DEPENDENCE ON HUMECTANTS, HEAT TRANSFER CO-EFFICIENT AND KINETICS OF MOISTURE REMOVAL IN DEEP-FRIED PRODUCTS

THESIS

By

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Submitted to

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Partial fulfillment of the requirements for the degree

OF

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(2002)

DEDICATED TO MY REVERED PARENTS

Parents are your world
No one can replace them
They are like a stem
That can never let you fall
Their love, their care is a precious gift
Those who are blessed with it have no regrets
Their love acts as a protective shelter
Which helps when anything is the matter
Trust them and at any cost
Never lie, be truthful to them
And with all their efforts they will make you a gem

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CERTIFICATE I

This is to certify that the thesis entitled **Dependence on humectants, heat transfer co-efficient and kinetics of moisture removal in deep-fried products,** submitted in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy** (**Home Science**) in the subject **Food Science and Nutrition** of CSK, Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Ms Julie Dogra** [H-99-40-01] daughter of **Major Piare lal** under my supervision and that no part of this thesis has been submitted for any degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the thesis entitled **"Dependence on humectants, heat transfer co-efficient and kinetics of moisture removal in deep-fried products"** submitted by **Miss Julie Dogra** daughter of **Major Piare Lal** to the CSK, Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy** (**Home Science**) in the subject of **Food Science and Nutrition** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Chapter-I

INTRODUCTION

CHAPTER - I

INTRODUCTION

We must eat daily, but the food is produced seasonally. Our daily diet must be balanced, but the seasonal food does not represent all food groups. Therefore, we must find ways and means of preserving food over long periods, which is safe and relatively nutritious. Exceptions perhaps water and some salts, the food constituents are of biological origin. Therefore, human foods are actually biological systems in whole and in part, which are consumed by a dynamic and disseminating biological system called human being. The various biological systems (bacteria, yeast's, fungi, plants, insects and animals) are dependent upon each other for food and survival. In the history of the world, therefore, the growth and survival of various cultures and civilizations has been absolutely and directly related to man's ability to feed him. In nearly, man is a unit of the dynamic biological cosmos of earth. By applying his intellect he has learned to nurture those organisms he needs for his food and to destroy there which are in competition with him and his sources of food.

Fishing in the Nile, fowling in the marshes among the millions of migratory birds on their way to south, and hunting in the dessert gave the early man his food. It is important to understand that modern methods of food preservation have developed through centuries on the basis of practices employed on the farm. In the Middle East and in Central Europe, sliced apples were strung and dried; grapes, split apricots, figs, dates, and almonds were dried and kept for winter use. Salting of vegetables was generally practiced. North American Indians commonly employed smoke preserving with salmon. The art of curing meat with "corn" (old name for salt crystals) is very old. Salt also has been widely employed for prolonging the edible life of butter, cheese and milk curds later transformed into cheese. Fermented apple juice or cider is recorded from the fourth and fifth centuries. Arctic peoples had used refrigeration for centuries and are said to have brought the first frozen meat to England. The credit of providing canned foods goes to Nicolas Appert who gave method of preserving food by heating it in hermetically sealed container.

Homosapiens from early Stone Age had perfected some techniques to preserve, store for rainy season, enhance palatability and retain nutrients. These innovations have come up by hit and trial methods based on the experiences and wisdom of the primitive man. Some of these techniques were based on the application of heat (pasteurization and cooking), removal of moisture (drying and dehydration), application of low temperature (freezing and cooling), controlled atmosphere (smoking), chemicals (fermentation, brining and salting) etc.

Frying has been one such endeavor with the application of heat in boiling a suitable media for preparation of food and it is today a universal method employed for cooking and preservation of foods. Today there are various time tested frying techniques, out of which shallow frying and deep-fat-frying are the most common. In shallow frying the amount of frying medium is less than that of food to be fried and in deep-fat-frying the food is completely immersed in large quantities of heated medium. Deep-fat-frying is more of a technique than science and that can be defined as a process of control dehydration and browning with hot oils as the heat transfer medium. This involves both heat transfer and mass transfer. By totally immersing the food in hot boiling fat. Here the cooking is more efficient than dry heat of an oven and more rapid than boiling in water due to higher temperature possible with deep-fat-frying resulting in more rapid penetration of heat into the product being cooked. Due to rapid penetration of heat, thermal inactivation of heat resistant spores normally follows. During frying as the temperature increases, the rate of inactivation increases and Z value (temperature change which results in ten fold change in decimal reduction time) is achieved.

