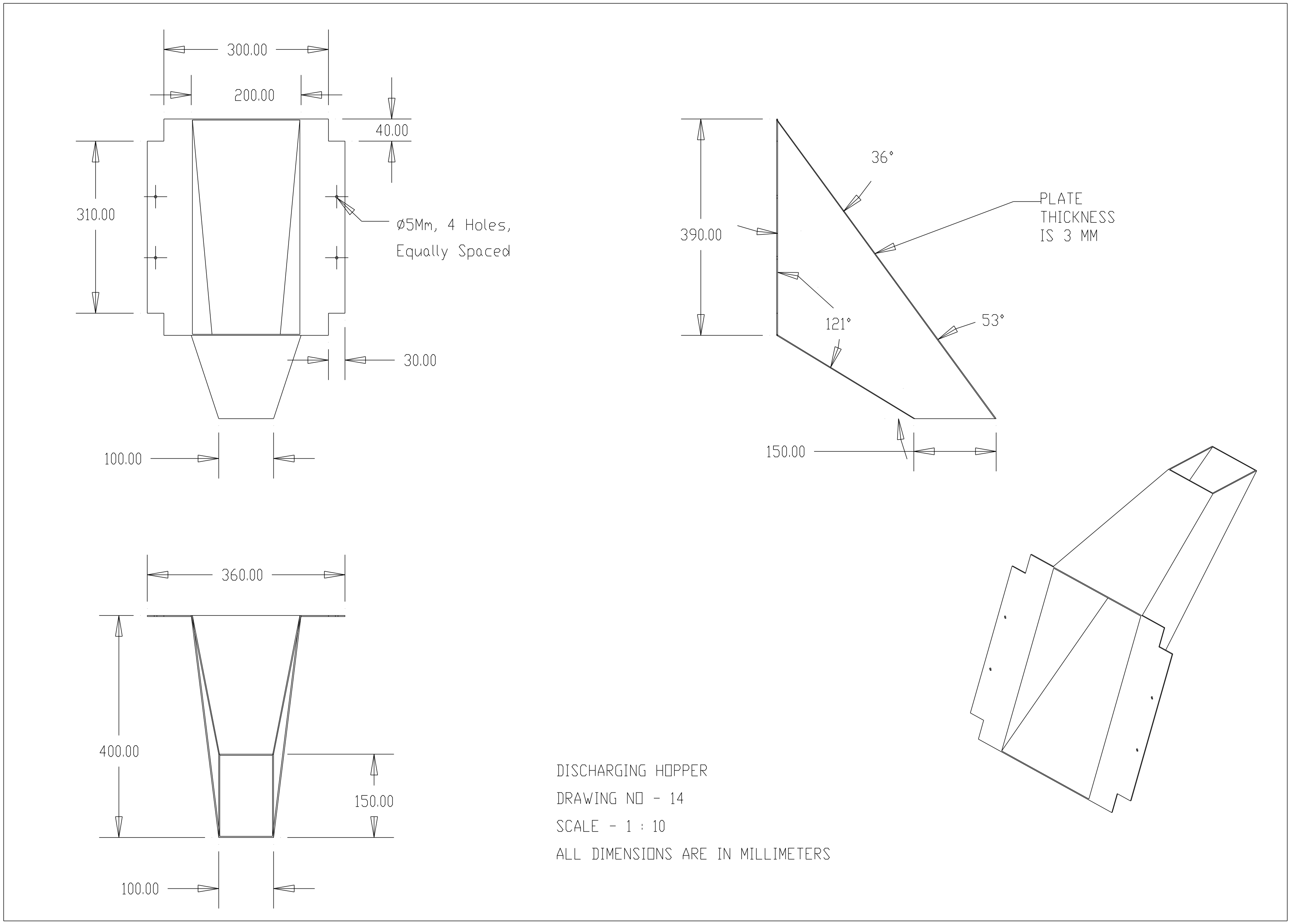
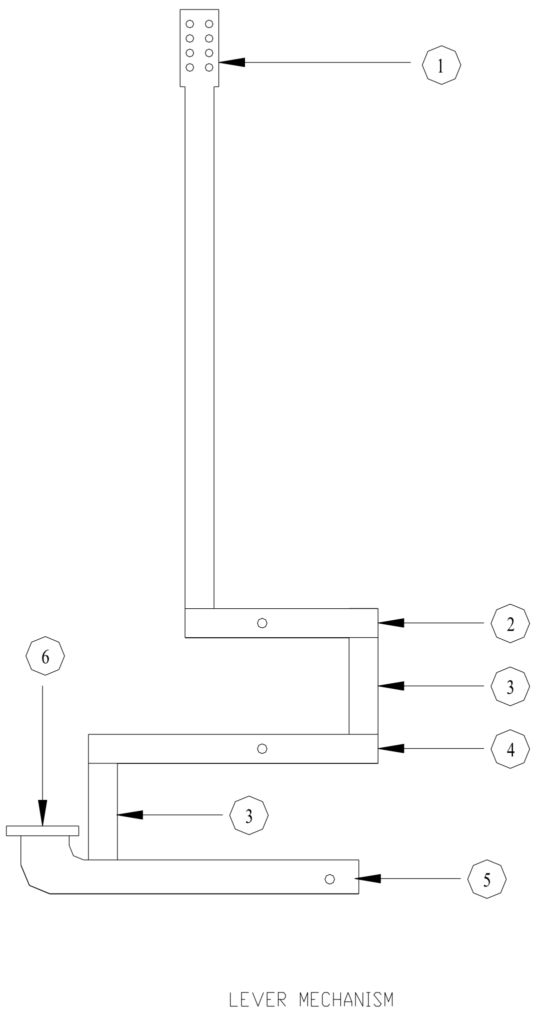
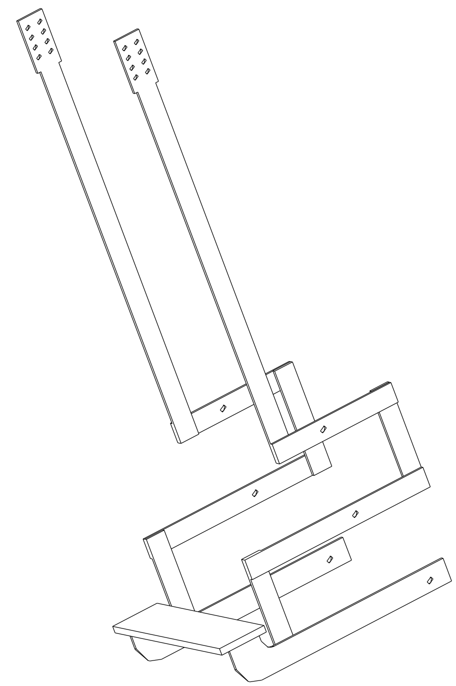


