EFFECT OF ELECTRON BEAM IRRADIATION ON PROXIMATE COMPOSITION OF MIXED FRUIT JAM AND JELLY PRODUCTS

3.1 INTRODUCTION

Jams, jellies, fruit bars and preserves are the most important fruit products manufactured in industries based on the high solids high acid principle and prepared from a combination of two or more fruits and they possess substantial nutritive value (Vidhya and Anandhi Narain, 2011). The knowledge of qualitative and quantitative chemical composition of product is of prime importance for enhancing the quality of products at various stages of production i.e. preparation, processing, packing, transportation, storage, trade and marketing.

Proximate analysis of food products were intended to establish the nutritional value of the products. The proximate properties of foods are ultimately determine their perceived quality, nutritional, sensorial attributes, shelf life and behavior of the food product during production, storage and consumption. There are usually a number of different analytical techniques available to determine the proximate composition of food material (Mazumdar and Majumder, 2003). In the present study, mixed fruit jam and jelly products were exposed to electron beam irradiation at doses of 2.5, 5, 7.5 and 10 kGy. The proximate values of control and irradiated samples were analyzed immediately after irradiation and at monthly intervals over a period of storage to evaluate the effect of electron beam irradiation on jam and jelly products. In this study proximate parameters of jam and jelly products including pH, electrical conductivity, acidity, moisture, total solids, ash, pectin, crude fibre, total and reducing sugars, total protein and lipids, calorific value, UV-Visible spectrum analysis and microscopic structure analysis were determined in irradiated and control samples by using standard food analytical methods (AOAC, 1984).
3.2 MATERIALS AND METHODS

3.2.1 Preparation of Fruit Products

The chosen fruit based products, mixed fruit jam and jellies were prepared without any chemical preservatives to determine the preservation efficiency of electron beam irradiation in jam and jelly products. It was prepared at Community Food and Nutrition Extension Unit, Madurai, Tamil Nadu. Jam and jellies can be prepared either from an individual fruit or mixed fruits. The important constituents in the preparation of jams and jellies are pectin, sugar and acids in correct proportion for proper gel formation. The fruits were selected for jam and jelly preparation as fresh, healthy, matured and firmly ripped wherein the pectin and acid contents are good and provide better nutrients.

3.2.1.1 Mixed Fruit Jam

Jam is prepared by boiling the fruit with sufficient quantity of sugar to reasonably thick consistency. The fruits such as papaya, banana, mango, apple, pineapple and guava were procured with the optimum stage of maturity for jam production from local wholesale market at Tirunelveli, Tamil Nadu. The fruits were washed in running tap water, peeled and cut into small pieces. For pulping, the fruits were passed through a sieve and ground into suitable consistency with using a mixer. The pulps were taken in equal proportions from various fruits used in this study; it has mixed with sugar and boiled in stainless steel kettle till the end point was reached. The end point can be determined by looking bubbles at the sides of the vessel while heating and plate method was also used for confirmation. In plate method, a drop of boiling mixture was taken on a stainless steel plate, cool and tilt the plate when the mixture moved as a single mass, if jam is ready to set. Finally the acidity of jam was adjusted with addition of lemon juice (source of acid) in the finished product (Singh et al., 2009; FPO, 1955). After preparation, the jam was placed in sterile glass jars and it cooled down to room temperature. The ingredients used for jam making was given in Table 3.1.
Table 3.1 Materials required for jam preparation

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit pulps</td>
<td>1 kg</td>
</tr>
<tr>
<td>Sugar</td>
<td>800 gm</td>
</tr>
<tr>
<td>Acids (Lemon juice)</td>
<td>Sufficient quantity</td>
</tr>
<tr>
<td>Red raspberry powder</td>
<td>a pinch</td>
</tr>
<tr>
<td>Pineapple essence</td>
<td>½ tsp</td>
</tr>
</tbody>
</table>

3.2.1.2 Mixed Fruit Jelly

Jelly can be prepared by boiling pectin rich fruit extract with sufficient quantity of sugar and acids which it will form a clear gel. The pectin rich fruits such as guava, apple and papaya were obtained from local wholesale market with the optimum stage of maturity for jelly preparation. The fresh sound fruits were selected and washed with running tab water, cut into thin circular pieces and it was boiled in water for extraction and meshed up slightly with wooden ladle. After, it was filtered through a strainer. The strained fruit extract (free from pulp) was collected and the amount of pectin present in the extract was determined by using clotting method for determining the quantity of pectin, sugar and acid required for jelly preparation. In clotting method, a drop of strained fruit extract is mixed with pinch of sugar and acids. Then observe the clot formation efficiency which is mainly based on the amount of pectin present in the extract. For preparation of jelly, the strained fruit extract was mixed with sugar, acid and boiled in stainless steel kettle till the end point was reached. The end point was determined by sheet method, using wooden ladle to pick up the boiled mixture, cool and drop it slowly. If jelly is ready to set it will fall in the form of sheet. After preparation, the jelly was poured in sterile glass jars and it cooled down to room temperature (FPO, 1955). The ingredients used for jelly preparation was given in Table 3.2.
Table 3.2 Materials required for jelly preparation

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strained fruit extract</td>
<td>1 kg</td>
</tr>
<tr>
<td>Sugar</td>
<td>750 gm</td>
</tr>
<tr>
<td>Acids (Lemon juice)</td>
<td>Sufficient quantity</td>
</tr>
<tr>
<td>Pineapple essence</td>
<td>½ tsp</td>
</tr>
</tbody>
</table>

3.2.2 Electron Beam Irradiation

The freshly prepared mixed fruit jam and jelly products were packed separately in polypropylene bags (6×6 cm). Each bag was packed with approximately 75 – 100 g of the product. The packed samples were exposed to Electron beam radiation at Microtron Centre, Mangalore University, Mangalagangothri, Karnataka (Plate 3.1). The conditions of the Microtron accelerator were maintained as: Dose rate, 3kGy min⁻¹; Beam energy, 8MeV; Electron pulse current, 15mA; Beam Uniformity, 8×8 cm. The samples were exposed to double side irradiation for uniformity in dose delivery. The dose levels applied to jam and jelly were 2.5, 5.0, 7.5 and 10 kGy. The absorbed dose was measured by using chemical dosimetry. All the irradiated samples were stored at room temperature for subsequent analysis and it was shown in the Plate 3.2 and Plate 3.3. The quality parameters were analyzed at monthly intervals over a period of storage (Ramathilaga and Murugesan, 2011).

3.2.2.1 Preparation of Control Samples

Jams and jellies are sugar containing food products which are possible to getting microbial spoilage immediately after preparation. The shelf life of traditional jam and jelly products have minimum storage period when without use of any preservation method. The commercially available jam and jelly products were routinely preserved with addition of chemical preservatives which have relatively long storage period than traditional products. Hence, the control jam and jelly samples were prepared based on the method stated above but with added chemical preservative (0.1% of Sodium benzoate) and packed separately in polypropylene bags. These packed
samples without irradiation were used as control sample in the entire study. The control samples used in this study are also defined as non-irradiated sample and 0 kGy. It was stored at room temperature and the quality parameters were analyzed at monthly intervals over a period of storage (Plate 3.2 and Plate 3.3).

**Plate 3.1 The view of Microtron Electron Beam Irradiator Facility used in the study at Microtron Centre, Mangalore University, Karnataka**

3.2.3 pH

3.2.3.1 Principle

The effective acidity of sample is determined by taking a direct reading on a pH meter. It signifies the hydrogen ion concentration of the food. It is a good measure of the intensity of acidity and alkalinity of a sample. As the pH is lowered the food becomes more acid (Mazumdar and Majumder, 2003).

3.2.3.2 Materials Required

Laboratory glassware, pH meter, Blotting paper and Distilled water
Plate 3.2 The packages of electron beam irradiated and control (0 kGy) mixed fruit jam products

Plate 3.3 The packages of electron beam irradiated and control (0 kGy) mixed fruit jelly products
3.2.3.3 Procedure

- The pH meter was standardized with a pH 4.0 buffer solution.
- Five gram of food sample was thoroughly mixed in 100 ml of distilled water
- The sample was stirred well and then allowed to settle down
- The electrode was immersed carefully into the suspension
- The pH of the samples was recorded digitally

3.2.4 Electrical Conductivity

3.2.4.1 Principle

Conductivity (EC) is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, valence and temperature of measurement. The conductivity indicates dissolved inorganic salts. The unit of conductivity is reported as millisiemens per meter (mS/m) (Ramathilaga and Murugesan, 2011).

3.2.4.2 Materials Required

Distilled water, Thermometer, Blotting paper Conductivity meter, 0.1N Potassium chloride, Calcium sulphate solution

3.2.4.3 Procedure

- The instrument was switched on and leave it undisturbed for about few minutes
- The accuracy of the instrument was checked by using a solution of known EC such as saturated calcium sulphate solution and 0.1N potassium chloride
- Five gram of sample was dissolved in 100ml of distilled water
- It was stirred well and then allowed to settle
- Before analysis the temperature of the solution was corrected to 25°C
• The electrode was washed with double distilled water and it was immersed into the suspension

• The electrical conductivity of suspension was measured digitally

### 3.2.5 Total Titrable Acidity

#### 3.2.5.1 Principle

The titrable acidity is directly related to the concentration of organic acids present in the sample. The total acidity of a sample could be determined by titrating with known amount of aqueous extract of a sample against an alkali solution of known normality. It is expressed as equivalence of any organic acid, e.g., citric acid, malic acid (Mazumdar and Majumder, 2003).

#### 3.2.5.2 Materials Required

Laboratory glassware, Phenolphthalein indicator, 0.1N NaOH, Burette and Distilled water.