The rationale for studying this process is that heat and mass transfer occurring during frying has a major influence on the final product quality. It is one of the few food processes where the heating medium becomes a major part of the final processed product. The physical changes occurring in food materials include evaporation of water, rise in temperature, dimensional changes, absorption of oil and changes in densities. The rate-controlling step for mass transfer in the frying of food could be energy transfer to the product or diffusion of water/vapour through the product. The properties such as thermal conductivity, specific heat and density play an important role in the design and analysis of frying process. For example for a two component system containing solids and water:

$$K = V_S K_S + V_W K_W$$

Where, V_S and V_W are volume fractions of solids and water and K_S and K_W are thermal conductivities of solids and water, respectively. Thermal conductivity decreases, as the food becomes drier. This thermal conductivity is used to calculate heat transfer co-efficients during deep-fat-frying because during this process steady state is achieved at all the positions inside the product whereas, steady state is reached much earlier in the portion closer to the surface of the product. Thus, the heat transfer co-efficient factor assumes a great significance.

The conservation of energy in the food processing entails internal energy, which is a function of temperature. A change of internal energy takes place when there is a temperature change. If no energy crosses the boundary than the process is called adiabatic. The internal energy plus the product of the pressure and the volume is known as Enthalpy, which is a thermodynamic property expressed as:

$$\Delta H = \Delta \mu + \Delta(pV)$$

Where H is enthalpy, μ is the change of internal energy and pV product of pressure and volume. The changes in enthalpy during food processing are important parameters.

The oil that is used to transfer heat energy is also responsible for delicious odour, flavour and texture associated with fried foods. Crust is formed during most deep-fat-frying and is one of the most palatable characteristics of fried foods. There is increase in the energy value of the food. The high temperature used for frying of foods destroys any pathogens present on the surface. Some of the foods that are not palatable in raw form are well accepted after frying; also shelf-life of the foods is enhanced. However, there is considerable loss of nutrients like vitamins (Vitamin C being the most sensitive) and minerals. Even the natural colour of some foods is lost during the process of deep-fat-frying. The cost of fried product is increased due to higher oil pickup. The higher oil content in deep-fat-fried foods is of concern for consumers because excessive consumption of oil is known to cause health problems.

The loss of moisture and absorption of oil by the food are important considerations for the determination of the product quality, process standardization and energy expenditure. Oil uptake by the products initially containing little or no fat, takes place at the surface. The absorbed oil is located near the surface and the crust. The nature of the food product, the frying medium, temperature, frying duration, shape, product composition, porosity, initial moisture content, crust of the food product to be fried, pre-treatment of the food product and other factors do affect the extent of oil absorption. Process parameters of importance during deep-fat-frying include temperature of frying, initial moisture content of the raw material and the time of frying.

Batters and breading can influence oil absorption but the reported results have been inconsistent. Initial and final water contents have a major impact on oil uptake during deep-fat-frying. As water retention is strongly affected by some food additives, the addition of alginates or cellulose may affect the amount of oil uptake and moisture during deep-fat-frying. Humectant refers to a substance that absorbs moisture and aids to maintain the water content of materials like baked products. They allow addition of sugar without adding more water and so prevent growth of moulds. These qualities are achieved through physical or chemical effects in which polyols behave as crystallization modifiers, hygroscopic agents or humectants, softening or plasticizing agents, sweetness controllers, dietary and rehydration aids.

The humectants viz., sorbitol, mannitol and glycerol are less sweet than sugar, ranging in rating from slightly less than half, as sweet as sugar to three fifth as sweet as sugar. In addition it should be pointed out that crystalline (dry sorbitol) exhibits a marked cooling effect and conversely to some persons glycerine exhibits hot taste. In generalization, it can be said that use of three polyols may modify a taste profile only slightly and may usually show a slightly reduced sweetening level in comparison with sugar. There are indications that sorbitol is fermented more slowly than sugars and it may be less cariogenic, when ingested orally because it is washed off the teeth or diluted with saliva before critical pH is reached. These humectants are cleared for uses as food additive (deemed GRAS by FEMA).

Thus, the present study was undertaken to determine the effect of different frying media, frying temperature, effect of packaging material and incorporation of humectants on kinetics of deep-fat-frying and shelf-life of doughnuts with following objectives :

- To ascertain the thermodynamic properties of frying.
- To study the kinetics of moisture removal during the process of deep-fat-frying of selected food.
- To ascertain the effect of humectants on the sorption equilibrium in fried foods.
- To study the effect of deep-fat-frying on the proximate composition.
- To work out economics of the product formulations.

It is hoped, the results of the study should be of immense value to the research scholars, food restaurants, human nutritionists, health professionals, teachers and students interested in the subject.

Chapter-II
REVIEW OF LITERATURE

CHAPTER -II

REVIEW OF LITERATURE

Some of the important work done in India and abroad relevant with the investigation has been reviewed in the following paragraphs.

