2. REVIEW OF LITERATURE

2.1. Function of fat in human health:-

Dietary fat is a major energy source, is essential for growth and development, and provides essential fatty acids needed for maintaining structure of cell membrane and for prostaglandin synthesis, in addition, fat aids in the absorption of fat-soluble vitamins and other phytochemicals (ADA Reports, 2005). Fats are a major source of energy supplying about 9kcal/g, while proteins and carbohydrates supply only 4kcal/g for each (O΄Brien, 2004).

Fat is also a necessary component of body tissue. The brain and central nervous system are rich in fat and fat must be sufficient in the diet in times when these tissues are developing, as in pregnancy and the first several years of life. The body uses fat to manufacture needed chemicals such as hormones. Fats protect the cells and internal organs and allow us to store calories to protect us from times when food is not available. Fats stay in the stomach longer than other foods, making us feel full. Fats are also important for keeping the body warm and they make food taste better. A healthy, well-balanced diet includes adequate fat intake. For people with inadequate total energy intake, dietary fats are especially important for increasing energy intake to more adequate levels. For everyone, adequate fat is an important part of a healthy diet that meets individual energy and nutrient needs and takes into account appropriate levels of physical activity. Fats needs are usually expressed as a percent of total energy needs, which depend on age and levels of physical activity (FAO, 2011).

2.2. Functions of fat in foods:-

It is well recognized that fat plays critical functional roles in foods by providing tender texture, glossy appearance, good flavour, and emulsifying property. Thus, fat gives positive sensory and functional properties when incorporated into food formulations and its contribution to physiological benefits is also well-documented. Therefore, the removal of fat in food formulations can cause undesirable changes in food quality attributes (Jongbin *et al.,* 2010).

Fat is also critical as a food ingredient because it imparts many essential functional and sensory properties to food and food formulation. Fats provide texture and mouth feel, such as smoothness or creaminess, and maintain moisture in food. Fats also carry, enhance, and release the flavours of other food ingredients (Giese, 1996). Fat absorbs many flavour compounds and rounds the flavour by reducing the sharpness of acid ingredients. In meat fat carries the flavour and contributes to the juiciness and tenderness, key to the difference in taste of the various kinds of meat and poultry.

Fat in food has multiple functions during cooking processes. Its heat transfer properties enable rapid heating and attainment of very high temperature achieved by frying and deep–fat frying create many browning (eg, Maillard Reaction) taste components that have positive sensory attributes (ADA Reports, 2005). The major function of fat is to entrap air to the batter during mixing. In the cake batter largest part of the fat crystals remain in the aqueous phase. When air starts expanding, fat crystals adsorbed to the air-water interface melt and thereby release the fat –water interface for bubbles expansion. Large numbers of adsorbed crystals release sufficient interface to allow the bubbles to expand without rupturing (Brooker, 1993).

Fats and oils offer a variety of functional properties in foods (Segall & Sanderson, 2001). The level of fat determines the physical, chemical and sensory characteristics of food. Before the replacement of fat in food products can be considered, however, it is essential to understand what are it various functions. Physical and chemical functions of fat in food products can be grouped together since the chemical nature of fats determines more or less their physical properties. Thus, the length of carbon chain of fatty acid esterified with the glycerol, their degree of unsaturation, and the distribution of fatty acids and their molecular configuration (i.e.whether in the form of cis or trans isomers), as well as the polymorphic state of the fat will all affect the physical properties of food such as viscosity, melting characteristics, crystallinity, and spreadability (Jones, 1996).

2.3. Importance of fats in baked products:-

Fats provide structure in baked goods by trapping air during the creaming process. They transmit heat rapidly and uniformly and provide crisping. Melting points of fat components in a food determine the foods softness or chewiness. Fat content also influences the storage stability of food. (Giese, 1996). Fat also influences the rheological properties of cookie dough (Jissy & Leelavathi, 2007). In baked products, fat inhibits the formation of tough gluten strands, softens the crumb, imparts tenderness, and delays staling. Crispiness in cookies is due to fat in combination with some of the other ingredients. In flaky products such croissants and pastries, fat's ability to pool in layers and coat gluten strands is crucial. (ADA Reports 2005).

Fat is a very important ingredient of cookies because it contributes texture and pleasing mouth feel and positively impacts flavour intensity and perception. Many cookies and especially soft-type cookies contain large amounts of fat. However according to dietary guidelines fats should be consumed only in moderation (Drewnowski *et al.*, 1998).

Fats and oils, and their derivatives, are important ingredients in the baking industry (Matz, 1992).Shortening, being a fat, is the only major ingredient in the batter or dough that is not changed during the baking process. It is the only ingredient that not dissolved in water or made wet by water. In addition, Shortening does not combine with other ingredients (Lawson, 1995).shortening comprise from 10 to 50% of most baked products. The contribution of shortenings to baked products is in a number of ways: (1) impart shortness, or richness and tenderness to improve flavour and eating characteristics; (2) enhance aeration for leavening and volume; (3) promote desirable grain and texture qualities; (4) provide flakiness in pie crusts, Danish, and puff pastries; (5) provide lubrication to prevent the wheat gluten particles from adhering together, which retard staling; (6) enhance moisture retention for shelf-life improvement; and (7) provide structure for cakes, icing, and fillings (Baldwin *et al.,* 1972& O´Brien,2004).

Additionally, and besides their direct use as an ingredient, fats and oils are important as heat transfer media in the frying of doughnuts and similar products; as release agents applied to the baking surface of pans; and they facilitate production operations and reduce the amount of damaged products (Matz, 1992).The ability of fats to produce the desired effect in baked products is directly dependant on two interrelated factors: (1) their molecular composition, which governs the solid fat index (SFI) or ratio of solids to liquid triglycerides; and (2) their crystal habit (size, shape, and form), which is dependent on molecular composition and conditions under which the fat is stored, processed, and used (Moncrieff,1970).