#### 3.2.5.3 Procedure

• Five gram of the sample was taken and extracted with known volume of distilled water by crushing

• Filtered the extract and it was made upto with again a known volume of distilled water

• A known volume of aliquot was taken in a conical flask

• Few drops of Phenolphthalein solution was added to this and shaken well

• The sample was titrated against 0.1N NaOH solution

• The appearance of pink colour and its persistence for few seconds as end point of this titration
3.2.5.4 Calculation

1 ml of 0.1N NaOH solution can neutralize 0.064g of Citric acid. Therefore the percentage of total titrable acidity present in the sample as equivalence of Citric acid

\[
\frac{\text{Burette reading of sample} \times 0.064 \times \text{Volume made with Distilled water}}{\text{Weight of sample} \times \text{Volume of aliquot taken for estimation}} \times 100
\]

3.2.6 Percentage of Moisture and Total Solids

3.2.6.1 Principle

The moisture and total solids contents were determined by measuring the mass of a food before and after the water is removed by evaporation methods it is necessary to remove all of the water molecules that were originally present in the food, without changing the mass of the food matrix and drying the sample in the oven at a temperature not exceeding 70°C until the sample reaches to a constant mass (El-Sohaimy and Hafez, 2010).

3.2.6.2 Materials Required

Evaporating dish and Hot air oven

3.2.6.3 Procedure

- Five gram of the sample was taken in pre-weighed evaporating dish
- It was dried at 70°C and drying was continued upto the constant weight was achieved when weighing at every two hours of intervals
- It was cooled in a desiccators and final weight has been taken
3.2.6.4 Calculation

\[
\text{Moisture (\%)} = \frac{\text{Initial weight of sample} - \text{Dry weight of sample}}{\text{Initial weight of sample}} \times 100
\]

\[
\text{Total Solids (\%)} = \frac{\text{Dry weight of sample}}{\text{Initial weight of sample}} \times 100
\]

3.2.7 Total Ash

3.2.7.1 Principle

The ash content of food products represents the inorganic residue remaining after destruction of organic matter in food sample (such as protein, carbohydrates and fat) by ignited at 525°C into a white ash. The ash value is the measure of amount of inorganic minerals present in food products (Mazumdar and Majumder, 2003).

3.2.7.2 Materials Required

Silica dish and Muffle Furnace

3.2.7.3 Procedure

- Five gram of dried sample was taken in pre-weighed silica dish kept in Muffle furnace at 525°C
- It was cooled in desiccator and weighed
- Percentage of ash was calculated by following formula

3.2.7.4 Calculation

\[
\text{Ash (\%)} = \frac{\text{Weight of ash after ignition}}{\text{Weight of dried sample used}} \times 100
\]
3.2.8. Total Pectic Substances

3.2.8.1 Principle

Pectic substances are polyuronides and are composed of mainly 1, 4 linked α-D-galactouronic acid, or its methyl ester with neutral sugars, i.e., galactose and arabinose as the side chains. After the extraction of pectin, it is saponified with alkali and precipitated as calcium pectate. After washing the precipitate is dried and weighed (Mazumdar and Majumder, 2003).

3.2.8.2 Materials Required

HCl (0.05N), 1N NaOH, 1N Acetic acid, 1N Calcium chloride and Whatman No.4 Filter paper

3.2.8.3 Procedure

- Five gram of sample was taken and boiled with known volume of 0.05N HCl at a temperature of 80°C for 2 hrs for extraction of pectic substances.
- After extraction, the mixture was allowed to cool. It was then filtered by Whatman No.4 filter paper. The extraction was repeated for upto maximum recovery of the pectin.
- The filtrate was made upto 50 ml with distilled water which was neutralized and made slightly alkaline with 1N NaOH solution. The solution was allowed to stand overnight.
- Then 10 ml of 1N Acetic acid solution was added to it. After 5 min, 5 ml of 1N Calcium chloride solution was mixed with constant stirring. It was kept left for an hour to precipitate as a calcium pectate.
The solution was then filtered through pre-weighed filter paper (Whatman No.4). The precipitate was washed repeatedly with boiling water to eliminate chloride ions present in the precipitate.

The filter paper containing calcium pectate was dried at 50°C and weighed.

3.2.8.4 Calculation

Percentage of pectic substances (as calcium pectate) present in the sample

\[
\text{Percentage} = \frac{\text{Weight of Calcium pectate} \times \text{Volume made with Distilled water}}{\text{Volume of aliquot taken for estimation} \times \text{Weight of sample}} \times 100
\]

3.2.9 Crude Fibres

3.2.9.1 Principle

The crude fibre is considered as the material left after making digestion of the tissue. It is mainly composed of cellulose, lignin and some minerals. Cellulose and lignin in plant tissues are digested by reacting with acid and alkali. On filtration, the residue is obtained and weighed after drying. It is thenashed and reweighed. From the ash weight, the amount of fibre present in the sample is determined (Mazumdar and Majumder, 2003).

3.2.9.2 Materials Required

Laboratory glasswares, Ether - Ethanol mixture, Sulphuric acid (0.255N), Sodium hydroxide (0.313N), Ethanol (70%)

3.2.9.3 Procedure

- Five gram of sample was taken and extracted with ether-ethanol mixture and the sample was heated (less than 50°C) to remove the lipid substances present.
- The residue was boiled with 0.255N Sulphuric acid for 30minutes.
- The residue was cooled and filtered and washed in boiling water. The washed material was again boiled with the 0.313N Sodium hydroxide solvent for 30 minutes.
- The residue was washed with water and ethanol
- The residue was taken in pre-weighed crucible and dried at 100°C for 2 hrs. The crucible containing residue was cooled and reweighed
- Then crucible containing residue was ignited at 600°C for few minutes in a muffle furnace and it was cooled and reweighed

3.2.9.4 Calculation

The amount of fibre present in the sample is calculated by the following formula

\[
\text{Percentage of fibre} = \frac{(c-b)-(d-b)}{a} \times 100
\]

Where,
- a - Weight of sample; b - Weight of crucible;
- c - Initial weight of crucible containing tissue sample before ignition
- d - Final weight of crucible containing ash after ignition

3.2.10 Total Sugar

3.2.10.1 Principle

Carbohydrates are first hydrolyzed into simple sugars using dilute hydrochloric acid. In hot acidic medium glucose is dehydrated to hydroxymethyl furfural. It forms a green coloured solution on reaction with anthrone. This intensity of the colour appeared is then measured colorimetrically at 630 nm to determine the amount of carbohydrate present in the sample (AOAC, 1984).
3.2.10.2 Materials Required

2.5N of HCl, Sodium carbonate, Anthrone, Sulfuric acid, Glucose

3.2.10.3 Procedure

- 100 mg of sample was taken in a boiling tube and it was hydrolyzed by kept in boiling water bath for 3 hrs with 5 ml of 2.5 N of HCl and then cool to room temperature.
- It was neutralized with solid sodium carbonate until the effervescence ceases.
- Then make up the volume of the sample to 100 ml with distilled water and it was centrifuged at 4000 rpm for 10 min.
- 0.2 ml of supernatant was taken for analysis and made up the volume to 1 ml with distilled water.
- 4 ml of anthrone reagent was added to the solution and heated for 8 min in a boiling water bath.
- The sample was allowed to cool and the green to dark green colour was appears and read at 630 nm in spectrophotometer.
- The amount of total sugars present in the sample was calculated from the standard graph of glucose.

3.2.11 Reducing Sugar

3.2.11.1 Principle

Sugars with reducing property (due to the presence of a potential aldehyde or keto group) are called reducing sugars. Reducing sugars have the property to reduce many of the reagents. The reagent 3, 5-dinitrosalicylic acid (DNS) in alkaline solution is reduced to 3 amino 5 nitro salicylic acid and to form orange-red colour. The intensity of the colour appeared is then measured colorimetrically at 510 nm to determine the amount of reducing sugars present in the sample (AOAC, 1984).
3.2.11.2 Materials Required

Laboratory glassware, Dinitrosalicylic acid reagent, 40% Rochelle salt solution and Distilled water.

3.2.11.3 Procedure

- 100 mg of sample was taken and the sugars are extracted twice with hot 80% ethanol. The supernatant was collected and kept in water bath at 80°C for evaporation.
- 10 ml water was added and the sugars are dissolved. 3 ml of extract was taken in a test tube.
- DNS reagent (3 ml) was added and it was heated by kept in boiling water bath for 5 min.
- 1 ml of 40% Rochelle salt solution was added at when contents of the tube are still warm.
- The tubes were cooled and the intensity of dark red colour was read at 510 nm.
- The amount of reducing sugars present in the sample was calculated from the standard graph of Glucose.

3.2.12 Total Protein

3.2.12.1 Principle

Protein reacts with Folin and Ciocalteu’s phenol reagent and gives a blue colored complex. The colouration is formed due to reaction of alkaline copper of the reagent with protein and the reduction of phospho-molybdate by the amino acids, tyrosine and tryptophan, present in the protein molecules. The intensity of the developed coloration of the protein solution depends on the amount of these aromatic amino acids present and hence, it varies for different proteins (Lowry et al., 1951).
3.2.12.2 Materials Required

Laboratory glasswares, 0.1N Sodium hydroxide, 10% Trichloroacetic acid, 0.5% Copper sulphate, 1% Sodium potassium tartrate, 1% Sodium carbonate, 1N Folin and Ciocalteu’s phenol reagent and Bovine Serum Albumin (BSA).