2.1 Chemical characteristics of refined wheat flour

2.2 Physical parameters of oil

2.3 Deep fat-frying

2.4 Heat and mass transfer

2.5 Kinetics of deep-fat-frying

- Thermal conductivity/Heat transfer co-efficient

- Moisture loss and oil absorption

2.6 Factors affecting oil absorption

2.7 Use of ingredient to lower oil absorption

2.8 Acceptability of fried foods

2.9 Shelf-life of fried foods.

2.1 Chemical characteristics of refined wheat flour

Wheat is usually ground into flour before being prepared as food. Flour containing the whole grain may be used but usually the germ and varying proportions of the outer layers are separated from the central portions of the grains and discarded as bran when it is to be used in baking. The proportion of whole grain that is utilized to make flour is known as extraction rate. Thus a 85 per cent extraction rate flour contains 85 per cent by weight of the whole grain and 15 per cent is discarded as bran. Thus, a flour of high extraction rate has lost little of aleurone layer and outer endosperm. Thus, the chemical composition of whole *atta* becomes moisture 12%, carbohydrates 64.1%, protein 10.8%, gluten 7.9%, total ash 1.5%, crude fibre 2.2%, fat 1.5%; refined wheat flour moisture 12.0%, carbohydrates 67.3%, protein 9.8%, gluten 9.2%, total ash 0.76%, crude fibre 0.17%, fat 1.5%), and of resultant *atta* moisture 12.0%, carbohydrates 64.2%, protein 12.4%, gluten 7.1%, total ash 1.66%, crude fibre 2.10%, fat 2.5%, respectively (Achaya, 1999). Low extraction rate flour as compared with high extraction rate flours have following advantages: they are whiter and bread made from them is more attractive to eye. They contain less fat, which makes it less likely to go rancid, and thus white flours are more easily preserved. They contain less phytic acid and therefore, the minerals remaining in them are more readily absorbed. They have, more uniform baking qualities and bread made from them has finer texture. However, they contain less of B group vitamins, calcium, iron, protein and other trace elements and fibre. However, Tipples *et al.*, 1978; Mok and Dick, 1999; Hatcher and Kruger., 1997 and Hatcher *et al.*, 1999; Manohar and Rao, 1999 reported variations in the chemical constituents of wheat flour on the basis of extraction rate, varietal differences and agro-climatic conditions. The variety hard red winter wheat flour had (moisture 9.24, protein 12.13, ash 1.19, water absorption 60.2%); hard white winter wheat flour had (moisture 13.0, protein 9.27, ash 1.52, water absorption 57.5%); soft red winter wheat flour had (moisture 13.0, protein 9.27, ash 1.49, water absorption 36-49.4%); Canadian western red winter wheat flour had (moisture 12.6, damaged starch 6.9, water absorption 59.0%) and in Canadian Winter red winter wheat flour had (moisture 11.9, protein 5.3, ash 0.39, water absorption 53.1%), respectively.

Therefore, because of lower nutritional properties of low extraction rate flours, it was less liable than whole meal flours to infestation by beetles and the depredations of rodents. They also pleased the bakers for it ensured strong flour. 'Strength' is a property that is apparently due to the removal of protein rich in sulphydryl (SH) groups that are present particularly in aleurone layer. It enables the dough to rise and so allows breads and cakes to be made with a firm, dry texture. Strong flours give the bakers the opportunity to show their art.

2.2 Physical parameters of oil

The quality of given fat or oil significant to humans is determined by means of a number of physical and chemical tests. Acid value is the number of milligrams of potassium hydroxide (KOH) required to neutralize the free fatty acids in one gram of fat/oil. Thus, it indicates the amount of free fatty acids present in fat & high acid value indicates unstable fat stored under improper storage conditions. Acid values of 0.16, 1.78, 6.45 mg $KOHg^{-1}$ have been reported by Tawfik and Huyghebaert,(1991) and Yoon *et al.*, (1987) in mustard oil, sunflower oil, refined palm oil while Kaur *et al.*, (1991) reported these values as 0.39 and 0.28 in case of mustard oil and groundnut oil. Kalia *et al.*, (1996) and Al Kahtan (1991) studied oxidation of oils in repeatedly used frying media. It was observed that the peroxide value of the frying media increased gradually with the increased number of frying and storage periods. A peroxide value of 14.04 per cent was obtained in case of mustard oil.

On the other hand, iodine value is a measure of degree of unsaturation and higher value indicates a higher degree of unsaturation of fatty acids present in the oil. The iodine values as reported by Tauifik and Huyghebaert (1991) for olive oil, sunflower oil, refined palm oil were 90.27, 138.02, 55.25, respectively. When four different oils (rape seed/mustard, cottonseed, groundnut and shortening/vegetable ghee) were used for frying potato chips (var. *Kufri. Jyoti)* of uniform size and thickness, they showed a gradual increase in viscosity, which was due to the thermal deterioration during the frying process (Chanderkanta and Kalia, 1995; Yoon *et al.*, 1987). Aryer *et al.*, (1969), Rajo and Perkins (1987) found that during frying, oils/fats are subjected to very high temperatures 180–240^{0}C and results in thermal deterioration of media accompanied by increased viscosity and off-flavour. On an average, Chanderkanta and Kalia (1995) have found that free fatty acid contents of ghee (shortening) were significantly lower than those of oils. Among oils, mustard oil showed highest free fatty acids content (0.246per cent) in initial heated samples. Average weekly comparison in free fatty acids showed that increased number of frying increased the free fatty acids content irrespective of the media. However, use of the same media resulted in free fatty acid contents being increased from an average of 0.205per cent of fresh sample to 0.885per cent after 6th week of frying. Similar findings have also been reported by Thompson *et al.*, (1967) and Stevenson (1984).