Physical and chemical functions of fats can be summarized as follows: Texture: the melting points of fats and accordingly the crystalline/solid fat content of a system are important determinants of food's softness, chewiness and/or creaminess, the interaction of fat and oils with other food components is also important. For example, fats play a very important role in the texture of certain baked goods such as cakes and cookies. The fat coats and prevents extension of the gluten molecules during mixing. This "shortening" effect results in a tender product. Another, resulted examples are pastries such as croissants. In these products, thin layers of fat are placed between the layers of dough. The layers of fat physically prevent development of the gluten network between dough layers and the result is a flakey texture (Segall & Sanderson, 2001).

Aeration: fats aid in the aeration of products such as baked goods and dairy desserts. In dairy desserts, the fat is found in the form of a partially coalesced network that provides stability to air cells whipped into the products (Goff *et al*., 1995).

Heat transfer: the excellent heat transfer properties of oil are well known and of course are the basis of some important food manufacture processes such as deep frying (Lawson, 1995). Further more, fat affects the physical and chemical properties of the products, and hence has several practical implications, the most important of which are: (1) post processing characteristics,(e.g. shear-sensitivity, tackiness, migration, and dispersion), and (2) storage stability, which can include physical stability (e.g.de-emulsification, fat migration, or fat separation), chemical stability (e.g. rancidity or oxidation), and microbiological stability (e.g.water activity and safety)(Jones, 1996).

2.4. Health disorders aspects of fats:-

The nutritional and health implications of fats and oils in the diet is an area filled with often contradictory and some-times inconclusive scientific findings as well as confusion on the part of consumers. Fats along with carbohydrates and protein are major component of the human diet. Fats provide calories, fat-soluble vitamins, and the essential fatty acids linoleic, and linolenic acids, which are required for proper growth. There is, however, several health concerns associated with fats. Fats can promote obesity because of their high caloric content. And, there is evidence that a link exists between high-fat diets and increased risk of colon cancer as well as a link between fat, cholesterol, and heart disease. In addition, health authorities agree that in diets where weight control is important, a balanced diet should avoid excessive intake of fats and oils. The average U.S. calorie consumption is 37% of calories from fat as compared to the recommended 30% (CCC, 1996). In the united states today, more than 23million children and adolescents are overweight or obese (Ogden *et al.*, 2010).

Excess body weight, poor diet, and sedentary behavior have been associated with an increased risk of many chronic diseases, including hypertension, and type 2 diabetes, as well as depression, poor self-esteem, and associated quality-of life issues (Schwimmer *et al.*, 2003). Although overweight and obesity are found in all subpopulations, the burden is particularly striking among children, adolescents, and underserved populations. Children and adolescents are now experiencing weight-related chronic diseases once seen only among adults. In addition, the prevalence of overweight is higher among adolescents compared to younger children, Mexican-American boys compared to non-Hispanic black or white boys and Mexican-American and non-Hispanic black girls compare to non-Hispanic white girls (Ogden *et al.*, 2010).

During the 1950s, interest developed in exploring the possible relationship between dietary fats and oils and the incidence of coronary heart disease. Since diet can affect serum cholesterol (elevated serum cholesterol is one of the risk factors for cardiovascular disease), some health organizations recommend diet modification to achieve lower cholesterol levels. These diet modifications include reducing consumption of total fat, saturated fat, and cholesterol. Some studies have linked high fat diets to an increased risk of colon cancer, but the evidence for this association is not conclusive (ACSH, 1995).

Multiple factors influence overweight and obesity rates but, ultimately, an imbalance between energy consumed and energy expended is the determining factor. The current environment (including food stores, restaurants, schools, and worksites) and customs surrounding food in the United States have been labeled "obesogenic" and "toxic" due to the contributions made to this imbalance by large portion sizes, snacking, away-form-home meals, and consumption of sugar-sweetened beverages (Brownell *et al.*, 2009).

The evidence linking high fat diets to other cancers (such as breast and prostate) is even less so. Recently, there has been a fair amount of controversy about partially hydrogenated vegetable oils containing Trans fatty acids and their effect on raising plasma cholesterol levels (ACSH, 1995). Studies on the effects of consuming different amounts and type of Trans fatty acids are ongoing and, presently, inconclusive. However, partially hydrogenated oils are probably no worse and may be better than saturated fats, which they usually replace in food products.

High fat intake is associated with various health disorders such as obesity, cancer, high blood cholesterol, and coronary heart disease. The dietary guidelines recommended limiting total fat intake to no more than 30% of the daily energy intake, with saturated fats not more than 10% and mono unsaturated and polyunsaturated fats accounting for at least two- third of daily energy intake(Akoh, 1998). This awareness has prompted consumer about the amount of fat in their diet (O'Neil, 1993). Individual is considered to be obese when his/her Body Mass Index, BMI (which is calculated by dividing the subject's weight in kilograms by the square of his/her height in meters) ≥30 (WHO, 2000). Data on body weight in along- term, low-fat diet trial and examined the relationships between weight changes and changes in dietary components especially fat. Their results showed that weight loss was greatest among women who decreased their percentage of energy from fat (Howrad *et al*., 2006).

The percentage of dietary energy from fat has been suggested to be an important determinant of body weight (Willet, 2002**).** American families are eating out more often, with the frequency of dining out rising by more than two thirds over the past 2 decades from 16% of all meals and snacks in 1977-1978 to 27% in 1995. Meals eaten away from home are energy dense and contain higher amounts of total fat and saturated fat. Fat contributed 31.5% of calories in home foods and 37.6% of calories in food eaten away from home **(**Capps *et al*., 2002). Over the past decade, obesity rates have increased by more than 60% among adults, with approximately 59 million adults being obese. Among youth's ages 6 to 19 years, approximately 9 million are considered to by overweight. Due to this reason, in spite of the important role played by fat, there have been continued efforts to reduce the fat content in food products and replace it with various fat replacers (CDCP, 2004).