Fig.4. 10: Detailed drawing of discharging hopper



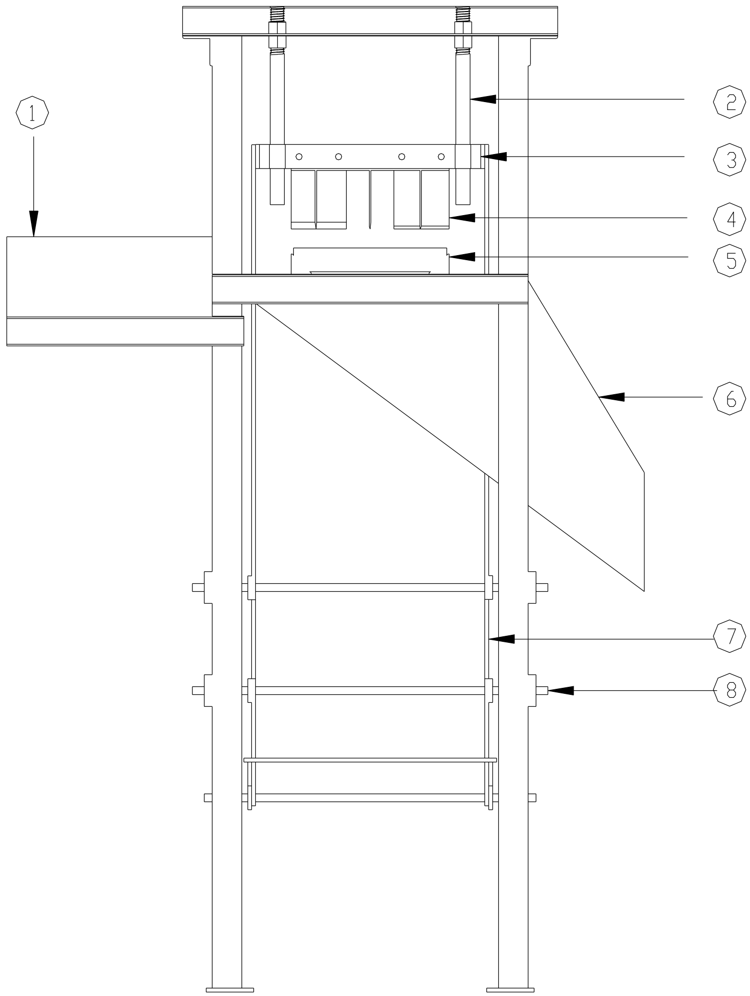


LEVER MECHANISM

S.No	DESCRIPTION	MATERIAL	QTY.	REMARKS
6	FOOT PLATE	MILD STEEL (0.2-0.3% C)	a No.	DRG. No. 06
5	FOOT LEVER	MILD STEEL (0.2-0.3% C)	2 Nos.	DRG. No. 05
4	HORIZONTAL LEVER-1	MILD STEEL (0.2-0.3% C)	2 Nos.	DRG. No. 08
3	VERTICAL LEVER-1	MILD STEEL (0.2-0.3% C)	4 Nos.	DRG. No. 07
2	HORIZONTAL LEVER-2	MILD STEEL (0.2-0.3% C)	2 Nos.	DRG. No. 10
1	VERTICAL LEVER-2	MILD STEEL (0.2-0.3% C)	2 Nos.	DRG. No. 09

PART LIST

Fig. 4.11: Details of lever mechanism



MANGO DICING MACHINE				
8	SHAFT	MILD STEEL (0.2-0.3% C)	3 Nos.	DRG. No. 03
7	LIVER MECHANISM	MILD STEEL (0.2-0.3% C)	1 No.	DRG. No. 05,06,07,08,09,10