3.2.12.3 Procedure

- Five gram of sample was taken and extracted with known volume of 0.1N Sodium hydroxide solution for 30 minutes
- The extract was centrifuged and the supernatant was collected. 10% of Trichloro acetic acid was added in the supernatant solution for precipitation of protein
- The precipitated protein was recovered by centrifugation at 5000 rpm for 10 minutes
- The protein pellet was dissolved in 0.1N Sodium hydroxide solutions and made upto known volume with the same solvent
- The aliquot was taken in test tube and 4ml of protein reagent was added to it. It was incubated at room temperature for 10 minutes
- 0.5ml of Folin and Ciocalteu’s phenol reagent was added to the test tube to develop blue colouration in the solution
- Allowing for 10minutes, the optical density value of the coloured solution was measured through 750nm wavelength against blank
- Total protein in a sample was calculated from standard graph of protein
3.2.13 Total Lipids

3.2.13.1 Principle

Lipids are fatty materials which are extracted in non-polar solvents. On extraction and subsequent evaporation of the solvent, the lipid extractive remains as residue and this is determined by weight (Mazumdar and Majumder, 2003).

3.2.13.2 Materials Required

Laboratory glasswares, Ether-Ethanol mixture.

3.2.13.3 Procedure

- 10 g of sample was taken and crushed with known volume of ethanol. The crushed sample was refluxed with ether ethanol mixture in a soxhlet’s apparatus not exceeding a temperature of 50°C for 3-4 hours.
- The supernatant containing the lipid matter was taken in a pre weighed container. The container with material was weighed again and warmed at the temperature below 50°C to evaporate the solvent.
- After cooling, the container with the material was weighed once again.

3.2.13.4 Calculation

Percentage of Lipid (Ether extractives) present in sample was calculated by using this formula

\[
\text{Percentage of Lipid} = \left( \frac{c - b}{a} - \frac{d - b}{a} \right) \times 100
\]

Where,

\( a = \text{Weight of sample; } \)
\( b = \text{Weight of glass container} \)
\( c = \text{Weight of glass container with material before evaporation of solvent} \)
\( d = \text{Weight of glass container with material after evaporation of solvent} \)
3.2.14 Calorific Value

The energy producing capacity of the food is usually characterized by using calorific values of the food. The amount of energy available from an item of food when digested usually measured in units of energy, calories per unit mass. Total energy values of the food products (kcal/100gm) calculated by the amount (gram) of protein, lipid and carbohydrate contents were found in the food products was multiplied by the factor of 4, 9 and 4 kcal/g, respectively (Mares et al., 2010).

3.2.15 UV-VIS Spectrum Analysis

3.2.15.1 Principle

UV-Visible spectrum analysis is one of the indirect measurements for evaluation of radiolytic products and internal component changes in the irradiated products (Brasoveanu et al., 2005). The extract of irradiated and control samples were analyzed in UV-VIS Spectrophotometer the wavelength range of 200-1100 nm. From the spectrum, to assess any changes in the absorption spectra of food product caused by irradiation when compared with spectrum of control sample.

3.2.15.2 Materials Required

Laboratory glasswares, ethanol, UV-Visible Spectrophotometer

3.2.15.3 Procedure

- Five gram of sample was weighed and extraction was prepared by crushing in the mortar and pestle by the addition of known volume of ethanol and stored in refrigerated condition (4°C) for overnight.
- After the incubation, samples were centrifuged at 5000 rpm for 10 minutes and the extract was collected.
- The extract was scanned by UV-Visible Spectrophotometer at different wavelength ranges from 200-1100 nm.
3.2.16 Microscopic Structure Analysis

3.2.16.1 Principle

Jams and jellies were commonly prepared from mixture of fruits. The visible decomposition or filth in the fruit is generally altered by the processing; thus, required indirect microscopic methods for evaluation of these defects. The changes in cell structures due to irradiation and the determination of foreign ingredients are based on the examination of cellular structures and morphological features of fruit tissues or non-food ingredients (pieces of hair, nylon fibre etc) were easily detected by microscopic analysis. Jams and preserves may be occasionally adulterated by the addition of other fruit tissues, which can be easily detected microscopically (Winton and Winton, 1935).

3.2.16.2 Materials Required

Glass slide, Cover slip, Microscope and Distilled water

3.2.16.3 Procedure

- Weighed out about 5 gram of food sample into a 20 mL beaker. Added sufficient amount of water to fill the beaker then stirred and allowed to stand for 10 minutes
- The supernatant was discarded and the sediment was taken in a slide
- It was viewed under microscope using low magnification
3.3 RESULTS

3.3.1 pH

3.3.1.1 pH Values of Mixed Fruit Jam

The pH values of jam were recorded in the range of 3.30 - 3.41 (Fig. 3.1). After irradiation of jam, the pH values were slightly decreased with increasing irradiation dose, it was found to be 3.39, 3.35, 3.35 and 3.30 in 2.5, 5.0, 7.5 and 10 kGy, respectively and in control it was 3.41. The same trend was found throughout the storage period. In 3rd month the pH values were recorded as 3.39, 3.39, 3.36, 3.33, 3.30 and in 6th month 3.38, 3.38, 3.36, 3.34, 3.30 for control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. The pH values of control and irradiated samples were 3.38, 3.39, 3.35, 3.35, 3.31 and 3.39, 3.37, 3.34, 3.34, 3.30 for 9th month and 12th months of storage, respectively. The storage not altered the pH values of irradiated jam at different doses while slight variation was observed in control sample.

3.3.1.2 pH Values of Mixed Fruit Jelly

The pH values were recorded in mixed fruit jelly after irradiation and storage period and it was shown in Fig. 3.2. The pH values were observed in the range of 3.04 - 3.13. After irradiation, the pH values of control and irradiated samples (2.5, 5, 7.5, 10 kGy) were found to be 3.13, 3.13, 3.13, 3.12 and 3.10, respectively. The pH values of jelly were not altered by irradiation except at higher doses where slight variation was observed. During storage the pH values were slightly lowered in both irradiated and control samples. The pH values were recorded as 3.12, 3.12, 3.11, 3.11, 3.11 for 3rd month, 3.10, 3.10, 3.09, 3.09, 3.07 for 6th month, 3.07, 3.07, 3.07, 3.06, 3.06 for 9th month and 3.07, 3.07, 3.07, 3.04, 3.04 for 12th month of storage in control and irradiated samples 2.5, 5, 7.5, 10 kGy, respectively.
Fig. 3.1 Effect of electron beam irradiation on the pH values of mixed fruit jam

Fig. 3.2 Effect of electron beam irradiation on the pH values of mixed fruit jelly
3.3.2 Electrical Conductivity

3.3.2.1 Electrical Conductivity Values of Mixed Fruit Jam

The electrical conductivity (EC) values of mixed fruit jam were recorded in the range of 0.13 – 0.16 mS/m (Fig. 3.3). The EC values of mixed fruit jam were 0.15, 0.14, 0.14, 0.15, 0.15 mS/m for control and irradiated samples (2.5, 5, 7.5, 10 kGy), respectively. In 3\textsuperscript{rd} month the EC values were recorded as 0.15, 0.15, 0.16, 0.14, 0.14 mS/m and in 6\textsuperscript{th} month 0.15, 0.16, 0.15, 0.15 mS/m for control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively.

The EC values of control and irradiated samples were 0.15, 0.13, 0.14, 0.15, 0.14 mS/m and 0.15, 0.15, 0.14, 0.14 mS/m for 9\textsuperscript{th} month and 12\textsuperscript{th} months of storage, respectively. The EC values of mixed fruit jam was not changed after irradiation and the same values was found during storage period in irradiated and control samples.

3.3.2.2 Electrical Conductivity Values of Mixed Fruit Jelly

The electrical conductivity (EC) values of mixed fruit jelly were recorded in the range of 0.11 – 0.13 mS/m and it was depicted in Fig. 3.4. After irradiation, it was found to be 0.11, 0.11, 0.12, 0.11, 0.12 mS/m for control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. The EC values of mixed fruit jelly were not altered by irradiation and on further storage period.

In 3\textsuperscript{rd} month it was recorded as 0.11, 0.11, 0.12, 0.11, 0.13 mS/m and in 6\textsuperscript{th} month 0.11, 0.12, 0.11, 0.12, 0.11 mS/m for control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. The EC values of control and irradiated samples were 0.11, 0.12, 0.11, 0.12 mS/m and 0.12, 0.12, 0.11, 0.12, 0.12 mS/m for 9\textsuperscript{th} month and 12\textsuperscript{th} months of storage, respectively.
Fig. 3.3 Effect of electron beam irradiation on the conductivity values of mixed fruit jam

Fig. 3.4 Effect of electron beam irradiation on the conductivity values of mixed fruit jelly
3.3.3 Acidity

3.3.3.1 Acidity Values of Mixed Fruit Jam

The acidity values of control and irradiated mixed fruit jam were studied (Fig. 3.5). The acidity values of mixed fruit jam was recorded after irradiation as 0.76, 0.78, 0.79, 0.80% for 2.5, 5, 7.5 and 10 kGy of irradiated samples, respectively. In control sample, it was 0.74%. After irradiation, the acidity values were slightly increased based on increasing irradiation doses. The same trend was maintained throughout the study period. The acidity values of control and irradiated samples were not altered during storage period. The values were 0.74, 0.77, 0.78, 0.79, 0.79% for 3rd month, 0.73, 0.77, 0.78, 0.78, 0.79% for 6th month and 0.74, 0.76, 0.79, 0.77, 0.80% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At the end of storage, in 12th month it was 0.75, 0.77, 0.77, 0.79, 0.81% for control and irradiated samples, respectively.

3.3.3.2 Acidity Values of Mixed Fruit Jelly

In mixed fruit jelly, the acidity values were found in the range of 0.83 – 0.95%. The values are illustrated in Fig. 3.6. After irradiation the acidity values were observed as 0.84, 0.83, 0.83, 0.85 and 0.87% in control and irradiated samples (2.5, 5, 7.5, 10 kGy), respectively. After irradiation, the acidity values were slightly increased based on increasing irradiation doses. The same trend was maintained throughout the study. The acidity values of control and irradiated samples were slightly increased during storage period. The values were 0.87, 0.85, 0.85, 0.87, 0.89% for 3rd month, 0.90, 0.85, 0.88, 0.88, 0.89% for 6th month and 0.88, 0.87, 0.89, 0.87, 0.90% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At the end of storage, in 12th month it was 0.90, 0.92, 0.92, 0.95, 0.94% for control and irradiated samples, respectively.
Fig. 3.5 Effect of electron beam irradiation on the acidity values of mixed fruit jam

![Graph showing the effect of electron beam irradiation on the acidity values of mixed fruit jam.]