2.5. Demand for Reduced-Fatty Foods:-

Consumers demand for more natural, more nutritional and healthier food products presenting both nutritional and health benefits has increased over the years. In view of the general consensus that the amount and type of fat consumed is of importance to the etiology of several chronic diseases (e.g. obesity, cardiovascular diseases, cancer), it is not surprising that consumers readily adhere to nutritional guidelines concerning fat consumption. Largely influenced by health related concerns, there has been pressure on the food industry to reduce the amount of fat, sugar, cholesterol, salt and certain additive in the diet. Food manufactures have responded to consumer demand and there has been a rapid market growth of products with a healthy image (Liu *et al*., 2007**).**

Consumer acceptance and demand for reduced-fat products seems to be growing as fast as food manufactures can introduce new products. A1996 national survey conducted by the calorie control council found that 88% of US adults (172million persons) eat reduced-fat or fat free foods and beverages. On average, these persons use at least five different reduced-fat food products regularly, and 41%want more reduced-fat products available. More than half (56%) of all consumer believe fat replacement ingredients are needed (Giese, 1996). Although fat replacers, and the fat modified products they make possible, are no substitute for long established principles of dietary balance, moderation, and variety, these new foods are becoming an important component of people's diets and provide additional good-tasting food choices that can help people reduce fat intake.

Its understandable, however, that people find it difficult to reduce fat intake. Dietary change is a complex process that involves changing food-related behavior patterns. Although nutrition authorities agree that the primary strategy for reducing excess fat intake is to replace high-fat foods with a variety of low-fat foods, such as grains, vegetables, and fruits, most also acknowledge that it's very difficult for persons to eliminate favorite high-fat foods from their diets. Sensory preference for fats is a characteristic human trait, and studies on dietary change show that limiting fat intake is one of the most difficult health behaviors to sustain. Modern food technology, which can now modify the fat content of foods through the use of fat replacement ingredients, offers help to persons struggling to reduce their fat intake. Many health groups, including ADA, have welcomed development of reduced- fat products as another tool for achieving national dietary goals for reduced fat intake. Thanks to fat replacers, persons can choose reduced-fat versions of favorite foods and enjoy the familiar flavors and texture of fat-based foods without ingesting fat calories (ADA, 1991).

2.6. Fat replacers:-

A fat replacer is an ingredient that can be used to provide some or all of the functions of fat, yielding fewer calories than fat. Fat replacers need to be able to replicate all or some of the functional properties of fat in a fat-modified food (Schwenk & Guthrie, 1997). Fat replacers are usually evaluated and regulated by the US Food and Drug Administration (FDA) in one of two categories: as substances generally recognized as safe (GRAS) or as food additives. GRAS substances do not have to undergo extensive testing because they are recognized by scientific experts to be safe for specific uses. Food additives are subjected to a rigorous evaluation of safety, and manufactures must submit extensive safety and scientific data to support the new ingredient. Most fat replaccers currently used are classified as GRAS (Giese, 1996).

At present, a wide variety of ingredients are employed as fat replacers to capitalize on the unique properties and qualities of each bakery product. However, the important point is the consideration of the functionality of these replacers in a variety of products to obtain products with similar quality parameters. The most difficult part of reformulating with these fat substitutes is obtaining the mouthfeel, texture, taste and lubricity equivalent to that found in the conventional products (Kamel & Raser, 1988).

Fat replacers indicate food ingredients that can take the place of all or some of the fat in foods and yet give similar organoleptic properties to the foods (Miraglio, 1995). In general, they serve two proposes which are the reduction of fat and calorie contents since fat has energy values of 9kcal/g. depending on their chemical structure, fat replacers are classified into lipid, protein, and carbohydrate-based fat replacers.

For the successful development of fat replacers, there are fundamental factors which can be taken into account. First, fat replacers should be safe for the use in food applications. They also should have similar functional and organoleptic properties of fat in order to minimize the quality loss from fat replacement. Most of all, fat replacers should have significantly less fat and calories. Furthermore, it would be better to consider consumer dynamics for reduce- fat foods. The efforts to manage weight and chronic conditions have driven current health-conscious consumers to food-based solutions for reducing the risk of diseases and improving their health conditions. However, they want to change their current lifestyle by the sacrifice of their diet patterns. Therefore, there is a need to consider more various factors when replacing fat in foods, in order to satisfy the demand of current consumers for reduced-fat foods (Jongbin *et al*., 2010).

From a conceptual point of view, fat replacement is the reduction in fat constituted calories by using food ingredients with fewer calories than conventional fat. Therefore, one of the strategies to develop fat replacers is to explore reduced-calorie compounds from non-lipid-based source (such as carbohydrate and proteins) or manipulate the composition of fatty acids for lipid-based fat replacers(such as structured lipid). Since most of fat replacers from carbohydrate or protein sources have less energy (i.e. generally 4kcal/g) the energy density of the foods can be readily reduced. As previously mentioned, a diet high in fat leads to undesirable health problems such as obesity, high blood pressure, and heart disease. Therefore, the World Health Organization recommends that the total fat intake should be less than 30%of the total calories and that the intake of saturated fat should not exceed 10%of the total calories (WHO, 2003). Hence, the reduced content of fat and calorie derived from the use of fat replacers is a nutritional approach to prevent chronic diseases, thus providing beneficial health effects.

Five terms are used to describe ingredients to be used in order to reduce total lipid content:

- Fat replacer: general term that describe any ingredient used instead of fat.
- Fat substitute: synthetic compound developed to replace fat without any mass change, usually chemical structures similar to fat, but more resilient against hydrolysis by digestive enzymes.
- Fat mimetic: compound utilized to imitate the characteristics of fat that needs high rate of water, but resist to the hydrolysis by the digestive enzymes.
- Low-calorie fat: synthetic triglycerides combined with non-conventional fatty acids on the glycerol chain, resulting in a reduced caloric value.
- Fat extender: fat system that contains a proportion of standard fats or oils combined with other ingredients (lourencetti *et al.*, 2013).