Fig. 4.12: Details of mango dicing machine

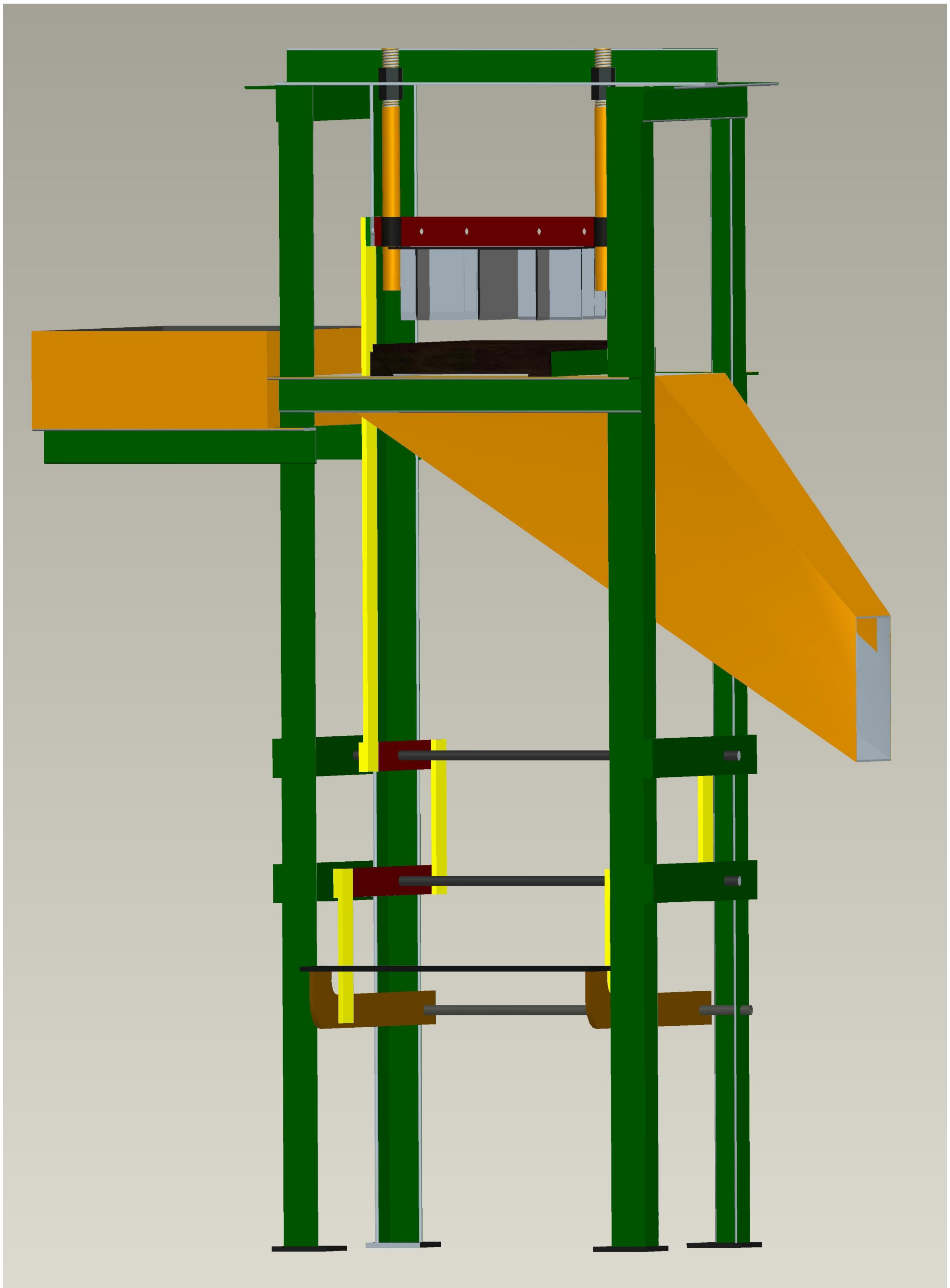


Plate 4.1: Designed mango dicing machine using ProE software

Plate 4.2: Manually operated mango dicing machine

CHAPTER V

MATERIAL AND METHODS

This chapter describes the way to determine some physical properties of mango where those required for designing of mango dicing machine and methodology, experimental set up to evaluate the performance of the developed mango dicing machine.

5. 1 Selection of raw material

The raw mangoes were selected randomly and purchased as a bulk from the local market for experiment. Those mangoes which were purchased were matured enough and suitable variety for preparation of mango pickle and specially people purchased these mangoes to prepare home-made pickles.

5. 2 Determination of physical characteristics of mango fruits

The physical characteristics of selected mangoes were determined at maturity state where mangoes are suitable for preparation of pickle. For determination of physical characteristics, fifty mango fruits were randomly selected from a lot to make uniform sample. The observations were recorded on the following physical parameters required for engineering designs of mango dicing machine.

The importance of these dimensions is in determining the size of blade, height of the blade particularly spacing blades and number of cubes expected from an average fruit. These dimensions are useful in estimating the size of cutting platform and other machine components too. The major axis has been found to be useful by indicating the natural rest position of the fruit and hence in the application of compressive force to induce mechanical rupture. As far as mango is concerned this dimension will be useful in applying shearing force during cutting process.

5. 2. 1 Fruit length

The length of the mango fruits from stalk base to the apex of the fruit was considered as length and was determined with the help of vernier caliper. The randomly selected mango fruits were used for study.

5. 2. 2 Fruit breadth

The maximum linear distance between two shoulders of the fruit was considered as the breadth and was determined with the help of vernier caliper of the same fruits whose length was measured earlier.

5. 2. 3 Fruit thickness