2.3 Deep-fat-frying

Deep-fat-frying is an important unit operation, which can be considered as the combination of frying and cooking (Mittleman *et al.*, 1983), while Varela (1988) expressed it as a complex and important operation widely used by the food industry and the consumers. According to Singh and Tyagi (2001) deep-fat-frying is more a technology than a science, which can be defined as a process of control dehydration and browning with hot oils as heat transfer mediums. They support that frying of a product results in distinctive structure (Hoyem and Osker, 1977). The upper part of the product is outer zone surface that results in crust and inner zone is core. The uppermost zone takes uniform golden brown colour in frying resulting in browning reaction or Millard reaction that occurs when sugar and protein present in the product react in presence of heat. The degree of colour development depends on the time and temperature of frying and on the composition of surface involved.

During deep-fat-frying, heat is transferred to the surface of food by convection from the frying oil and through the product by conduction. Moisture from the food migrates out of the food due to a concentration gradient and similarly fat from frying medium is transferred into the product (Williams and Mittal, 1999). Similar observations were given by Gamble *et al.*, (1987) and Blumenthal, (1991). They reported that when the slice is placed in hot oil, the moisture at the surface is lost rapidly. A diffusion gradient is provided, since the outer surface is dry, the inner moisture is converted to vapour and this causes a pressure gradient, then the vapour during frying of a product migrates from the central portion to the surface. At the same time oil enters the voids left by the vapour.

The chemical reactions that take place during deep-fat-frying bring about hydrolysis, oxidation and polymerization of the frying medium. Oil degrade with continued use involving thermal and oxidative alterations (Tseng *et al.*, 1996). Factors that influence the proportions of breakdown components in vegetable oils are temperature, presence and extent of oxygen, heating time, frying capacity, turnover method of heat transfer, metal in contact with oils etc. Mitlleman *et al.*, (1983) added that several chemical and physical changes like starch gelatinization, protein denaturation and crust formation occurs.

2.4 Heat and Mass Transfer

Like many food processing operations, frying of foods involves simultaneous heat and mass transfer and process parameters of importance during deep-fat-frying include temperature of frying, initial moisture content of raw material and time of frying (Mittleman *et al.*, 1983). Saguy and Pinthus (1995) stressed that there are both conduction and convection modes of heat transfer and heat is transferred from the oil to the food samples. In addition to heat transfer, mass transfer also takes place. Pravisani and Calvelo (1986) added that study of these parameters and of temperature profile of the product during frying operation, gives an insight into the heat and mass transfer characteristics of the process and the product. During deep-fat-frying oil/fat serves as heat transfer medium, migrates into the food providing flavour and increasing caloric content.

During deep-fat-frying heat transfer is accompanied by mass transfer, which is characterized by penetration of oil into the product and exit of water as vapour from the product (Blumenthal, 1991). But according to Varela, (1988) crust is formed during frying due to loss of moisture and diffusion of oil into the sample and development of this crust influences heat and mass transfer process and oil uptake (Farkas *et al.*, 1992). Deep-fat-frying has also been stated as a process of control dehydration (Gupta, 1993) with hot oil as heat transfer medium and this involves both heat and mass transfer. Models for frying and mass transfer in foods coated with edible films have been reported. A model for deep-fat-frying of beef meat ball includes heat, moisture and fat transfer (Ateba and Mittal, 1994)

2.5 Kinetics of deep-fat-frying

2.5.1 Thermal conductivity/ Heat transfer co-efficient

Literature reported show wide variations in the values of heat transfer co-efficients from 300-1800 $Wm^{-2}k^{-1}$ during frying. However, in case of frying of urd vada in a model system, the heat transfer co-efficient was reported to be 939 ± 54 $Wm^{-2}k^{-1}$,whereas, it was not clear if the value of 'h' varied with initial moisture content (Indira, 1996). For a shaped product such as meat patties at a frying temperature of 160^{0}C, the heat transfer co-efficient was reported as 500±200 $m^{-2}k^{-1}$ by Dagerskog and Bengston (1974), while Rene *et al.*, (1986) reported this value as 900 Wm^{-2} k^{-1} at oil side during frying of potato slices. A mathematical model for moisture loss during potato slice frying was developed and heat transfer co-efficient of the oil film for a solid copper sphere was calculated as 1800 Wm^{-2} k^{-1} (Mittleman *et al.*, 1983).