Fig. 3.6 Effect of electron beam irradiation on the acidity values of mixed fruit jelly

![Graph showing the effect of electron beam irradiation on the acidity values of mixed fruit jelly.]

Control | 2.5 kGy | 5 kGy | 7.5 kGy | 10 kGy
3.3.4 Percentage of Moisture

3.3.4.1 Moisture Values of Mixed Fruit Jam

The moisture values of mixed fruit jam were determined after irradiation and storage period. It was shown in Fig. 3.7. In control and irradiated samples the moisture values were found in the range of 33.47 - 34.85%. After irradiation the moisture values were observed as 34.80, 34.17, 34.05, 33.80 and 33.50% in control and irradiated samples 2.5, 5, 7.5, 10 kGy, respectively. Based on the increase in irradiation dose the moisture values of jam were reduced when compared to control samples. The same trend observed throughout the study period. The values were 34.85, 34.18, 34.04, 33.82, 33.51% for 3rd month, 34.80, 34.16, 34.06, 33.78, 33.53% for 6th month, 34.80, 34.16, 34.06, 33.80, 33.47% for 9th month and 34.83, 34.13, 34.02, 33.81, 33.53% for 12th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. No significant changes were observed in moisture values of irradiated and control samples during the storage period.

3.3.4.2 Moisture Values of Mixed Fruit Jelly

In mixed fruit jelly the moisture values were observed in the range of 39.62 - 41.30% (Fig. 3.8). After irradiation the moisture values were observed as 41.15, 41.12, 41.00, 39.80, 39.62% in control and irradiated samples 2.5, 5, 7.5, 10 kGy, respectively. After irradiation, the moisture values were slightly reduced in the order of increase in irradiation dose. The same trend was observed throughout the study period. The values were 41.15, 41.12, 41.07, 39.85, 39.63% for 3rd month, 41.15, 41.13, 41.08, 39.87, 39.68% for 6th month, 41.15, 41.12, 41.11, 39.90, 39.70% for 9th month and 41.30, 41.15, 41.10, 39.89, 39.73% for 12th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. In irradiated and control samples, showed small variations in moisture values during the storage period.
Fig. 3.7 Effect of electron beam irradiation on the moisture values of mixed fruit jam

Moisture (%)

Storage Period (Month)

Control  2.5 kGy  5 kGy  7.5 kGy  10 kGy

Fig. 3.8 Effect of electron beam irradiation on the moisture values of mixed fruit jelly

Moisture (%)

Storage Period (Month)

Control  2.5 kGy  5 kGy  7.5 kGy  10 kGy
3.3.5 Percentage of Total Solids

3.3.5.1 Total Solids of Mixed Fruit Jam

The total solids values of control and irradiated mixed fruit jam were studied (Fig. 3.9). The total solids values of mixed fruit jam was recorded after irradiation as 65.83, 65.95, 66.20, 66.50% for 2.5, 5, 7.5 and 10 kGy of irradiated samples, respectively. In control sample, it was 65.20%. After irradiation, the total solids values were increased based on increasing irradiation doses. The same trend was maintained throughout the study. The total solids values of control and irradiated samples were not altered during storage period. The values were 65.15, 65.82, 65.96, 66.18, 66.50% for 3rd month, 65.20, 65.84, 65.94, 66.22, 66.51% for 6th month and 65.20, 65.86, 65.94, 66.21, 66.52% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At the end of storage, in 12th month it was 65.17, 65.87, 65.98, 66.19, 66.47% for control and irradiated samples, respectively.

3.3.5.2 Total Solids of Mixed Fruit Jelly

In mixed fruit jelly, the total solids values were found in the range of 58.70 – 60.38%. The values are illustrated in Fig. 3.10. After irradiation the total solids values were observed as 58.85, 58.88, 59.00, 60.20 and 60.38% in control and irradiated samples 2.5, 5, 7.5, 10 kGy, respectively. After irradiation, the total solids values were slightly increased based on increasing irradiation doses. The same trend was maintained throughout the study. In total solids values of control and irradiated samples small reduction were noticed during storage period. The values were 58.85, 58.88, 58.93, 60.15, 60.37% for 3rd month, 58.85, 58.87, 58.92, 60.13, 60.32% for 6th month and 58.85, 58.88, 58.89, 60.10, 60.30% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 58.70, 58.85, 58.90, 60.11, 60.27% for control and irradiated samples, respectively.
Fig. 3.9 Effect of electron beam irradiation on the total solids of mixed fruit jam

Fig. 3.10 Effect of electron beam irradiation on the total solids of mixed fruit jelly
3.3.6 Percentage of Total Ash

3.3.6.1 Ash Values of Mixed Fruit Jam

The total ash values were tested in irradiated and control samples of mixed fruit jam. It was shown in Fig. 3.11. After irradiation the ash values were found to be 0.35, 0.34, 0.34, 0.35, 0.35% in control and irradiated samples 2.5, 5, 7.5, 10 kGy, respectively. Irradiation did not affect the ash values of mixed fruit jam. The values were 0.35, 0.35, 0.36, 0.34, 0.34% for 3rd month, 0.35, 0.36, 0.35, 0.35, 0.34% for 6th month and 0.35, 0.33, 0.34, 0.35, 0.34% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 0.35, 0.35, 0.34, 0.34% for control and irradiated samples, respectively. No significant changes were observed in ash values of irradiated and control samples during the storage period.

3.3.6.2 Ash Values of Mixed Fruit Jelly

The ash content in control and irradiated samples of mixed fruit jelly were estimated and it was ranged from 0.17 – 0.21% (Fig. 3.12). After irradiation similar ash values were found in the all doses of irradiated and control samples. It was found to be 0.21, 0.22, 0.21, 0.22 and 0.22% of ash in the control, 2.5, 5, 7.5 and 10 kGy respectively. The values were 0.21, 0.21, 0.23, 0.20, 0.20% for 3rd month, 0.21, 0.20, 0.21, 0.19, 0.19% for 6th month and 0.19, 0.19, 0.20, 0.19, 0.22% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 0.17, 0.20, 0.20, 0.20, 0.19% for control and irradiated samples, respectively. All doses of irradiated samples, no significant changes were observed in ash values during the storage period and in control sample, small reduction was noticed in ash values.
Fig. 3.11 Effect of electron beam irradiation on the total ash values of mixed fruit jam

Fig. 3.12 Effect of electron beam irradiation on the total ash values of mixed fruit jelly
3.3.7 Percentage of Pectic Substances

3.3.7.1 Pectic Substances of Mixed Fruit Jam

The effect of electron beam irradiation on pectic substances of mixed fruit jam was studied (Fig. 3.13). After irradiation, it was noticed that 1.03, 1.03, 1.02, 1.00, 0.98% of pectin in control, 2.5, 5, 7.5 and 10 kGy, respectively. The pectin values were slightly reduced based on the order of increase in irradiation dose. The condition was maintained throughout the study. The values were 1.02, 1.01, 1.01, 1.00, 0.95% for 3rd month, 1.00, 0.97, 0.98, 0.97, 0.94% for 6th month and 0.98, 0.96, 0.96, 0.94, 0.92% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 0.97, 0.93, 0.92, 0.90, 0.86% for control and irradiated samples, respectively. During storage small reductions were observed in pectin values of all doses of irradiated and control samples.

3.3.7.2 Pectic Substances of Mixed Fruit Jelly

The pectic substances of mixed fruit jelly were determined after irradiation and storage period. It was shown in Fig. 3.14. The pectic substances of mixed fruit jelly was ranged from 1.24 – 1.37%. After irradiation it was showed that 1.37, 1.37, 1.37, 1.34, 1.34% in control and 2.5, 5, 7.5, 10 kGy, respectively. After irradiation, the pectin values of jelly were slightly reduced with an increase in irradiation dose. The values were 1.35, 1.35, 1.36, 1.32, 1.34% for 3rd month, 1.35, 1.34, 1.32, 1.32, 1.32% for 6th month and 1.31, 1.32, 1.28, 1.29, 1.28% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 1.28, 1.31, 1.28, 1.26, 1.24% for control and irradiated samples, respectively. During storage the pectin values were slightly lowered in all doses of irradiated and control samples.
Fig. 3.13 Effect of electron beam irradiation on the pectic substances of mixed fruit jam

![Graph showing the effect of electron beam irradiation on the pectic substances of mixed fruit jam.](image)

Fig. 3.14 Effect of electron beam irradiation on the pectic substances of mixed fruit jelly

![Graph showing the effect of electron beam irradiation on the pectic substances of mixed fruit jelly.](image)
3.3.8 Crude Fibres

3.3.8.1 Crude Fibre Values of Mixed Fruit Jam

The crude fibre values of mixed fruit jam were determined after irradiation and storage period (Fig. 3.15). The crude fibre values of mixed fruit jam was ranged from 2.11 – 2.17%. After irradiation, it was found to be 2.14, 2.12, 2.13, 2.14, 2.14% in control and 2.5, 5, 7.5, 10 kGy, respectively. The crude fibre values of mixed fruit jam were not changed by irradiation and on further storage period. The values were 2.16, 2.12, 2.12, 2.12% for 3rd month, 2.14, 2.13, 2.12, 2.14, 2.14% for 6th month and 2.12, 2.14, 2.12, 2.14% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 2.13, 2.13, 2.12, 2.14, 2.12% for control and irradiated samples, respectively.