The maximum linear distance between two cheeks of the fruit was considered as the thickness. It was determined with the help of vernier caliper of the same fruits whose length and breadth was measured earlier. The average thickness of each mango was recorded.

5. 2. 4 Weight of the fruit

Individual fruit was weighed on digital electronic top pan balance of 200g capacity having least count of 1 mg. The mangoes used for weight measurements were the same mangoes those obtained their length, breadth and thickness.

5. 3 Performance evaluation

The mango dicing machine was tested with two varieties which are generally used for pickle making viz., desikeri-1 variety and desikeri-2 variety. The mango was cut in to pieces in such a way that the hard embryo cover is present in every mango pieces for ensuring that the mango pieces shape to be kept intact. Due to the presence of the hard embryo cover, shape is maintained till its consumption. Based on this factor, the performance of the machine was evaluated using the following methodology.

- Capacity of the mango dicing machine
- Breakage percentage
- Dicing efficiency
- Loss percentage
- Size of diced mangos (Final Product)

The first, known quantity (2, 5 and 10 kg) of mango was weighted using electronic weighing balance having capacity of 5kg with least count 0.1g. Then, the mango was kept in a feeding hopper. After that, dicing operation was started. The cutting of mangoes in to cubes was achieved in two stages. First, the raw mangoes were fed in to the mango dicing machine and cut into slices along with the kernel. Then, the sliced mango pieces were re-fed to the machine keeping cut surface down and cut in to cubes. Likewise, the mango dicing machine testing was replicated thrice with two, five and ten kilograms of mangoes. The time taken for each operation was recorded by a stop watch by seconds. Almost all the kernels were separated due to impact of the cut cubes in the outlet. The kernels were separated and weight was recorded by using same weighing balance. The sound diced mangos, damaged diced mangos and stones were separated and weighed by using same electronic weighing balance. Later, the sizes of the diced mango were measured by using vernier caliper. The diced mangos were randomly selected for size measurement.

5. 3. 1. Time taken for dicing mango

The time taken for cutting a batch of 2, 5 and 10 kg mangoes were measured by using digital stop watch. The three replicates were used from each batch.