2.6.1. Types of fat replacers:-

There are hundreds of ingredients available for replacing some or all of the fat in prepared foods. Many are common food components, such as water or sugar. Actually, the most popular fat replacement strategy is the binding of water with carbohydrates or protein (Washington, 1995). There are several categories of fat replacers, these are summarized as follows:

<u>2.6.1.1. Fat substitutes:</u> are ingredients that resemble conventional fats and oils and can replace fat on a gram-for –gram basis. Because they are fat based, they are often stable at cooking and frying temperature and provide all the function of fat while yielding <9kcal/g, which could be zero calories if none is absorbed.

<u>2.6.1.2. Fat analogs:</u> are compounds with many of the characteristics of fat but have an altered digestibility and altered nutritional value.

<u>2.6.1.3. Fat extenders:</u> optimize the functionality of fat, thus allowing a decrease in the usual amount of fat in the product.

<u>2.6.1.4. Fat mimetic:</u> are ingredients that mimic one or more of the sensory and physical functions of fat in food. They are based on carbohydrate, protein, or fat components used alone or in combination and provide from 0 to 9 kcal/g. they provide lubricity, mouth feel, and other characteristics of fat by holding water. The additional water makes them unsuitable for fat function such as frying; however, some can be used for baking and at retort temperature. However, they may be subject to excessive browning at high heat (ADA Reports, 2005).

Because fat replacers may contain calories, food manufactures using these products should assume responsibility for ensuring that the final product is not only reduced in fat but also reduced in total calories. The four broad categories of fat replacers include carbohydrate-based, protein-based, fat-based, and combination fat replacers. It is unlikely that one fat replacer is ideal for all uses, as discussed below.

2.6.2. Carbohydrate-based fat mimetics:-

Carbohydrate based fat replacers are the most widely used fat replacing ingredients. They are made primarily from grains, cereals, and other plant products. Carbohydrate based fat replacers are divided into those are digested and therefore, have a caloric value, and those are not digestible (Gershoff, 1995). Compared with traditional fats, which contain 9 kcal/g, carbohydrate based ingredients provide 0 to 4 calories per gram. When it is hydrated, however, its calorie density drops to 1-2 calories per gram of the finished product. Other carbohydrate such as cellulose and xanthan gum, are digested by bacteria in the lower intestine and contribute negligible calories (IFIC, 2000).

Carbohydrate based fat replacers still play multiple roles in foods, these roles range from improving qualities to reducing fat content in many categories of foods. Carbohydrate based fat replacers are commonly used to reduce and sometimes eliminate-"fat calories" in such foods as frozen desserts, puddings, salad dressings, gravies, sauces, baked goods, processed meats, cheeses, sour cream, and yogurt (IFIC, 1995).

Carbohydrate based fat replacers can not be used to fry foods, however, as they break down at high temperatures required for frying (Napier, 1997). Part or all of the fat in food can be replaced by carbohydrate based fat replacers bound to water, this is possible because starches, cellulose, dextrin, and maltodextrin can hold at least three times their weight in water; on the other hand, some gums can hold as much as 100 times their weight. Typically, translates into replacing nine "fat calories" with 0- 1.33" non fat calories "depending on whether a digestible or non digestible carbohydrate based fat replacer is used (Finley & Leveille, 1996).

Carbohydrate based fat replacers incorporate water into a gel type structure, resulting in lubricant or flow properties similar to those of fat in some food systems. It is likely that desirable texture can be achieved using those types of replacers, in addition to that there are few regulatory obstacles regarding any toxicological potential (Hassel, 1993). Moreover, among fat replacement materials, carbohydrate based fat replacers are widely used in foods especially in baked products, partly they have economical advantages over many other fat replacers (Alexander, 1992). These fat replacers are based on carbohydrates, such as cellulose, dextrins, maltodextrin, polydextrose, gums, fiber, and modified starch.

Carbohydrates based fat replacers can provide up to 4kcal/g, but, because they are often mixed with water, they typically provide only 1to2kcal/g, and, some (such as cellulose) provide zero calories. They are used mainly as thickeners and stabilizers and are typically used in a variety of food, including dairy-type products, frozen desserts, sauces, salad dressings, processed meats, baked goods, spreads, chewing gums, and sweets. However, they are not suitable for use in food that will be fried. The most common ones are dextrin and modified starches, which absorb water and form gels that impart a texture and mouth feel similar to fat.

Gums are used in baked goods and salad dressings, in which they act as stabilizers and thickeners and retain moisture in the reduced-fat product. Pectin can also be used as fat substitutes because of their gelling properties. Indigestible fiber such as cellulose is ground into micro particles that can form gels for use as fat substitutes. Polydextrose, a glucose polymer, resistant to digestive enzymes, provides about 1kcal/g, is used to replace sugar or fat in foods, keeps the food moist, and acts as a bulking agent replacing fat and sugar volume. When hydrated, polydextrose forms a gel that mimics some of the functional characteristics of fat. Maltodextrins, a nutritive polysaccharide derived from hydrolysis of cornstarch, can function as fat mimetics in flour-based dry mixes, baking systems, filling, and icings (Swanson *et al.*, 2002).

Maltodextrins can be substituted for 25% to 35% of fat in cookies, whereas indigestible fiber, such as cellulose, can replace 50% of fat in bakery products without compromising sensory characteristics. Thus, the diverse properties of these plant-based carbohydrates and their derivatives are used when developing fat mimetics (Conforti *et al.*, 2001).