Researches have also shown that the temperature and moisture contents have a pronounced effect on the thermal properties of the foods. The marked effect of the moisture content on the thermal properties was possibly due to the reason that both specific heat and thermal conductivity of water were considerably higher than that of the air filled pores occurring at reduced moisture content. The thermal conductivity and specific heat increased with increase in moisture content and temperature (Jha and Prasad, 1983; Yamada, 1970; Rao et al., 1975; Abdul, 1983; Tschubik and Maslow, 1973 and Wang and Brenan, 1992). Also the thermal diffusivity increased with increase in temperature which is supported by the findings of Mathews and Halls, (1968) and Rice et al., (1988).

2.5.2 *Moisture loss and oil absorption*

A conventional way to describe fat uptake is as a percentage of total weight of the product (wet basis), few work present results on dry basis (Makinson *et al.*, 1987) or on the basis of weight of pre-fried sample (Weaver *et al.*, 1975). While Sweetman (1936) added that oil temperatures had no effect on final oil content when frying temperatures were above 121^{0}C. Lowering initial moisture content and reducing the frying time may be used to produce chips with low oil content but this will necessitate a post -fry drying operation, which automatically takes place when hot chips are removed from oil and cooled in air. Extensive work has been done on deep-fat-frying characteristics of potato chips, french fries and meat patties and reported a relationship between oil uptake and moisture loss during frying of potato slices has been developed (Gamble and Rice, 1987). They also examined the variations in moisture and oil content of sample of 1.5 mm thick slices of potato at frying temperature of 145, 165 and 185^{0}C as a function of time and the moisture loss and oil uptake were found to be interrelated. Both moisture and oil contents were linear functions of the square root of frying time and were independent of frying temperature within the temperature range examined (Gamble *et al.*, 1987).

Similarly Mittleman *et al.*, (1983) developed a mathematical model for moisture loss during potato slice frying and Pravisani and Calvelo (1986) estimated the cooking time required for potato strip frying. The process variable for preparation of fresh fried potato chips were optimized (Pokharkar and Mahole, 2001) and minimum frying time to reach a final moisture content of 3 per cent were found to be 256 sec at 145^{0}C, 166 sec at 165^{0}C and 111 sec at 185^{0}C for 2.0 mm slices. The corresponding time for 1.5 mm slices were 221 sec at 145^{0}C, 151 sec at 165^{0}C and 99 sec at 185^{0}C. The oil content of chips increased with increasing frying time upto 238 sec at 145^{0}C, 150 sec at 165^{0}C and 104 sec at 185^{0}C for 2.0 mm slices. Beyond these periods, the increase in oil uptake and moisture loss was very small. The oil content of 39-41 per cent was observed for both 1.5 mm and 2.0 mm slices when residual moisture content was 2-3 per cent.

During frying process, the oil replaces water; hence it can be perceived that flour requiring a higher level of water would have higher oil content after the frying operation. The temperature of the product being fried exists in a temperature range from room temperature up to 100^0C at which it is lost as steam (Annapure *et al.*, 1988). But Reddy and Das (1993) added that the oil content at any time is found to be independent of oil temperature and thickness of slice, but is closely related to moisture present during frying of potato slices. A correlation co-efficient of 0.98 was obtained between oil and moisture contents. While Farkas *et al.*, (1992) and Keller *et al.*, (1986) added to the above statement that oil uptake during deep-fat-frying of products initially containing little or no fat takes place at the surface of the product and absorbed oil is located near the surface and crust. Pinthus *et al.*, (1992) developed a oil uptake criterion, Ur expressing the weight ratio between oil uptake and moisture loss as:

$$Ur = \frac{\text{oil uptake (g)}}{\text{water removed (g)}}$$

Considering the initial and momentary moisture and oil contents derives the value of Ur. The criterion was found to alleviate the dependency of oil uptake on water replacement.

In a study (Indira, 1996) during frying of urd vada, it was observed that oil content of the product increases gradually with frying at all temperature. At lower frying temperatures (155 and 165^0C), the oil content was slightly higher as compared to that at higher temperature ($172\text{-}192^0C$). Further more, at frying temperatures of 182 and 192^{0}C, the oil was noticed to be just on the surface of the product. Analysis of the crust showed around 12per cent (w/w) of oil where as hardly any extra oil had been absorbed by the core which was found to be around 5per cent (dry basis) and closer to the oil content of raw material. Guilalumin (1988) observed a similar phenomenon for a crust-forming product. Some researchers worked out kinetics of moisture loss and fat absorption during frying of plantian and described overall behavior of frying at a temperature of 185^{0}C into two phases. An initial phase between 0 and 20 sec, during which there is rapid moisture loss and considerable fat uptake. In second phase starting at 20 seconds, exchanges slowed down markedly and the rate of moisture loss and oil uptake dropped (Diaz *et al.*, 1999)

Multiple linear regression model has been successfully applied (Sahin *et al.*, 2000) to describe the variation in moisture content with respect to temperature, time and oil content and oil was found to be negatively correlated with moisture content and changed quadratically with frying time. Moisture content decreased while oil content increased as temperature and/or frying time increased.