5. 3. 2. Capacity of the mango dicing machine

A known quantity of mango was fed in to the mango dicing machine at a time. The diced mangos were collected at the outlet. The sound diced mangos, stones and damaged diced mangos were separated and weighed by using electronic weighing balance. The capacity of the mango dicing machine was calculated using following equation (Nehru and Kumaran, 2004).

$$C_c = (W_m \times 60 \times 60)/t \qquad \text{... (5.1)}$$

Where,

C_c	-	Capacity of the mango dicing machine, kg per hour.
W_m	-	Weight of the mangoes fed into mango dicing machine, kg.
t	-	Time taken, second

5. 3. 3. Breakage percentage/Percent damage

The breakage percentage or percent damage of the mango dicing machine was calculated using following equation (Simonyan *et al*, 2003).

$$PD = \left(W_d / W_c \right) \times 100 \qquad \text{... (5.2)}$$

Where,

PD	-	Percent damage
W_d	-	Weight of the damaged diced mangos, kg
W_c	-	Weight of the all diced mangos, kg

5. 3. 4. Dicing efficiency

The dicing efficiency of the mango dicing machine was calculated using following equation (Owolarafe *et al*, 2007).

$$\eta_d = \left(W_{sc} / W_m \right) \times 100$$

... (5.3)

Where,

η_d	-	Dicing efficiency, percent
W_{sc}	-	Weight of the sound diced mangos, kg
W_m	-	Weight of the mangoes fed into mango dicing machine, kg.

5. 3. 5. Percentage of losses

The percentage of losses during operation was calculated by taking in to consideration loss and weight of the mangoes fed into mango dicing machine.

$$Ls = \left(W_{loss} / W_m \right) \times 100$$

... (5.4)

Where,

Ls	-	Loss, percent

W_{loss} - Weight of the mangos fed into mango dicing machine - Weight of the all

diced mangos ($W_m – W_c$), kg

W_m - Weight of the mangos fed into mango dicing machine, kg.

5. 3. 6. Size of diced mangos

The sizes of diced mangos were measured by using vernier caliper having the least count of 0.1mm. For determination of sizes of diced mangos, fifty diced mangos were randomly selected from a lot to make uniform sample.

5. 4 Experimental procedure

The manually operated mango dicing machine was operated and the data were recorded. The performance of mango dicing machine was evaluated on the basis of dicing capacity, dicing efficiency, breakage percentage and size of diced mangos.

5. 4. 1 Independent variable

1. Varieties of mango – 2
2. Operation Method - Manual

5. 4. 2 Dependent variable

1. Dimensions of mangos-length x breadth x thickness (mm)
2. Weight of mangos (g)
3. Capacity of Machine (kg/h)
4. Breakage Percentage (%)
5. Dicing efficiency (%)
6. Percentage of losses (%)
7. Size of diced mangos -length x breath x thickness (mm)

5. 5 Details of the laboratory set up for testing

The laboratory set up consists of following accessories, equipments and instruments for conducting laboratory tests of the manually operated mango dicing machine.

1. Manually operated mango dicing machine
2. Stop watch for time measurements
3. Electronic weighing balances
4. Venire caliper

5. 5. 1 Manually operated mango dicing machine

The manually operated mango dicing machine (Plate 4.1) was fabricated by using commercially available material such as mild steel and stainless steel. All the parts that are in contact with food such as cutter blades and two hoppers were fabricated using stainless steel; the cutting platform was constructed using wood. The pins were made of wrought iron and other parts of the machine were fabricated and machined by using mild steel with different carbon content.

5. 5. 2 Stop watch for time measurements

The stop watch was used to measure the time required in making mango cubes for evaluating the actual capacity of the machine. Model number KK-1045, sport timer was used as stopwatch. The least count of the stopwatch is 0.01 seconds.

5. 5. 3 Electronic weighting balances

A digital electronic top pan balance of 310g capacity having least count of 1 mg was used for measuring the weight of single mango fruits. The model number is PRECISA 310 M. A separate electronic weighing balance was used for weighing of the mango and diced mango cubes (whole sample) for evaluating capacity, dicing efficiency and breakage percentage. The maximum capacity and the least count of the balance were of 5kg and 0.1g respectively. The model number is MASTEC weigh scale, MTT 101.

5. 5. 4 Vernier caliper for size measurements

Vernire caliper was used to measure the length, width and thickness of mangoes which were used for experiments. The same vernier caliper was employed for obtaining the size measurements of diced mangos. The model number of the vernier caliper is VOLVOX NC 3P 23 and least count is 0.1mm.

CHAPTER VI

RESULTS AND DISCUSSION

The manually operated mango dicing machine was designed and developed to produce the mango cubes which are used in preparation of pickles. All the design and fabrication work was done by taking into consideration hygienic design practice. The machine was evaluated for performance on the basis of capacity, dicing efficiency, breakage percentage and size of the final product. The results of the experiments and testing carried out are discussed in this chapter. The results on physical properties of selected mangos, performance evaluation of manually operated mango dicing machine are discussed in the following subheadings.