3.3.8.2 Crude Fibre Values of Mixed Fruit Jelly

The crude fibre values of mixed fruit jelly were determined after irradiation and storage period. Fig. 3.16 showed the crude fibre values of mixed fruit jelly. The crude fibre values of mixed fruit jelly was ranged from 1.41 – 1.49%. After irradiation, it was found to be 1.47, 1.47, 1.47, 1.44, 1.44% in control and 2.5, 5, 7.5, 10 kGy, respectively. The crude fibre values of mixed fruit jelly were not changed by irradiation but slight variations were observed at higher doses. The values were 1.45, 1.45, 1.46, 1.42, 1.44% for 3rd month, 1.45, 1.44, 1.42, 1.42% for 6th month and 1.41, 1.42, 1.48, 1.49, 1.48% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 1.48, 1.41, 1.48, 1.46, 1.44% for control and irradiated samples, respectively. During storage no significant changes were observed in crude fibre values of irradiated and control samples.
Fig. 3.15 Effect of electron beam irradiation on the crude fibre of mixed fruit jam

![Graph showing the effect of electron beam irradiation on the crude fibre of mixed fruit jam.](image)

Fig. 3.16 Effect of electron beam irradiation on the crude fibre of mixed fruit jelly

![Graph showing the effect of electron beam irradiation on the crude fibre of mixed fruit jelly.](image)
3.3.9 Total Sugar

3.3.9.1 Total Sugar Values of Mixed Fruit Jam

The total sugar values of mixed fruit jam were evaluated after irradiation and storage period (Fig. 3.17). The total sugar values of mixed fruit jam was ranged from 48.53 – 49.40%. After irradiation, it was found to be 48.53, 48.55, 48.70, 48.90, 49.33% in control and 2.5, 5, 7.5, 10 kGy, respectively. The total sugar values of mixed fruit jam were increased with an increasing irradiation doses and the condition was maintained during the storage period. The values were 48.62, 48.62, 48.77, 48.92, 49.34% for 3rd month, 48.58, 48.70, 48.71, 49.01, 49.38% for 6th month and 48.59, 48.69, 48.75, 48.98, 49.35% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 48.60, 48.65, 48.77, 48.90, 49.40% for control and irradiated samples, respectively. The total sugar values of control and irradiated samples were not altered during storage period.

3.3.9.2 Total Sugar Values of Mixed Fruit Jelly

The effect of electron beam irradiation on total sugar values of mixed fruit jelly were studied (Fig. 3.18). The total sugar values of mixed fruit jelly were ranged from 43.11 to 43.54%. After irradiation, it was found to be 43.11, 43.15, 43.20, 43.28, 43.45% in control and 2.5, 5, 7.5, 10 kGy, respectively. The total sugar values of jelly were increased with an increase in irradiation dose whereas on storage it was slightly increased but not in significant manner. The values were 43.20, 43.18, 43.27, 43.32, 43.49% for 3rd month, 43.36, 43.26, 43.29, 43.34, 43.54% for 6th month and 43.34, 43.26, 43.35, 43.37, 43.50% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 43.20, 43.24, 43.33, 43.33, 43.48% for control and irradiated samples, respectively.
Fig. 3.17 Effect of electron beam irradiation on the total sugar values of mixed fruit jam

![Fig. 3.17](image)

Fig. 3.18 Effect of electron beam irradiation on the total sugar values of mixed fruit jelly

![Fig. 3.18](image)
3.3.10 Reducing Sugar

3.3.10.1 Reducing Sugar Values of Mixed Fruit Jam

The reducing sugar values of mixed fruit jam were recorded in the range of 22.25 to 22.31% (Fig. 3.19). The reducing sugar values of mixed fruit jam were 23.31, 23.35, 23.31, 23.31% for control and irradiated samples (2.5, 5, 7.5, 10 kGy), respectively. After irradiation and further storage, no significant differences were found in reducing sugar values of both irradiated and control samples. In 3\textsuperscript{rd} month the reducing sugar values were recorded as 22.33, 22.35, 22.33, 22.33, 22.30% and in 6\textsuperscript{th} month 22.31, 22.36, 22.33, 22.33, 22.25% for control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. The reducing sugar values of control and irradiated samples at 9\textsuperscript{th} month were 22.31, 22.36, 22.36, 22.35, 22.28% and 22.30, 22.33, 22.37, 22.37, 22.28% for 12\textsuperscript{th} month of storage, respectively.

3.3.10.2 Reducing Sugar Values of Mixed Fruit Jelly

The reducing sugar values of mixed fruit jelly were recorded in the range of 17.03 to 17.19% and it was depicted in Fig. 3.20. After irradiation, it was found to be 17.14, 17.14, 17.14, 17.13, 17.14% for control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. The reducing sugar values of mixed fruit jelly was not changed after irradiation and the same values was found during storage period in irradiated and control samples. In 3\textsuperscript{rd} month it was recorded as 17.14, 17.15, 17.15, 17.13, 17.14% and in 6\textsuperscript{th} month 17.19, 17.18, 17.17, 17.15, 17.15% for control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. The reducing sugar values of control and irradiated samples at 9\textsuperscript{th} month were 17.11, 17.16, 17.11, 17.17, 17.16% and 17.03, 17.10, 17.14, 17.06, 17.06% for 12\textsuperscript{th} month of storage, respectively.
Fig. 3.19 Effect of electron beam irradiation on the reducing sugar values of mixed fruit jam

Fig. 3.20 Effect of electron beam irradiation on the reducing sugar values of mixed fruit jelly
3.3.11 Total Protein

3.3.11.1 Total Protein Values of Mixed Fruit Jam

The total protein values were tested in irradiated and control samples of mixed fruit jam. It was shown in Fig. 3.21. After irradiation the total protein values were found to be 0.34, 0.33, 0.34, 0.35, 0.35% in control and irradiated samples 2.5, 5, 7.5, 10 kGy, respectively. Irradiation did not affect the total protein values of mixed fruit jam. The values were 0.34, 0.32, 0.33, 0.34, 0.33% for 3rd month, 0.33, 0.33, 0.34, 0.34, 0.32% for 6th month and 0.32, 0.31, 0.32, 0.34, 0.32% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 0.31, 0.31, 0.32, 0.32, 0.32% for control and irradiated samples, respectively. In total protein values of irradiated and control samples, no significant changes were observed during the storage period.

3.3.11.2 Total Protein Values of Mixed Fruit Jelly

The total protein values in control and irradiated samples of mixed fruit jelly were estimated and it was ranged from 0.20 – 0.25% (Fig. 3.22). After irradiation similar total protein values were found in the all doses of irradiated and control samples. It was found to be 0.23, 0.23, 0.24, 0.25 and 0.24% of total protein in the control, 2.5, 5, 7.5 and 10 kGy respectively. The values were 0.22, 0.22, 0.23, 0.24, 0.22% for 3rd month, 0.22, 0.23, 0.23, 0.24, 0.22% for 6th month and 0.20, 0.21, 0.22, 0.23, 0.22% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 0.20, 0.21, 0.22, 0.22, 0.22% for control and irradiated samples, respectively. In total protein values of all doses of irradiated samples, no significant changes were observed during the storage period.
Fig. 3.21 Effect of electron beam irradiation on the total protein values of mixed fruit jam

- Control
- 2.5 kGy
- 5 kGy
- 7.5 kGy
- 10 kGy

Fig. 3.22 Effect of electron beam irradiation on the total protein values of mixed fruit jelly

- Control
- 2.5 kGy
- 5 kGy
- 7.5 kGy
- 10 kGy
3.3.12 Total Lipids

3.3.12.1 Total Lipids Values of Mixed Fruit Jam

The total lipid values of mixed fruit jam were evaluated after irradiation and storage period. Fig. 3.23 showed the total lipid values of control and irradiated mixed fruit jam. The total lipid values of mixed fruit jam was recorded after irradiation as 0.14, 0.14, 0.14, 0.14, 0.15% for control and 2.5, 5, 7.5 and 10 kGy of irradiated samples, respectively. After irradiation, the total lipid values of jam were not altered in all doses of irradiated samples. The values were 0.14, 0.15, 0.14, 0.14% for 3rd month, 0.13, 0.13, 0.13, 0.12% for 6th month and 0.12, 0.12, 0.12, 0.12% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At the end of storage, in 12th month it was 0.11, 0.12, 0.11, 0.12, 0.11% for control and irradiated samples, respectively. During storage the total lipid values showed small variations in all doses of irradiated and control samples.