Apart from physico-chemical changes during deep-fat-frying, the loss of moisture from the product and entrance of oil into the product are of importance as these determine the product quality, process standardization and energy expenditure (Gamble and Rice 1987, Blumenthal, 1991).

2.6 Factors affecting oil absorption

A considerable range of oil uptake quantities during frying has been reported due to differences in the formulation, variation between batches and manufacturers (Smith *et al.*,1985). The percentage of oil pickup may be reduced by using potatoes of high specific gravity, manipulating slice thickness, partial drying of slices prior to frying, high oil temperature (170-180°C) and less frying time (Mottur, 1989). According to Pinthus *et al.*, (1995) porosity was a significant factor affecting oil absorption during deep-fat-frying. The influence of porosity was manifested in two aspects:

- Initial porosity of the product determined the final oil uptake in linear relationship and
- Both porosity and oil uptake increased during frying process and were dependent on each other.

However since the increase in porosity caused higher uptake and simultaneously increased uptake reduced porosity.

Factors influencing oil absorption	Reference
• Temperature, duration of frying, surface area exposed to frying medium, the character, composition and moisture content of food materials and fat source	**Ng *et al.*, 1957** **Hoyem and Oskar, 1977** **Singh and Seetha, 1993**
• Oil quality, product and oil temperature, frying duration, product shape and content (eg.	**Pokorny, 1980** **Augustin and Berry, 1983** **Selman and Hopkins, 1989**

solids, moisture, fat, protein), porosity, pre-frying treatments (eg. drying and blanching), coating, surface roughness and others • Temperature of frying, initial moisture content of the raw material and time of frying • Gel-strength, oil/product initial interfacial tension are additional factors	**Abdel-Aal Karara, 1986** **Fan and Arce, 1986** **Blumenthal, 1987** **Mittleman *et al.*, 1983** **Ashkenazi *et al.*, 1984** **Keller and Escher, 1989** **Pinthus and Saguy, 1993, 1994** **Saguy and Pinthus, 1994**
• Quality of oil • Composition • Temperature, time and shape of product • Initial moisture content • Initial interfacial tension • Porosity • Crust of food which is to be fried • Gel-strength • Method of frying	**Pokorny, 1980** **Makinson *et al.*, 1987** **Blumenthal, 1991** **Zeddelmann and Olendrof, 1979** **Pravisani and Calvelo, 1986** **Gamble and Rice, 1988** **Rice and Gamble, 1989** **Pinthus *et al.*, 1993** **Yoshikawa *et al.*, 1980** **Hau *et al.*, 1986** **Pinthus and Saguy, 1994** **Lulao and Orr, 1979** **DuPont *et al.*, 1992** **Guillaumin, 1988** **Farkas *et al.*, 1992** **Pinthus *et al.*, 1992** **Annapure *et al.*, 1998**

Berry *et al.*, (1999) carried out frying of potato chips in different frying media and reported that carboxy methyl cellulose (0.1per cent) was found to be effective in reducing oil uptake. Frying is a surface phenomenon, wherein an increased hydrophobicity of the surface would result in an increased oil uptake as suggested by Pinthus and Saguy (1994). It may be speculated that the surfaces of the samples containing protein hydrolysates are more hydrophobic than those containing proteins.

2.7 Use of ingredients to lower fat absorption.

It has been observed that oil uptake increased as the removal of water from the test sample increased (Gamble *et al.*, 1987) while another researcher (Duxbury 1984) added that initial and final water content has a major impact on oil uptake during deep-fat-frying. As water retention is strongly affected by some food additives, the addition of cellulose or alginates may affect the amount of oil uptake and moisture during deep-fat-frying. Same scientist further stated that batters and breadings can influence oil absorption but the reported results have been inconsistent. Powdered cellulose and some cellulose derivatives have reduced oil uptake (Anon, 1987; Henderson, 1988; Grover, 1993; Meyers, 1990). Such cellulose ingredients may be applied in several ways : 1) dry admix (0.5 -3.0 per cent) to the formula of product such as donuts and restructured potatoes, 2) included in batter or breading or 3) sprayed on the product as water solution (1-

3per cent) prior to frying. Similarly alginates could be used for the same purpose. Cellulose derivatives reduce oil absorption through film formation at temperatures above the incipient gelation temperature, especially when added in pre-hydrated forms, or they facilitate the natural barrier properties of starch or proteins (Grover, 1995; Meyers, 1990).