6. 1 Physical characteristics of selected variety of mango fruits

The summary of the results of the determined physical characteristics is shown in Table 6.1**.** The data were analyzed and the results are discussed below.

Table 6.1: Some parameters of selected mango fruits

Variables	Minimum value	Maximum value	Mean value
Desikeri-1 variety			
Length,(mm)	58.8	75.4	67.3±4.6
Breadth, (mm)	51.2	63.7	56.7±3.5
Thickness, (mm)	45.8	56.4	49.9±2.6
Weight, (g)	80.065	147.766	108.031±17.213
Desikeri-2 variety			
Length, (mm)	73.3	107.6	89.8± 7.8
Breadth, (mm)	58.9	74.1	64.8± 3.3
Thickness, (mm)	52.3	81.6	58.7± 4.3
Weight, (mm)	136.612	255.074	186.083± 28.343

It is inferred from Table 6.1 that the maximum fruit length of desikeri-1 variety and desikeri-2 variety were 75.4 mm and 107.6 mm respectively whereas the minimum length of mango fruit of were 58.8mm and 73.3 mm respectively. The mean length of mango fruit of desikeri-1 and desikeri-2 varieties were 67.3±4.6 mm and 89.8±7.8 mm respectively.

Similarly, mean breadth in desikeri-1 variety and desikeri-2 variety was 56.7±3.5 mm, 64.8±3.3 mm respectively. The minimum and maximum breadths of desikeri-1 variety were 51.2 mm and 63.7 mm respectively while for desikeri-2 variety, it was 58.9 mm and 74.1 mm respectively. The thickness indicated that the minimum and maximum thickness of 45.8 mm and 56.4 mm was recorded in desikeri-1 variety and followed by 52.3 mm and 81.6 mm was recorded in desikeri-2 variety. The mean value of the thickness of two varieties shows that desikeri-1 variety has 49.9± 2.6 mm and desikeri-2 variety has 58.7±4.3 mm. Respective data related to fruit length. Breadth and thickness were presented in Appendix B

It could also be seen that fruit weight of the desikeri-1 variety varies from 80.065 g to 147.766 g and 136.612 g to 255.074 g for desikeri-2 variety. The average weight of mango fruit was observed as desikeri-1 variety as 108.031±17.213 g and desikeri-2 variety as 186.083±28.343 g respectively. Respective data related to weight was also presented in Appendix B

6. 2 Development of mango dicing machine

A manually operated mango dicing machine was designed, developed and fabricated successfully as per the hygienic conditions incurred in food process equipment design. All the design calculations were made according to the standard procedures given machine design books. The material selection for machine components was also made by considering process, durability and cost of the material. The components of mango dicer were first drawn as 3D object using ProENGINEER software according to the dimension and then the components were assembled as a machine. The required detailed engineering drawings were prepared using AutoCAD software. The developed mango dicer was presented in Plate 4.2.

6. 3 Performance evaluation of developed mango dicing machine

The machine testing was replicated thrice with 2, 5 and 10 kg of mango fruits, respectively and its performance was evaluated on the basis of capacity of the machine, dicing efficiency of the machine, percentage of broken, percentage of loss during operation and size of diced mangos. The machine was loaded with mango one by one and then cutter was operated by pressing foot plate. It was observed that faster the speed of operations more the rate of dicing. The speed of operation depends on operator’s skill. The mango was retaining on the cutting platform and cutting blades were pressed against mango fruit. As there is no need to hold mango against cutting platform, Therefore, there is no risk for operator to meet any accident while operating the machine.

Table 6. 2: Performance results of the manually operated mango dicing machine

Variety	Sample size	Capacity, (kg/h)	Broken percentage, (%)	Dicing efficiency, (%)	Loss, (%)
1	2 kg	28.31	2.23	86.59	1.02
	5 kg	24.77	1.49	86.42	0.50
	10 kg	27.22	1.61	86.22	0.92
2	2 kg	25.04	2.25	86.72	0.96
	5 kg	24.15	1.40	88.91	0.40
	10 kg	26.68	1.46	87.72	0.23

6. 3. 1 Capacity of manually operated mango dicing machine

The capacity of the mango dicing machine was expressed as operating capacity. The operating capacity was determined by feeding raw mangoes in to machine per unit time and reported in Appendix C. The results of the experiments which were determined by using Eq.5.1 are shown in Table 6.2. The highest and lowest capacity was noticed as 29.64 and 23.73 kg per hour respectively for the desikeri-1 variety and that of for desikeri-2 variety was observed as 28.33 and 22.61 kg per hour respectively. The capacity of the mango dicing machine varied with variety of mango and ability of operator as this machine is manually operated. According to the experiments, the capacity was in the range of 22.61 kg/h to 29.64 kg/h. Once the operator gets practiced with the system, capacity may be increased. Sorting of mango will also increase the capacity as it is easy to pick and place mango with less adjustments.