2.6.2.1. Gums: gums, starches, pectin, cellulose, and other carbohydrate ingredients provide some of the functions of fat in foods by binding water as well as providing texture, mouthfeel, and opacity. Gums are long –chain polymers that are obtained from plant material such as seaweed, seeds, and tree exudates, they may also be produced by the chemical modification of polysaccharides or from microbial fermentation. They dissolve or disperse in water to provide thickening or viscosity-increasing effects, or combinations of gums with bulking agents may be used to reproduce the texture of dispersed fat. Gums most often used in low fat foods include xanthan, guar, locust, bean gum, and carrageenan. Gums are classified as GRAS (Generally Recognized as Safe) by the Food and Drug Administration (FDA) (Giese, 1996). Mucilage and gums are water soluble polysaccharides found in a widespread number of plants and also in some microorganisms. In many areas of West Africa, mucilaginous foods are commonly used to impart a desired slimy consistency to local soups and stews.

2.6.2.2. Flaxseed gum: flax typically has a small seed 3-6mm in length and 2-3.5mm in diameter. It is unique among cultivated seed plants with its contents of specific carbohydrates, protein and lipids. By far the most human nutritional interest in this seed has focused on the carbohydrate, in the form of fiber, and on the lipids, especially the essential alpha-linolenic acid.

Flaxseed contains 35-45% of fiber of which two-thirds are insoluble and one-third soluble. Insoluble fiber consists of cellulose, hemicellulose and lignin. Soluble fiber is in the form of mucilaginous material composed of polysaccharides. The majority of these polysaccharides are of non-starch type, similar to for instance guar gum, with major relative composition of gel forming carbohydrates (rhamnose, xylose, galactose and uronic acids). The optimal pH range for viscosity of flaxseed mucilage is 6-8, the pH environment in human intestines (Anneli *et al.*, 2005).

Flaxseed gum is commonly employed in the cosmetic industry as texturing agents; however, in the food industry, their application has not yet been extensively examined. Polysaccharides extracted from flaxseed have shown promise as a novel food ingredient, however, very little is understood on its effect when added to food emulsions. Flaxseed gum has shown considerable potential as a food hydrocolloid (Mazza and Biliaderis, 1989, BeMiller *et al.*, 1993 & Cui *et al.,* 1994). Flaxseed contains many nutrients and functional components such as polyunsaturated fatty acid, lignans, protein and gum (Oomah & Mazza , 2000 & Zhang *et al.*, 2009).

Flaxseed gum, which comprise about 8% of the seed yields L-galactose, D-xylose, L-arabinose, L-rhamnose and D-galacturonin acid by acid catalyzed hydrolysis(Mazza & Biliaderis,1989 & Warrand *et al.*, 2005).flaxseed gum has good water holding capacities and the water binding ability and rheological properties of flaxseed gum are similar to those of guar gum(Fedeniuk & Biliaderis, 1994). Flaxseed gum also shows weak gel properties, so that it can be used to replace most of the non-gelling gums for food and non-food applications (Chen *et al.*, 2006).

2.6.2.3. Okra gum: Latin binomial names for okra are *Abelmoscbus esculentus* and *Hibiscus esculentus* (Kumar *et al.,* 2010), and it is commonly known as bhindi in India, okra plant, gombo, and bhindi in South East Asia. However, in Middle East it is known as bamia, bamya or bamieh and gumbo in Southern USA and lady's finger in England (Ndunguru & Rajabu, 2004).

Okra is a flowering plant which belongs to the mallow family. It is mostly known for its edible green pods. The earliest records of okra show that the Egyptians grew this plant in the Nile valley and they used it as a main food source. In 1658, okra was introduced into Brazil and from there it spread to other South American countries. The okra plant's first appearance in North America was in Philadelphia in 1748. Today the plant is cultivated in the tropical and high temperature regions all around the world. Okra is an excellent crop because it is easy to grow, robust, and is rarely affected by pests and diseases. Additionally, okra grows well in difficult conditions such as droughts and tropical regions where other food plants prove unreliable. The yields for okra crop are very high since the plant is less affected by parasites and diseases (McWilliams, 2012).

Okra is known for its viscous mucilaginous solution that results when it is crushed and extracted in water. This solution, called okra gum, has many potential applications ranging from the pharmaceutical field to the food industry. For example, in the pharmaceutical field, okra gum has been shown to be a good diuretic agent. It is also used for the treatment of dental diseases. As for the food industry, okra gum has been used as a thickening ingredient for soups and stews. In addition okra gum can be used as egg white and fat substitutes in baked and frozen desserts (Jewkes, 2008 & McWilliams, 2012).

There are many health benefits that are associated with substituting fat ingredients with okra gum. Lowering the consumption of fat content in our daily food may reduce the risk of developing atherosclerosis. Atherosclerosis is a situation in which an artery wall thickens as a result of the buildup of fatty materials such as cholesterol or formation of plaque within the arteries. Another important health benefit of using okra gum in our diet is okra's ability to stabilize blood sugar in type 2diabetes, because it contains high levels of soluble fiber that reduces the absorption of sugars in the intestine. Studies have shown that obese patients with type 2 diabetes are at a very high risk of suffering from cardiovascular diseases. Therefore, a low fat diet is an important strategy for weight loss and reducing these risks (Wylie-Rosett, 2002 & McWilliams, 2012).

Okra contains proteins, carbohydrates and vitamin C (Dilruba *et al.,* 2009**),** and plays a vital role in human diet (Rabbani & Saifullah, 2009). Consumption of young immature okra pods is important as fresh fruits, and it can be consumed in different forms (Ndunguru & Rajabu, 2004). Fruits can be boiled, fried or cooked (Akintoye *et al.,* 2011).The composition of okra pods per100g edible portion(81%of the product as purchased, ends trimmed) is: water 88.6g,energy 144.00kj(36kcal), protein 2.10g, carbohydrate 8.20g, fat 0.20g, fiber 1.70g, Ca 84.00mg, P 90.00mg, Fe 1.20mg, β-carotene185.00mg, riboflavin0.08mg, thiamin 0.04mg, niacin0.60mg, ascorbic acid47.00mg(Gopalan *et al.,*2007& Varmudy, 2011). Carbohydrates are mainly present in the form of mucilage (Liu *et al*.,2005 & Kumar *et al*.,2009**).**That of young fruits consists of long chain molecules with a molecular weight of about 170.000made up of sugar units and amino acids. The main components are galactose (25%), rhamnose (22%), galacturonic acid (27%) and amino acids (11%). The mucilage is highly soluble in water. Its solution in water has an intrinsic viscosity value of about 30%.