Besides cellulose, maltodexin ingredient can be used for development of reduced calorie food replacing more than 50 per cent of the oil and fat normally called for in a formulation. When used at the appropriate level and temperature, the oil and fat replacer forms a thermostable gel with a smooth fat like texture and neutral taste (Kaper and Gruppen, 1987). Similarly protein ingredients may be added to baked goods (Rakoshy, 1988) to improve sensory attributes, to supplement protein quality or content or to decrease fat pickup. Similar observations were given by Padmore (1993). In general, high protein materials and high water absorbers tend to reduce fat absorption while tenderizing agents such as sugars, hydrogenated fats and emulsifiers increases fat absorption. Food ingredient methyl cellulose was found to be more effective than cellulose in reducing oil uptake for doughnuts (Pinthus *et al.*, 1992). Prosise, (1990) has used small amounts of polyvinyl pyrrolidone. Similarly, effects of protein as additives and ingredients on donut oil uptake characteristics have been investigated (Martin and Davis 1986, Mohamed *et al.*, 1995). They also used soybean flour in doughnuts for its functional quality, as it functions to decrease water absorption (Wolf, 1970). At all PDI (Protein dispersibility Index) levels above 50, the quantity of soybean added is the best prediction of fat absorption control. On the other hand, in case of deep-fat-fried noodle like products from model individual blends of corn starch with casein, soy protein and their hydrolysates in ratios ranging from 80:20 to 20:80 of protein/hydrolysate : starch, oil content increased for all blends with an increase in the content of protein/ protein hydrolysate (Goel *et al.*, 1999).

The batter coatings apparently functioned to reduce water loss during frying which, in turn, lessened oil absorption and incorporation of long fibre cellulose into batters or donut mixes also reduced oil absorption during deep-fat-frying (Ang, 1990; Ang *et al.*, 1990; Williams and Mittal, 1999). It was also observed that initially coated samples had slightly higher fat contents than non-coated samples but after 1, 3, 4 minutes of frying, coated samples had lower fat than non-coated. Gellan gum films (thickness 2.0 -2.5mm) reduced fat absorption by 60 per cent. Fish pieces deep-fried for 2 min at 182^{0}C showed that gellan gum films reduced fat absorption by as much as 68 per cent (Kelco, 1995) depending on concentration of gellan gum solution applied. Incorporating snack foods with chickpea genotypes with isolated starch fractions and protein fractions has also been carried out and these starch fractions increased the oil absorption by seviya prepared from the blends. The oil absorption increased from 37.4 per cent in control to 56.6 per cent when 30 per cent starch was added. Also, the addition of protein fraction to the flour sample of same genotype decreased oil absorption. These results suggest that genotypes with low starch and high protein would have decreased oil absorption in deep-fried products.

Ability of the dry ingredient curdlan, a microbial polysaccharide. (0 to 1per cent w/w) to lower oil uptake and moisture loss in doughnuts during deep-fat-frying was compared with cellulose derivatives (Funami *et al.*, 1999). The addition of curdlan showed a linear effect on reducing each parameter ($P \leq 0.001$) with in a range of 0 to 0.5 per cent, this effect was probably attributed to its thermal gelling property and heat induced gel during frying probably functioned as an oil and moisture barrier. Additionally, the introduction of small amounts of gelatinized rice flour to the batter of rice flour was beneficial to the fried batter mix in terms of overall oil uptake properties (Shish *et al.*, 2001). Use of egg white, soy protein isolate, skimmed milk powder or whey powder instead of whole egg resulted in fried doughnuts with reduced fat content. This can partly be due to the low fat content of these proteins and partly due to low fat absorption during frying (Mohamed *et al.*, 1995). The decrease in oil absorption may be related to the rate of denaturation of the protein, which will inhibit the oil from entering the rest of the dough. Honey, a product perceived by consumers as natural and healthy possesses functional characteristics that can serve as fat substituting components in low or no fat snack products while simultaneously adding to the products natural healthy appeal. (Anonymous ,1997).

2.8 Acceptability of fried foods

The focus of frying is to produce high quality uniform fried food for immediate food service (Thomson, 1990). The oil that is used to transfer heat energy is responsible for delicious odour, flavour and texture associated with fried food (Swackhamer, 1989), similar observations have been reported by Bhatt and Indira, 1982. They added that fried food develops an appealing flavour and odour due to the reaction of the frying fat with proteins and carbohydrates of the food materials. Use of deep-fat-frying as a cooking method has increased significantly over the years due to short cooking times and the development of unique flavour, colour and odour in the final product. Reactions of fat with many constituents of the food being fried causes desirable change in foods (Gumuskesan and Kavas, 1993). While Tseng *et al.*, (1996) added that quality of fried product depends not only on the frying conditions but also on the type of oil and food materials used for frying. Also frying in hot oil prevents sticking of food materials on to the hot surfaces. It yields a well-prepared food with appealing flavour, aroma and desired outside crispness and inside tenderness (Sabikhi and Tiwari, 1999).