6. 3. 2 Breakage percentage/Percent damage

Experiments were also carried work out breakage percentage of both mango varieties. Those diced mangos crushed due to impact force or small pieces either mango or mango stone were considered as breakage. However, those small pieces can also be added to process in pickling. Breakage percentage was determined by using Eq.5.2 and it was observed that highest and lowest breakage percentage of desikeri-1 variety was as 2.78 and 1.23% respectively and those of desikeri-2 variety were 2.95 and 1.12 % respectively. The breakage percentage mainly depends on maturity of mango, correct placement of mango in cutting platform, sharpness of the cutting blades. The respective data have been presented in Appendix- C.

6. 3. 3 Dicing efficiency of the machine

The required data for working out the dicing efficiency of the machine was collected and dicing efficiency was calculated according to the process given in section 5.2.4 by using Eq.5.3. The highest dicing efficiency of desikeri-1 variety was observed as 87.29 percent and lowest dicing efficiency of same variety was calculated as 85.62 percent as shown Table 6.2. In case of desikeri-2 variety, the highest and lowest dicing efficiencies were obtained 89.62 and 86.10 percent respectively. Weight of mango stones have not been taken in to consideration at the time of manipulating dicing efficiencies. If the weight of mango stones were considered, then dicing efficiency will be increased because of low broken percentage and losses. The capacity of the machine can be increased considerably by grading the mango fruits before feeding into the machine.

6. 3. 4 Percentage of losses

There may be small losses occurred while operating the machine. The data required to find out percent losses, were manipulated using data collected during the testing and reported in Appendix C. Average losses of mangoes were determined by using Eq.5.4 and that of desikeri-1variety and desikeri-2 variety were observed as 0.81% and 0.57 % respectively. The average losses of manually operated mango dicing machine were obtained as 0.69%. These losses occurred mainly due to mango juice and stones. While dicing, some juice got removed from mangoes and stones were got crushed and thrown as small pieces out of discharging hopper.

6. 3. 5 Sizes of diced mangos

The size of diced mangos were also measured as detailed in section 5.3.6 and presented in Appendix D. The results of the physical parameters of diced mangos are shown in Table 6.3. The data were analyzed and the results are discussed below.

The spatial dimensions viz., length, width and thickness of diced mangos were determined. The data revealed that the desikeri-2 variety fruits held maximum length 50.8 mm, width 39.6 mm and thickness as 21.6 mm followed by the fruits in the desikeri-1 variety held maximum length 44.2 mm, width 39.2 mm and thickness as 19.5 mm. It was recorded that mean length, width and thickness of desikeri-1 variety was 36.71±3.3 mm, 33.34±3.0 mm and 14.86±2.1 mm respectively and that of desikeri-2 variety was 41.91±4.7 mm, 28.53±8.2

mm and 16.79±2.4 mm respectively. Mangoes and diced mangos are shown in Plate no. 6.1 and Plate no. 6.2 respectively.

Table 6. 3: Some parameters of selected diced mangos

Variables	Minimum Value	Maximum value	Mean value
Variety-1			
Length, (mm)	27.4	44.2	36.71± 3.3
Width, (mm)	25.8	39.2	33.34±3.0
Thickness, (mm)	9.6	19.5	14.86±2.1
Variety-2			
Length, (mm)	33.6	50.8	41.91±4.7
Width, (mm)	13.8	39.6	28.53±8.2
Thickness, (mm)	13.1	21.6	16.79±2.4

Plate 6.1: Some mangos used in dicing and diced mangos by using developed manually operated mango dicing machine.

Plate 6.2: Some diced mangos cut by using developed manually operated mango dicing machine

CHAPTER VII

SUMMARY AND CONCLUSION

The mango (*Mangifera indica L*) is one of the most important tropical and subtropical fruit of the world and is popular both in the fresh and the processed form. Mangoes retain a special significance in the culture of South Asia where they have been cultivated for millennia. It has been the national fruit of India itself. It is grown in almost all the states. India shares about 56% of total mango production in the world. Its production has been increasing since independence, contributing 39.5% of the total fruit production of India. Mango is perhaps one of the most important fruits of the world which can be utilized by the processing industry during the different stages of its growth, development, maturity and ripening. The products prepared both from ripe and green mangoes are highly popular in India and abroad. India dominated the world trade of processed mango products; even though hardly 1% of the total mango production in India is processed. Mango is one of the important fruit particularly used for preparing pickle. Pickles of various kinds are known throughout India and many part of the world. There is wide and growing export market for these products which are associated with the well known Indian condiments. Pickles are good appetizers and add to the palatability of a meal. There is considerable demand in other countries for mango pickles apart from massive local market.