Moreover, okra mucilage is suitable for industrial and medicinal applications (Akinyele&Temikotan, 2007). Industrially, okra mucilage is usually used for glace paper production and also has a confectionery use. Okra has found medical application as a plasma replacement or blood volume expander (Savello *et al*., 1980, Markose&Peter, 1990, Lengsfeld *et al*., 2004, Adetuyi *et al*., 2008 & Kumar *et al*., 2009**).**

2.7. Fat replacement in cake:-

Large quantities of bakery products are consumed all over the world. Because of changes in consumer behavior and eating habits, ready-to-eat convenience foods that are frequently available as small products intended for mobile consumption are of increasing importance. Bakery products made of refined wheat flour lack the natural bioactive components found in dietary fiber and consequently may yield lowered health benefits compared with whole wheat products. However, the consumption of refined wheat flour products has continuously increased (Institute, 1995 & Cheong, 2001**).**

A promising way for the food industry to provide healthful food is to replace fat and dietary fiber. Therefore, many bakeries are selling more products that have replaced wheat flour with dietary fiber in response to the latest health and wellness trends (Huh, 2006**).**

To be able to successfully replace fat in cakes, it is necessary to understand how it functions in the product. In cake making, fat has the property of air entrapment, which is of vital importance. The basis of the cake structure is formed during mixing when a myriad of minute air bubbles are incorporated into the batter. These expand as the temperature rises during baking and eventually, just as the batter is setting, they burst into one another to form the familiar, porous structure of cake crumb. Without some of stabilization, the air bubbles trapped during mixing would rapidly coalesce and rise to the surface of the batter to be lost. In cake, this function is performed by the fat. Any reduction in fat in the recipe will result in less air being mixed into the batter, resulting in cakes which are smaller in volume, with denser, drier texture and shorter shelf- life due to the premature staling (Dwyer & Gallagher, 2001).

In a study performed by Conforti *et al*., (2001) the performance of a maltodextrin gel as a replacement (25, 50, 75 and 100%) for shortening along with high-fructose corn syrup-90 (HFCS-90), adjusted for sweetness in each treatment, were evaluated in a high-ratio white-layer cake formulation. Two controls were used as a reference to fat-replaced cakes: control A (100% fat and 100% sucrose) and control B (100%fat with 50%sucrose/50%HFCS-90), which closely matched the sugar system of the fat- replaced cakes. Volume of cakes showed that treatment F (100% fat-replaced) was significantly different ($P \leq 0.05$) from the other treatment. Cakes made with fat replacers had a significantly ($P \leq 0.05$) higher moisture content. Result from both the physical and sensory analysis indicated that the combination of maltodextrin gel up to 75% reduction for shortening and sucrose/HFCS-90 resulted in satisfactory cakes.

Kim *et al*., (2001) showed that shortening in a conventional yellow layer cake was replaced by maltodextrin(MD), amylodextrin (AD), octenyl succinyated amylodextrin (OSAD), or mixture (MD+AD and MD+OSAD). The physical and sensory characteristics of the shortening-free cakes were investigated. The specific gravity and viscosity of the cake batter, and the volume index of the baked cake were significantly reduced by MD, whereas the cake with added AD or OSAD showed a higher volume index than the control cake containing the shortening. An equivalent mixture of MD and AD, or MD and OSAD, however, produced cakes with a volume index and colour defined as ΔE (ab) that was similar to the control cake. Sensory evaluation revealed that the cakes containing AD or OSAD had significantly higher firmness than the control, but the cake containing a mixture of MD and AD had firmness, springiness, and overall flavor scores similar to that of the control cake. According to instrumental texture profile analysis (TPA), MD addition, either alone or mixed with AD or OSAD, reduced firmness, whereas AD addition made the cake significantly firmer. When the shortening-free cakes were stored for eight days at 4°C, TPA revealed greater changes in cake firmness and adhesiveness for MD alone. Cakes made from mixture of dextrin (MD+AD and MD+OSAD) showed texture change with storage similar to that of the control cake, although the MD+AD cake remained softer than the control.

Shaltout *et al*., (2004) selected two types of carbohydrate-based fat replacers derived from potato starch and citrus peel known respectively as Paselli SA2 (P-SA2) and Slendid 100(S100) were used to replace shortening in two types of bakery products(oriental cookies "Gourayeba" and pound cakes). Results revealed that the addition of P-SA2 at all levels did not affect the sensory scores and products were highly scored as the full-fat control samples in cakes rather than cookies.

Kocer *et al*., (2005) studied the effect of polydextrose-substitution on the high-ratio cake in terms of the cake batter structure (emulsion drainage time, average bubble size, size distribution and uniformity), and expansion characteristics of the cake (cake height, average pore size and shape factor, size uniformity, size and shape distribution). Imaging technique suggested for the analysis of batter microstructure allowed detection of relative differences among formulations. Increase in polydextrose-substitution reduced emulsion drainage time, but decreased average bubble size and increased uniformity. Sugar-replacement decreased average pore size and uniformity within the crust and increased them within the crumb related with reduced batter stability as indicated by a decrease in emulsion drainage time. Fat-replacement had a similar effect on the crust, but the crumb was not affected to the same extent. Simultaneous polydextrose-substitution allowed 25% fat-replacement and 22% sugar-replacement resulting in 22% reduction in calorific value based on total sugar and fat content.