3.3.12.2 Total Lipids Values of Mixed Fruit Jelly

The total lipid values of mixed fruit jelly were evaluated after irradiation and storage period. In mixed fruit jelly, the total lipid values were found in the range of 0.10 – 0.12%. The values are illustrated in Fig. 3.24. After irradiation the total lipid values were observed as 0.11, 0.11, 0.11, 0.12 and 0.12% in control and irradiated samples 2.5, 5, 7.5, 10 kGy, respectively. The total lipid values of jelly were not affected by irradiation and on further storage. The values were 0.10, 0.11, 0.11, 0.12, 0.12% for 3rd month, 0.10, 0.10, 0.11, 0.10, 0.10% for 6th month and 0.10, 0.10, 0.10, 0.10, 0.10% for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At the end of storage, in 12th month it was 0.10, 0.10, 0.11, 0.11, 0.11% for control and irradiated samples, respectively.
Fig. 3.23 Effect of electron beam irradiation on the total lipid values of mixed fruit jam

![Graph showing effect of electron beam irradiation on total lipid values of mixed fruit jam.](image)

- **Storage Period (Month):** 0 to 12
- **Total Lipids (%):** 0.04 to 0.2
- **Irradiation Levels:** Control, 2.5 kGy, 5 kGy, 7.5 kGy, 10 kGy

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Fig. 3.24 Effect of electron beam irradiation on the total lipid values of mixed fruit jelly

![Graph showing effect of electron beam irradiation on total lipid values of mixed fruit jelly.](image)

- **Storage Period (Month):** 0 to 12
- **Total Lipid (%):** 0.04 to 0.16
- **Irradiation Levels:** Control, 2.5 kGy, 5 kGy, 7.5 kGy, 10 kGy
3.3.13. Calorific Value

3.3.13.1 Calorific Value of Mixed Fruit Jam

The calorific values of mixed fruit jam were ranged from 196.59 – 200.12 kcal/100gm of sample (Fig. 3.25). After irradiation, it was found to be 196.74, 196.74, 197.41, 198.35, 199.99 kcal/100gm of sample in control and 2.5, 5, 7.5, 10 kGy, respectively. The calorific values of mixed fruit jam were increased with an increasing irradiation and the same trend was maintained throughout the study period. The values were 197.10, 197.07, 197.67, 198.34, 199.94 for 3rd month, 196.77, 197.30, 197.31, 198.57, 199.89 for 6th month and 196.68, 197.09, 197.34, 198.41, 199.74 kcal/100gm of sample for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 196.67, 196.96, 197.37, 197.99, 199.91 kcal/100gm of sample. The calorific values of control and irradiated samples were slightly lowered during storage period.

3.3.13.2 Calorific Value of Mixed Fruit Jelly

The calorific values of mixed fruit jelly were ranged from 174.34 to 176.13 kcal/100gm of sample (Fig. 3.26). After irradiation, it was found to be 174.34, 174.50, 174.74, 175.20, 175.84 kcal/100gm of sample in control and 2.5, 5, 7.5, 10 kGy, respectively. The calorific values of jelly were increased with an increase in irradiation dose and the condition was maintained throughout the storage period. The values were 174.58, 174.58, 175.00, 175.32, 175.93 for 3rd month, 175.23, 174.85, 175.08, 175.31, 176.13 for 6th month and 175.07, 174.79, 175.19, 175.40, 175.78 kcal/100gm of sample for 9th month of storage in control and 2.5, 5, 7.5, 10 kGy of irradiated samples, respectively. At 12th month of storage, it was 174.51, 174.71, 175.18, 175.19, 175.80 kcal/100gm of sample for control and irradiated samples, respectively.

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Fig. 3.25 Effect of electron beam irradiation on the calorific values of mixed fruit jam

Fig. 3.26 Effect of electron beam irradiation on the calorific values of mixed fruit jelly
3.3.14 UV-VIS Spectrum Analysis

After irradiation, UV-Visible spectrum analysis was carried out for irradiated and control samples of mixed fruit jam and jelly products. It was shown in Fig. 3.27 and Fig. 3.28. In the spectrum analysis of irradiated and control samples, the absorption curves were found between 200 and 600 nm. In both jam and jelly products, the shape of the spectrum was similar in all doses of irradiated (2.5, 5, 7.5, 10 kGy) and control samples. The absorption values of irradiated samples, only slight variation were found between 200 and 300 nm.

3.3.15 Microscopic Structure Analysis

The microscopic structure of electron beam irradiated and control jam and jelly products were studied. It was given in Plate 3.4 and Pate 3.5. In jam, the crushed pieces of fruit tissues and fragments of fibre with varying size and shape were observed under the microscope. In jelly, tiny fruit particles only were found. These are observed in all doses of irradiated and control samples. Extraneous materials were not found out in both jam and jelly products. In microscopic structure analysis, there is no any notable differences showed in electron beam irradiated jam and jelly products compared to control samples.

3.4 DISCUSSION

In the present study, mixed fruit jam and jelly products were exposed to electron beam irradiation at doses of 2.5, 5, 7.5 and 10 kGy. The proximate values were analyzed after irradiation and storage period to evaluate the effect of irradiation on jam and jelly products. The pH values of irradiated jam and jelly products were recorded in the range of 3.30 - 3.39 and 3.04 - 3.13, respectively.
Fig. 3.27 UV-Visible spectrum for electron beam irradiated and control mixed fruit jam

a) Control
b) 2.5 kGy
c) 5 kGy
d) 7.5 kGy
e) 10 kGy
Fig. 3.28 UV-Visible spectrum for electron beam irradiated and control mixed fruit jelly

a) Control

b) 2.5 kGy

c) 5 kGy

d) 7.5 kGy

e) 10 kGy
Plate 3.4 Microscopic structures of electron beam irradiated and control mixed fruit jam products

(a) Control,  (b) 2.5 kGy,  (c) 5.0 kGy,  (d) 7.5 kGy,  (e) 10 kGy
Plate 3.5 Microscopic structures of electron beam irradiated and control mixed fruit jelly products

(a) Control,  (b) 2.5 kGy,  (c) 5.0 kGy,  (d) 7.5 kGy,  (e) 10 kGy
After irradiation of jam, the pH values were slightly decreased with an increasing irradiation dose. The same trend was found throughout the experimental period. The storage not altered the pH values of jam. After irradiation of jelly, only slight variation was observed in pH values at higher irradiation doses (7.5 and 10 kGy). During storage the pH values of jelly were slightly lowered in both irradiated and control samples. The similar findings were reported by Al-Bachir (2014), electron beam and gamma irradiated chamomile powder sample showed decrease in pH value with increasing irradiation dose (10 and 20 kGy), it was probably due to release of the organic acids during irradiation treatment. It is an agreement with the Aleid et al. (2013) reported that pH value was slightly lowered in dates treated with low-energy X-ray irradiation at doses of 3, 5 and 7 KGy and it did not affect the overall quality of the dates. The pH value is one of the main factors in influencing the quality of product. It always controls some physical, chemical and microbiological properties of product (Liu et al., 2011). The desirable level of pH for jam is 3.20 to 3.60 and for jelly 3.00 to 3.20, within this level the products were keeping their quality and shelf life as good (Frey, 2005). In this study, pH value of irradiated and control samples were maintained under the desirable level. It is inferred that electron beam irradiation did not affect the pH value of jam and jelly products.

Contrary to these results was reported by Moreno et al. (2006) the increase in pH values were observed in the Tommy Atkins mango fruit samples treated with the higher doses of irradiation due to reduction of acid contents of the fruits. Rico et al. (2010) reported that irradiation treatment with 10 kGy did not affect the pH values of dried red pepper. No significant change was observed in pH values of lyceum fruit exposed to gamma irradiation at doses of 4 kGy, 8 kGy and 15 kGy (Wen et al., 2006).
The pH value of herbals, rose, guggul, chirata and gulvel and herbal formulations were not affected by gamma radiation treatment with 10 kGy (Kumar et al., 2010).

The acidity values were found in the range of 0.73 – 0.81% for jam and 0.83 – 0.95% for jelly. After irradiation, the acidity values of jam and jelly products were slightly increased with increasing irradiation doses. The same trend was maintained throughout the study. In jam, acidity values of control and irradiated samples were not altered by storage whereas in jelly it was slightly increased during storage period. Similar findings were reported by Kim et al. (2008) the acidity value of irradiated organic materials were increased could be due to release of organic acids and it might be due to the formation of carboxylic groups during irradiation treatment. Wang and Yu (2009) reported that the titratable acidity of gamma irradiated wheat flour increased from 4.9 to 30%. The acidity value was increased in gamma irradiated mango samples at doses between 0.5 and 1 kGy (Youssef et al., 2002). Aleid et al. (2013) stated that the increase in the acidity value of irradiated products may contribute to stability of the products against microbial spoilage. The ascorbic acid, pectin and sugar degradation may be responsible for formation of acidic compounds (Sogi and Singh, 2001; Iftikhar et al., 2007). The fruits Tommy Atkins mangoes exposed to electron beam irradiation at doses of 1, 1.5 and 3.1 kGy had an acceptable acidity level and that remain unaffected during storage period (Moreno et al., 2006). In irradiated jam and jelly products the increased acidity and decrease in pH values were recorded but not at significant level. Generally pH and acidity of the food products are interrelated when acidity increased, pH decreased. It did not affects the overall quality of jam and jelly the products.

The electrical conductivity (EC) values of jam and jelly products were recorded in the range of 0.13 – 0.16 mS/m for jam and 0.11 – 0.13 mS/m for jelly. After
irradiation, EC values of jam and jellies were not altered. Also during the storage period, EC values of irradiated and control jam and jellies were remain unchanged. Similar findings were reported by Ramathilaga and Murugesan (2011) the electron beam irradiated chyavanaprash herbal ayurvedic formulations at doses of 0, 2.5, 5 and 7.5 and 10 kGy, the EC values was found in the range of 0.09 – 0.12 mS/m and EC values were not altered by electron beam irradiation. Most of the irradiated vegetables EC values showed no consistent variations were found between irradiated and control samples (Hayashi and Kawashima, 1983).

Contrary to these results was reported by Ahamed (1998) EC values of dried fruits and nuts showed variations between irradiated and control samples. The differentiated EC values were observed between control and irradiated samples of potatoes (Hayashi and Kawashima, 1983) and fish samples (Ehlermann, 1972). The concentration of mineral salts, organic acids and proteins were determine the electrical conductivity values of honey samples and the ionic strength of a food material directly influences their conductivity values (Terrab et al., 2004). It is inferred that the electron beam irradiation did not affect the EC values of jam and jellies.

The moisture content is an important quality factor in the preservation and packaging of food products as excess moisture can promote microbial growth, which rapidly deteriorates the quality of food (Fennema, 1996). The moisture and water activity of sample is most importance as its controls radiochemical changes (Wilkinson and Gould, 1998). In the present study, the increase in irradiation doses the moisture values of jam and jelly products were slightly reduced. The moisture values of irradiated jam and jelly products were lowered than control samples. The same trend was observed throughout the study. The moisture values of irradiated and control jam
samples did not showed any significant changes during storage period whereas in jelly small variations were observed.