Mango pickle processing is one of the traditional activities in India. Products like pickle, chutney, murabba are consumed throughout the year. Dicing is a most important operation in mango pickle making process. Raw mango fruit needs to be diced before it can be further processed to prepare mango pickle. This operation is tedious especially when a large quantity of the fruit has to be processed as a pickle in cottage and small scale industry; hence there is need for machine to perform it. At present, there are different types of power driven, semi and fully automated machines in the market. In cottage level and small scale pickle production industry, adaptation of these machines is not economically viable and feasible. There should be machinery with appropriate technology, less power consumption and adaptable prices suitable for such industries. Especially, such industries at off grid locations or remote areas, requires manually operated machines such as hand held, hand operated or pedal operated etc.

Therefore, the scope of this project is to design, development and evaluation of manually operated mango dicing machine with a view to introducing for cottage level and small scale pickle industry. This will be ultimately beneficial to the growers and producers to sell their mango and mango based food product in international market or in domestic market to fetch higher prices of produce. Hence, a project was taken to develop a small manually operated mango dicing machine to perform the operation.

As a first step in the design of this machine, the some physical parameters of the fruit need to be known. This study undertook the determination of the relevant physical parameters of fruits namely length, breadth, thickness and weight. This was undertaken as a first step in the development of an appropriate technology for mango processing with a view to introduce cottage level and small scale pickle industry in rural areas in India. The machine was designed and fabricated from locally available materials as per the hygienic design. Then the mango dicer was evaluated for its performance with regards to its working capacity, dicing efficiency, broken percentage, percentage of losses and size of diced mango.

The specific conclusions which have emerged from the present investigation are summarized below.

1. Average length, breadth and thickness of mangos in desikeri-1 variety are 67.3 (4.6), 56.7 (3.5) and 49.9 (2.6) in millimeter respectively and that of desikeri-2 variety are 89.8 (7.8), 64.8 (3.3) and 58.7 (4.3) in millimeters respectively.
2. Average weight of mango desikeri-1 variety and desikeri-2 variety are 108.031 (17.213) and 186.083 (28.343) in grams respectively.
3. The mango dicer has an average capacity of 25.75 kg/h.
4. Dicing efficiency of the machine is 87.10 %.
5. The average broken percentage of the machine is 1.74%.
6. The percentage of losses is 0.69 %.
7. The average length, width and thickness of diced mangos are 36.71 (3.3), 33.34 (3.0) and 14.86 (2.1) in millimeters for desikeri-1 variety and 41.91 (4.7), 28.53 (8.2) and 16.79 (2.4) in millimeter for desikeri-2 variety respectively.
8. The machine is easy to operate and there is no need any skill or skill person.
9. The manually operated mango dicer was designed, developed and fabricated to cut mango in to eight or twelve pieces within two strokes, therefore this will reduced more number of strokes used in traditional mango dicing machine.

10. The effective capacity of the mango dicer could be changed according to the operator's ability.
11. If mangos are sorted before dicing, we can have nearly similar size of diced mango.
12. The mango dicer which was designed and fabricated from different cheap and locally available materials are simple in design and therefore it can be manufactured locally.
13. The mango dicer is portable in size; hence it can be moved one place to another if necessary.
14. There is no special operating cost as this mango dicer is manually operated.
15. Repair and maintenance requirements are minimum as there is no more tearing and wearing parts.
16. The mango dicer can be used for dicing different fruits and vegetables by changing the cutter design.

Hence this machine is very useful for pickle industries having 200-250 kg per day especially at off grid locations.

SUGGESTIONS FOR FUTURE WORK

Based on the study conducted on the design, development and fabrication of manually operated mango dicing machine, following suggestions are put forward for the further research on this subject.

1. As the mango dicer is operated by manually, there should be ergonomic evaluation of this machine. According to that, the machine can be modified to reduce human drudgery before giving to target group.

2. The cutting platform can be covered with Teflon sheet for maintaining better hygienic condition.

3. This study may be further extended to modify this machine for other fruit and vegetable slicing and dicing purposes in other fruit and vegetable processing industries.

4. The machine can be developed to have mango feeding system towards cutter blade so that it will be reduced the risk involved during feeding.

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