The effect of fat replacement by maltodextrin on cake batter viscosity and the quality of the resultant cakes was studied by Lakshminarayan *et al*., (2006). The viscosity of batter was reduced significantly when fat was replaced with equal quantities of maltodextrin. Cakes prepared from this batter had low volume and firmer texture. Relatively better cakes were obtained when lower quantities of maltodextrin were used in formulation. Viscosity of the above cake batter was relatively higher. A relationship between batter viscosity and cake volume was observed. Further improvement in cake volume could be achieved using emulsifiers. In the presence of glycerol monostearate little improvement in cake batter was observed, but the resultant cake volume was improved. However, sodium steroyllactylate, which improved the batter viscosity, did not improve the cake volume or texture.

Wafaa *et al*., (2011) studied microcrystalline cellulose (MCC), pectin and egg white as fat replacers in baked products, to produce low fat cakes and cookies. Cakes and cookies substituted with 25% egg white and pectin had dough properties much close to those of control samples. While acceptability of cakes and cookies with 25 and 50% MCC and egg white were quite similar to those with full fat control samples and had higher mean scores.

Kim *et al*., (2012) investigated the quality characteristics of sponge cakes made with cheonnyuncho powder. Cheonnyuncho (*cpuntia hum.fusa*) has multiple functional properties and is a good source of dietary fiber. The moisture, ash, and dietary fiber levels in the sponge cakes increased linearly with the addition of 0-9g of cheonnyuncho powder/100g of wheat flour, and carbohydrate and calorie contents of the sample decreased. The specific gravity and yield of dough increased with addition of cheonnyuncho powder. For the crumb color values, *L*and *a* decreased with addition of cheonnyuncho powder whereas the *b* and *ΔE* values increased. In the texture analysis, hardness and gumminess were reduced, but cohesiveness and springiness were increased by the addition of cheonnyuncho powder. When the sensory characteristics were evaluated, the addition of 9g of cheonnyuncho powder/100g of wheat flour showed the best sensory properties. Overall, the addition of 9g of cheonnyuncho powder/100g of wheat flour improved the physical quality and taste of the sponge cake.

Alamri *et al*., (2013) studied the effect of okra extract (OE) on the flowing and thermal properties of wheat and corn starch using rapid visco-analyzer (RVA), Brookfield viscometer, differential scanning calorimetry (DSC), and light microscopy. Starch- OE blends were prepared by replacing 5, 10, and 15% of the starch. The RVA data showed that OE reduced the peak viscosity of both starches relative to the control. That was expected because of the reduction in the amount of starch that was replaced by OE. However, the drop in starch setback was more than just the omitted starch in the blend. The DSC scan data of the blends showed higher peak temperature compared to the control, indicating slower starch-granules gelatinization in the presence of OE. Brookfield profiles (performed at 50 ˚c) demonstrated increase in shear stress as a function of shear rate, but at high OE content, the shear stress of the blends showed resistant to change which was confirmed by lower slope of shear stress as a function of shear rate at higher OE content. Overall, it can be concluded that OE has influenced the investigated properties of the starches, either by indirectly controlling water movement, or by interacting with amylase as indicated by starch gel setback outcome.

Fat was replaced at 35% to 100% in cake by maltodextrin (dextrose equivalent=3), inulin (high performance and granulated), oligofructose, citrus pectin, and microparticulated protein. Fat replacement by 35% did not induce significant differences in general. Above 65% fat replacement resulted in statistically significant ($P<0.05$) decreased viscosity (excepted for pectin) that was followed by statistically significant decrease in air incorporation and broader bubble size distribution. The starch gelatinization temperature showed a statistically significant increase when fat was replaced by fructose oligosaccharides. The cakes presented statistically significant increase or hardness, elasticity, and decrease of volume development as fat replacement increased above 65%. Also cake with increased fat replacement received lower scores on taste and flavour, whereas at total fat replacement they were evaluated as not acceptable. Nevertheless, at 65% fat replacement, the samples presented acceptable texture, physical, and sensorial attributes (Vassiliki & Vassiliki, 2013).

The influences of texturizing inulin as a fat replacer on some physicochemical, viscosity, colour, texture profile and sensory properties of some food products were investigated by Abd El-Razek *et al*, (2013). Fat was substituted by inulin (Frutafit® TEX) at levels of 50% and 100% in cake mayonnaise and chocolate cream pudding formulations. As well as, addition of inulin at concentrations of 2% and 4% as fat mimetic in *Karish* cheese. The results indicated that all the studied products with inulin had higher moisture content than products without inulin. Cake containing inulin had higher specific volume values as compared to control. The addition of inulin decreased the instrumental texture parameters, but the lowest values were figured out by products containing 100% inulin. The lightness value (L^*) with inulin was the highest of all formulations as compared to the control, except for low calorie pudding sample. Products containing 50% inulin and *Karish* cheese prepared in presence of 4% inulin showed the highest sensory overall acceptability scores compared to the control. Inulin can be utilized as a natural alternative to fat in the production of low-calorie food. Moreover, the foods containing inulin have high nutritional value while retaining the characteristics and qualities of similar textures of full-fat products. These low fat products can be used for obese people and diabetics.

2.8. Fat replacement in cookies:-

Fat is one of the principal ingredients that affect cookie texture, contributes pleasing mouthfeel, and positively impacts flavour intensity and perception. Many cookies contain large amounts of fat. On the other hand, in the U.S.A. and Europe, daily fat consumption represents about 40% of total caloric intake (Giese 1996).