The similar findings were reported by Bhat and Sridhar (2008) the electron beam irradiation could significantly reduce the moisture content in lotus seeds based on increase in radiation dose and it has advantageous in maintenance and improvement of shelf life of lotus seeds. The same trend was observed by Sarker et al. (2014) cucumber, tomato, carrot, green leaf lettuce and green capsicum were treated with 1, 2, 2.5 and 3 kGy of gamma irradiation showed decrease in moisture value with increasing irradiation doses. The moisture decreases are in agreement with the findings of Bhat et al. (2008) for electron beam irradiation of Mucuna pruriens seeds and Warchalewski et al. (1998) for gamma and microwave irradiation of wheat grain. On contrary to this results Nortje et al. (2005) reported that moisture content was significantly increased in gamma irradiated moist beef biltong at doses between 2 and 8 kGy. No significant changes were found in moisture values by absorbed radiation doses in irradiated feta cheese (Konteles et al., 2009), chicken tissues (Heath et al., 1990), Tilapia nilotica (Cozzo-Siqueira et al., 2003), rawa (Rae et al., 1994).

The total solids values of electron beam irradiated and control samples of jam and jellies were studied. It was ranged from 65.15 – 66.53% total solids for jam and 58.70 – 60.38% total solids for jelly. The increase in irradiation doses the moisture values of jam and jelly products were decreased and consequently total solids content of the products were increased. Similar results were reported for total solids and moisture changes in gamma irradiated apples by Mostafavi et al. (2012). After irradiation, the total solids values of jam were increased based on increasing irradiation doses. The condition was maintained throughout the storage period. The total solids values of control and irradiated jam samples were not altered during storage period.
The same trend was also observed in jelly. The products with absence of microorganisms as well as stable pH, moisture, total soluble solids, color and viscosity values during storage indicate the stability of the product is more (Martina Avasoo and Linda Johansson, 2009). The increased solid content of the food materials results in increased protein, minerals, carbohydrates and other nutrients (Akther et al., 2012).

It was agreed with Aleid et al. (2013) the moisture and total solids values of X-ray irradiated dates at doses between 3 and 7 kGy showed increased values of total solids and decreased values of moisture. The similar findings were reported by Ladaniya et al. (2003) the increase in total soluble solids of irradiated mandarins and oranges at doses upto 1.5 kGy. The increase in total soluble solids values were observed in irradiated blueberries and cherries (Eaton et al., 1970) and irradiated mangoes (Lacroix et al., 1992). The different findings were reported by Mitchell et al. (1992) showed no variations in soluble solids of irradiated mango at doses of 75, 300 and 600 Gy and reduction in the soluble solids of peaches at 75 Gy, these differences may be associated with variation between the samples. Innocenzo and Lajolo (2001) reported that total soluble solids of papaya fruits were not affected by irradiation. According to the Codex standards for jam and jellies, the total solids content should be between 60 - 65% for jam and 40 - 65% for jelly (CODEX, 2009). The total solids content of electron beam irradiated jam and jellies had an acceptable level of total solids and that remain unchanged during storage period.

The total ash content of irradiated and control samples were studied. It was ranged from 0.33 – 0.36% ash for jam and 0.17 – 0.21% ash for jelly. In this study the ash content of jam and jelly was also similar with cherries and apricots jam (0.28%) (Belitz et al., 2009), strawberry jelly (0.19%) (Miguel et al., 2008) and cubiu jelly (0.22%) (Yuyama et al., 2008). After irradiation similar ash values were found in all
the doses of irradiated and control samples. Irradiation did not affect the ash values of mixed fruit jam and jelly. Also during storage period, no significant changes were observed in ash values. Similar findings were reported by Ramathilaga and Murugesan (2011) in chyavanaprash ayurvedic formulations the total ash value was not changed by electron beam irradiation at doses of 2.5 - 10 kGy. Similarly, the irradiation had does not affect the ash content of electron beam irradiated wheat straw (Shawrang et al., 2013) and gamma irradiated Castanea sativa (Fernandes et al., 2011a).

Different findings were reported in earlier studies as Bhat et al. (2008) the ash values of Mucuna pruriens seeds were significantly declined after electron beam irradiation and Azelmat et al. (2006) reported that the gamma irradiation (0.6, 0.9 and 1.8 kGy) increased ash content of Moroccan dates. Bhat and Sridhar (2008) reported that increased ash value was found in electron beam irradiated lotus seeds. Ash values of food products are used as an index of the quality of food materials. (Pomeranz and Clifton, 1981). The ash values of food products represents amount of minerals present in food products, high ash represents high in minerals (Vadivel and Janardhanan, 2004). The minerals (phosphorus, potassium, sodium, calcium and iron) were also found in jam and jelly products, showed minerals values remain unchanged after irradiation and storage period. No significant changes were observed in ash values of irradiated jam and jelly samples. The results of this study showed that there was a relation between ash and minerals values, so that, the same trend was observed after electron beam irradiation in both ash and minerals values of jam and jelly products.

The important constituents of jams and jellies are pectin, sugar, acids. These constituents should be maintained in correct proportion for retain the gel structure and to keep the stability of product (Costell et al., 1993). The effect of electron beam irradiation on pectic substances of mixed fruit jam and jellies were studied. The
insignificant reduction of pectin values was observed after irradiation and storage based on increase in radiation dose. The same condition was observed in both jam and jelly products. The decrease in pectin values was observed in irradiated dehydrated vegetables, fruits and legumes at doses of 3 to 10 kGy (Agarwal et al., 1972). It was agreed with Tripathi et al. (2013) reported that the decreased firmness values of gamma irradiated ready-to-cook (RTC) ash gourd at the dose range of 0.5 – 2.5 kGy due to radiation induced breakdown of pectin and other cell wall components. Generally, the firmness values of food samples are associated with pectin contents of food material. The decreased firmness and pectin values were reported in gamma irradiated apple slices (Gunes et al., 2001) and electron beam irradiated strawberries (Yu et al., 1996) and some irradiated fresh cut fruits and vegetables (Fan et al., 2008) and electron beam irradiated sliced mushrooms (Yurttas et al., 2014) but it did not affect the overall quality of the products.

During storage, the reductions in pectin values were also observed in control samples of jam and jellies. In fruits, decreased pectin values was also observed in non-irradiated samples during storage might be due to the presence of higher microbial counts could produce pectinolytic enzymes that hydrolyze the pectic substances (Juven et al., 1985; Fraaije et al., 1997; Liao et al., 1997). The different results were reported by Chuanyao et al. (1993) the firmness of irradiated apples (0.3–0.9 kGy) was higher than control samples with increasing storage time. Irradiation had delaying the pectin degradation in climacteric fruits (Khan et al., 1974; Akamine and Moy, 1983; Zhao et al., 1996). The jellying power is the most important property of pectin (Doesburg, 1965). In this study, the slight variations were observed in pectin values after irradiation and storage but the values were comparable to traditional jams and jellied
products and it showed that, the electron beam irradiation did not affect the gel structure and overall acceptability of the product.

Fruits and fruit-based products are good source of fibre. The advantages of fibre containing foods are essential for healthy life. It is mostly preferred in many diets because of their ability to prevent digestive disorders, constipation, help in regulating bowel movements and reduce blood cholesterol level (Champ et al., 2003). The crude fibre values of jam and jelly were determined after irradiation and storage period. The crude fibre values of jam was ranged from 2.11 – 2.17% and in case of jelly, 1.41 – 1.49%. These values were close to that of commercial jam and jellies (Belitz et al., 2009). The crude fibre values of mixed fruit jam were not changed by irradiation. In jelly, slight variations in fibre values were observed only at higher doses. During storage, no significant changes were observed in crude fibre values of irradiated and control samples of jam and jellies. Similar findings were reported by Aleid et al. (2013) there was no differences observed in crude fibre values of dates treated with x ray irradiation (3, 5, 7 kGy).

Different results were observed by Bhat and Sridhar (2008) the electron beam irradiation decreased the crude fibre of lotus seeds at doses of 2.5 – 30 kGy. The fibre content of African oil bean seed was significantly reduced by gamma irradiation at dose of 10 kGy (Enujiugha et al., 2012). Shawrang et al. (2013) and Banchorndhevakul (2002) were reported that at higher doses of irradiation (250 to 500 kGy), the decrease of neutral detergent fibre (NDF) and acid detergent fibre (ADF) of agricultural residues significantly as a result of radiation induced degradation of cellulose and hemicellulose into soluble substances. Irradiated fruits, the insoluble fibre contents were broken down to soluble compounds, causing the fruit to become soft (Aleid et al., 2013; Lund et al., 1983). Fibre levels of irradiated fruits decreased based on the level of absorbed dose of
irradiation may be due to depolymerisation and delignification (Jerome et al., 1952). The results of this study showed that the electron beam irradiation at this dose level (2.5 to 10 kGy) did not affect the crude fibre values of jam and jellies.

The ratio of sugar and acid is often used as an index of consumer acceptability and quality in fruits and fruit products (Vidhya and Anandhi Narain, 2011). The total sugar values of jam and jelly were evaluated after irradiation and storage period. After irradiation, it was found to be 48.53, 48.55, 48.70, 48.90, 49.33% total sugar for jam and in case of jelly 43.11, 43.15, 43.20, 43.28, 43.45% in control and 2.5, 5, 7.5, 10 kGy, respectively. The total sugar values of jam and jelly were increased slightly with an increase in irradiation dose and the condition was maintained throughout the experimental period. The total sugar values of control and irradiated samples were also slightly increased during storage period in both jam and jelly products. The same trend was also reported by Bhat and Sridhar (2008) the electron beam irradiation could increase the sugar content in lotus seeds with an increase in radiation dose, might be due to breakdown of complex polysaccharides into simpler forms of sugars. Similar results were observed in Moroccan dates were treated with gamma irradiation, at 0.9 kGy significantly increased glucose and total sugars contents (from 81.58 to 87.43%) and reduction in the starch content was also observed during storage (Azelmat et al., 2006). The reducing sugar values of jam and jelly products was not changed after irradiation and the same values was found during storage period in irradiated and control samples. It was recorded in the range of 22.25 to 22.31% reducing sugar for jam and in jelly it was 17.03 to 17.19% reducing sugar.

Different findings have been reported in the effect of irradiation on the sugar values of food products. Total sugar and reducing sugar values were not changed by irradiation in Maroc Late oranges at doses of 0.125 - 0.5 kGy (Moussaid El Idrissi et
and the same trend observed in kiwifruits by low-dose e-beam irradiation at 0.3 and 0.6 kGy (Kim et al., 2007) and in onions (Diehl, 1977; Thomas et al., 1986; Guma and Rivetti, 1970). El-Samahy et al. (2000) reported that the gamma irradiation (0.5 to 1.5 kGy) of mangoes had no effect on total sugars but it was slightly increased the reducing sugars values. Castell-Perez et al. (2004) reported no effect of electron beam irradiation (1.0, 1.5 and 3.1 kGy) on the total sugars content in cantaloupe. Wall (2007) reported that X-ray irradiated dwarf Brazilian bananas, starch and total sugar concentrations were similar and not changed by irradiation (200 - 800 Gy). Din et al., (2011) reported that the total sugar values of dates significantly decreased with increase in irradiation dose (1, 2 and 3 kGy). In the traditionally formulated wood apple jam, fruit bar (Vidhya and Anandhi Narain, 2011) and cereal based papaya powder (Aruna et al., 1998) showed the total sugar, reducing sugar and total soluble solids values were increased with an increase in storage time due to the conversion of starch and insoluble carbohydrate into sugars but it did not cause negative effect on the quality of products. In view of that, the irradiation did not affect the quality of jam and jelly products as a result of increase in sugar values.

In the present study, the total protein and lipid values were tested in irradiated and control samples. After irradiation similar protein values were found in all doses of irradiated and control samples. Irradiation did not affect the total protein values of jam and jelly products. The same trend was also observed during storage period. Similar findings were reported by Shawrang et al. (2013) the effect of electron beam irradiation on the chemical composition of wheat straw showed irradiation had no effect on lipids, crude protein and ash values even at doses of 250 and 500 kGy. The different results were reported by Dario and Salgado (1994) the protein value was increased significantly in gamma irradiated cowpea. Mucuna pruriens seeds treated with electron
beam irradiation at doses of 2.5 to 30 kGy could increase seed protein values might be attributed to the dissociation of complex protein molecules into simpler forms. In Mucuna pruriens seeds, a dose dependent decrease of crude lipid values was also found (Bhat et al., 2008). Bhat and Sridhar (2008) reported that the decreased crude protein and lipid values were found in electron beam irradiated lotus seeds. In the present study, the total lipid values of jam and jellies were not changed after irradiation and on further storage period. Only small variations were observed in lipid values of irradiated and control jams during storage period. Irradiation of higher lipid containing foods, the production of off-odour might be attributed to breakdown of lipids on irradiation which is limiting the shelf life of the products (Diehl, 1995). In the present study, the low level of protein and lipids was found in jam and jellies; it ranged from 0.10 - 0.15% of lipids and 0.20 - 0.36% of protein, thereby the impact of electron beam irradiation on protein and lipid values of jam and jellies was insignificant.

In general, after irradiation the macronutrients like protein, lipid and carbohydrates quality does not loss (WHO, 1999) and micronutrients like minerals also shown to remain stable (Diehl, 1995). AL-Bachir (2010) reported that the proximate composition of gamma irradiated Sheesh Tawoq showed that irradiation doses (2, 4, 6 kGy) had no effect on the major constituents moisture, protein and fat values of Sheesh Tawoq. Aleid et al. (2013) reported that the dates treated with X-ray irradiation (3, 5, 7 kGy), has produce no negative effect on the physical and chemical quality parameters such as crude fibre, soluble dietary fibre, sucrose, glucose, fructose, moisture, total soluble solids, pH, water activity and colour. Irradiation is also known to cause fewer overall physical and chemical changes than cooking, refrigeration and canning (Enujiugha et al., 2012; Josephson et al., 1978; Molins, 2001).
The energy producing capacity of the food is usually characterized by using calorific values of the food (Mares et al., 2010). The calorific values of jam were ranged from 196.59 – 200.12 kcal/100gm of Sample and in jelly it was 174.34 to 176.13 kcal/100gm of Sample. After irradiation, it was slightly increased with an increasing irradiation dose in both jam and jelly products and the same trend was maintained throughout the study period. During storage period, small variations were found in calorific values but not at significant level. Similar findings were obtained by Bhat and Sridhar (2008) the electron beam irradiation could increase the calorific value of lotus seeds at doses of 2.5, 5 and 7.5 kGy due to increased carbohydrate content and preserved the concentration of other nutrients of lotus seeds after irradiation. The same trend was observed by Fernandes et al. (2011b) carbohydrates, fat and energy value of gamma irradiated chestnut (0.25, 0.5, 1 and 3 kGy) was greater than control samples. It was also agreed with Enujugha et al. (2012) the cooking and combined treatment of gamma irradiation (10 kGy) increased the energy value of African oil bean seed as a result of increase in fat and calorific content. Different results were reported by Bhat et al. (2008) the electron beam irradiation slightly decreased the total energy values of Mucuna pruriens seeds with increase in irradiation dose (2.5 to 30 kGy) might be attributed to crude lipid, crude fibre and ash content of seeds declined after irradiation.

Jam and jellies are prepared from combination of different fruit pulps which is a good source of carbohydrates, vitamins, minerals, pectin, dietary fibers and high energy value that are essential components for normal growth and development (Vidhya and Anandhi Narain, 2011). In this study, the electron beam irradiation had produced no significant effect on proximate composition of jam and jellies. In irradiated jam and jelly products, there was no variation observed in crude fibre, protein, lipids values whereas total solids, total sugar and reducing sugar values were increased slightly based on irradiation dose and storage period. These results indicate that, electron beam irradiated jam and jelly products contains higher amount of
nutrients and thereby the calorific value of irradiated samples were relatively increased than control sample. In this study, after irradiation and storage period, the proximate composition of jam and jelly products were found within the standard limits and comparable to earlier reports on various jam and jelly products (Ferreira et al., 2004; Touati et al., 2014; Belitz et al., 2009).

UV-Visible spectrum analysis is one of the indirect measurements to evaluate the radiolytic products formed and internal component changes in the food products after irradiation (Brasoveanu et al., 2005). Orozco et al. (2012) reported that the UV-Visible absorption and FTIR analysis was carried out to assess the physico-chemical changes between various doses of gamma irradiated (600 – 3500 kGy) and control samples of orange peels and found that similar spectra patterns in control and irradiated samples but at higher doses of irradiation, the changes in functional groups and decreased the sugar absorption values as a results of substrate degradation by radiolysis. In the present study, the UV-VIS absorption spectrum of jam and jelly samples were not altered by irradiation doses. In irradiated samples, the absorption values only slight variation was found between 200 and 300 nm.

Similar results were reported by Brasoveanu et al. (2005) the UV-VIS absorption spectrum of Spirulina platensis was not altered by electron beam irradiation even at higher doses (80 kGy). Nemtanu et al. (2006) reported that the slight decrease and increase in absorption values was also found in irradiated Spirulina and the same trend was reported by Lee and Song (2002) in irradiated myoglobin. Similar results were reported by Akram et al. (2012) the radiation-induced changes in gamma irradiated mushroom was analysed by using FTIR analysis (400 to 4000 cm$^{-1}$) had a comparable spectra pattern found between control and irradiated samples (2 to 50 kGy). In this study, the shape of the spectrum was similar in all doses of irradiated (2.5, 5, 7.5, 10 kGy) and non-irradiated jam and jelly products. The same condition was also found during storage period. From the results, no radiolytic products were found in
both jam and jelly products after electron beam irradiation at this dose level (2.5 to 10 kGy) and it was not significantly altered the overall composition of jam and jelly products.

In general, the processing of foods brings about changes in their microstructure. However, the physical changes of food material upon irradiation are less or non-significant than other conventional food processing methods like cooking, heating, refrigeration and drying (Akram et al., 2012). In this study, the microscopic structural analysis was carried out in irradiated and control samples by using light microscopy. In microscopic structure analysis of jam and jelly products, showed no significant differences between irradiated and control samples. Similar findings were reported by Moreno et al. (2006) during SEM analysis the minimum changes were observed in microstructure of electron beam irradiated Tommy Atkins mangoes (at 1 kGy). Akram et al. (2012) reported that the radiation-induced physical changes in gamma irradiated dried mushroom (0-50 kGy) was analysed by using scanning electron microscopy (SEM) showed microstructural damage after irradiation due to decreased percentage of rehydration but it did not cause significant effect on the quality of the mushroom.

The light microscopy analysis is an important food quality analysis tool to identify the extraneous materials and authenticity in commercial fruit products such as jam, jelly and preserves (Morais et al., 2004). According to food standards, jams and jellies are must be prepared with sound fruits and free of any extraneous material (Ministry of Health, 1978). In this study, there was no extraneous material and foreign plant tissues found in both irradiated and control samples of jam and jelly products. The results of present study reveals that electron beam irradiation at this dose level (2.5 to 10 kGy) did not altered the proximate composition of jam and jelly products and it can be used as a potential treatment to preserve the quality attributes of jam and jelly products.