Romanchik *et al*., (2002) studied the effect of using okra gum and applesauce as a fat replacer in chocolate bar cookies. Fat-free cookies were prepared with okra gum (OK) or applesauce (AP), replacing margarine and egg yolk in high fat cookies (CTL). The moisture content of cookies was determined by using a drying oven. The moisture contents of fresh OK (28.3±0.4%) and AP (27.6+1.1%) cookies were higher than CTL (8.5±0.3%) and remained higher after 48 hours ($P<0.001$) (n=3). Fifty two consumers evaluated the quality of cookies using a hedonic scale. Sensory scores for colour, smell, flavour, aftertaste, moistness, and overall acceptability for fresh cookies were acceptable, yet lower for flavor and aftertaste in fat-free cookies than CTL($P<0.01$). After 48 hours, moistness ratings for fat-free cookies were acceptable and higher than CTL ($P<0.01$). Okra gum is an acceptable fat replacer in chocolate bar cookies.

Carbohydrate- or proteins- based fat mimetic were used to replace up to 50% of fat in cookies. The effect of the type of fat mimetic and of the percentage of fat replacement on textural behavior of the products was studied by compression tests. The stress-strain curves obtained were fitted by an exponential equation containing as parameters the maximum stress (σ max), the maximum strain (ε max) and a viscoelastic exponent (f). A simple mathematical model for σ max and the ratio σ max/ε max, indicative of hardness and brittleness of the cookies, respectively, was developed. Both these values depended on the percentage of fat replacement and the type of fat replacer used. Hardness and brittleness of the cookies generally increased with fat replacement, but a moderate increase was obtained by some of the fat mimetics, resulting in products with better textural characteristics than their low-fat, no mimetic-added counterparts. The viscoelastic exponent increased also with fat replacement and the model parameters depended on the type of the fat mimetic (Zoulias *et al*., 2002).

Mansour *et al*., (2003) evaluated low-fat cookies prepared by partial replacement of butter oil with different type of carbohydrate-based fat replacers. The low-fat cookies prepared with paselli D-lite, paselli MD10, and litesse had lower ($P\leq0.05$) rating scores than the control for all attributes except crispness, which was similar ($P\leq0.05$) to the control. On the other hand, cookies prepared with firm-tex(1:1) had similar ($P\leq0.05$) sensory scores as the control for all attributes except flavour and appearance in cookies prepared with N-flate combined with firm-tex which had higher ($P\leq0.05$) scores than the control. Ratings of the sensory panel showed that cookies prepared with N-Oil and N-Flate plus Firm-Tex (1:1) were preferred for all attributes.

The feasibility of substituting okra gum for 25%, 50%, 75%, or 100% milk fat in frozen chocolate dairy dessert was examined. Fifty-six consumers evaluated the frozen dairy desserts using a hedonic scale. Consumers rated colour, smell, texture, flavour, aftertaste, and over all acceptability characteristics of all products as acceptable. All ratings were similar among the products except for the aftertaste rating, which was significantly lower for chocolate frozen dairy dessert containing 100% milk-fat replacement with okra gum compared with the control (0% milk-fat replacement) ($P<0.05$). The melting points of all products were similar, melting rates slowed significantly as milk-fat replacement with okra gum increased, suggesting that okra gum may increase the stability of frozen dairy desserts ($P<0.05$). Overall, this study shows that okra gum is an acceptable milk-fat ingredient substitute in chocolate frozen dairy dessert (Romanchik *et al*., 2006).

The shortening content in a wire-cut cookie formulation was reduced at 10, 20, 30 and 40% and replaced with apricot kernel flour (AKF). The effect of increased concentrations of AKF on the properties of cookies was investigated. Protein, fat and total dietary fiber (TDF) contents of the apricot kernels were determined as 21.8%, 40.2% and 35.8%, respectively, which confirmed that the apricot kernel is an important source of dietary protein as well as oil and fiber. Addition of AKF decreased the spread ratio and increased the hardness of the cookies ($P \leq 0.01$). However, sensory evaluation revealed that the cookies containing AKF were acceptable to the panelists at all concentrations ($P \leq 0.01$). TDF contents of the cookies increased significantly ($P \leq 0.01$) as the AKF supplementation increased. AKF is a suitable replacer of shortening in cookies at 10 and 20% (Seker *et al.*, 2010).

The structure, texture, appearance, color and consumer sensory analysis of low-sucrose muffins in which the sucrose had been totally or partially replaced (25%, 50%, 75%) by a sucralose:polydextrose mixture(1:1012) was studied by Martinez *et al.*, (2012) . The structural characteristics of the muffin batters and of the baked muffins were studied through rheometry, microscopy, image analysis and texture analysis. The replacement of sucrose decreased the viscosity, image analysis and texture analysis. The replacement of sucrose decreased the viscosity, viscoelasticiy and specific gravity of the raw muffin batter. The evolution of the batter's viscoelastic properties during heating reveals a decrease in the thermosetting temperature with sucrose replacement. These changes in the batter were associated with a muffin with less height, hardness, springiness, cohesiveness, chewiness and resilience and fewer air cells than the control. For 50%sucrose replacement, the appearance, colour, texture, flavour and sweetness and general acceptability were similar to those of the control. Significantly less acceptable muffins were obtained with 100% sucrose replacement.

Formulations of cookies with partial replacement (standard-0%, R1-25%, R2-50% and R3-75%) of fat by inulin were studied. Results indicated that the partial replacement of fat by inulin in the production of cookies was effective in reducing the percentage of total lipids in the final product, with maximum reduction of 86% in formulation R3, without changing the parameters for moisture, crude fiber and instrumental colour. Once inulin was increased, the size of the cookies after baking decreased, therefore increasing the crispness of the cookies made from the formulation with the highest level of replacement, represented by R3, which negatively impacted the sensory evaluation of flavour and purchase intention for the product, while formulation R2, with 50% fat replacement by inulin, presented similar results to the standard product, being the formulation with the greatest sensory acceptance and physical characteristics. Therefore formulation R2 exhibited the beast nutritional and sensorial performance (Lourencetti et al., 2013).