Deep-fat-fried products forms the largest group of marketed snack foods in India and are liked for their crunchy texture and fried aroma (Kulkarni *et al.*, 1994). These snacks are usually prepared from cereals, cereal-pulse or cereal-vegetable-starch combination in order to provide variety. It is also speculated that consumers are attracted to the rich flavour, crispness and mouth feel of the savory snacks. Although these characteristics are appealing to consumers, much of the savory snack, flavour, texture and appearance consumers are attracted to, be due to lipid, fatty acid and salt content. This is especially true for some of the leading categories such as potato and tortilla chips (Khalil, 1995). The moisture content, oil content and colour are important factors, which determine the quality of chips. For good acceptance, the colour of the chips should be light yellow (Anand *et al.*, 1982). Although fried foods have high acceptance by the public, poor penetration of theoil into deep-fat-fried products is wide spread. The common mistakes or mishandling practices, which contribute to low quality of fried food, include incorrect temperature and use of deteriorated fats (Thorner, 1973).

Oxidation of fat containing food is a serious problem in the food industry (Noor and Augustin, 1984). In many cases, the limiting storage reaction of high fat containing foods such as deep-fried snack products is the oxidation of lipids, which results in organoleptic rancidity. Besides resulting in the development of off-flavour, oxidation of lipids causes other undesirable effects such as discoloration and nutrient losses. Similar findings on loss of acceptability as a result of rancidity reactions causing development of off-flavour are reported by Schutlz *et al.*, (1962).

Studies have also shown successful utilization of liquid and dry honey in chips incorporated at various combinations (Cardetti, 1997). Liquid honey and a 1:1 mixture of liquid and dry honey both produced desirable colour and texture properties. Certain liquid/dry mixtures matched or exceeded commercial products when compared and also did improved the colour attributes of the chips.

2.9 Shelf-life of fried foods

One of the most important reactions leading to quality loss is rancidity of food products. It is development of off-flavour by oxidation and hydrolysis that makes food unacceptable (Labuza, 1971; Paquette *et al.*, 1985; Robards *et al.*, 1988). For longer shelf-life the moisture content of chips should be with in 2 to 3 per cent (Simpson, 1969) and from economic point of view, the oil content of chips should be as low as possible. The quality and shelf-life of the packaged food are mainly determined by the barrier properties of the package against moisture, oxygen and the interaction of food constituents with packaging materials (Karel and Heidelburgh, 1975; Gilbert and Mannheim, 1982; Thakker *et al.*, 1987). Hence, the major function of packaging is to minimize reactions that affect the stability of the contained products.

Due to higher oil pickup, shelf-life is shortened and the cost of the fried products is increased (Sandhu and Bawa, 1993; Mohamed *et al.*, 1995; Sharma *et al.*, 1990). Potato chips fried in cotton seed oil picked up less oil and were more crisp and retained better quality during storage when packed in PP pouches and stored under ambient conditions 20-35^{0}C and 30-65 per cent RH (Berry *et al.*, 1999). On the contrary, banana chips fried in fresh coconut oil, 300 gauge high density polyethylene and 400 gauge low density polyethylene bag packing are satisfactory up to two months, while packing in tin under CO_2 is satisfactory up to six months at room temperature (28-32^{0}C) (Krishnankutty *et al.*, 1981). The moisture content after two months of storage in 300 gauge HDP increased to 3.8 per cent from the initial 3.2 per cent while that of chips packed in 400 gauge LDP bags increased to 4.6 per cent. Bhatt and Indira (1982) also supported enhanced shelf-life after deep–fat-frying. These findings are supported with the findings of Kulkarni *et al.*, (1994); Yau *et al.*, (1994). They reported increased moisture content during storage due to higher vapour transmission rate in LDPE and PP bags. The increase in levels of free fatty acids also increased due to development of hydrolytic rancidity however, colour (golden yellow), crunchy texture remained well throughout storage period. The peroxide value of sevian also increased gradually probably due to auto oxidation of the oil absorbed during deep-fat-frying. These findings are in agreement with those of Onyejegbu and Olorunda (1995).

Colocasia snack products when packed in 120 gauge polyropylene pouhes had initial moisture content (0.9per cent) which rose to 2.8 per cent during 40 days of storage, peroxide value change from nil to 1.07 meq O_2/kg. The product was acceptable only upto 30 days storage (Manan *et al.,* 1991). Similarly *Aadun and Kokoro*, two corn products became mouldy before seven days but samples treated with butyl paraben did not show signs of mouldiness or off-flavour and moisture content and pH were reduced (Adegoke and Adebayo, 1992). Studies have also shown decrease in iodine value and acid value of the oil extracted from samples as storage time increase, while peroxide value increases on storage when preserved at room temperature (Khader and Patel, 1982). In these lines Rho *et al.,* (1986) used three methods of extending shelf life in instant fried noodles (Raymon). These were addition of 200 ppm BHA to frying oil or TBHQ coating on inner surface of polyethylene package or addition of mixture of TBHQ and EDTA to frying oil. BHA approximately doubled while TBHQ tripled the shelf-life of raymon. After packaging the factors that affect raymon stability includes light, temperature, humidity and oxygen permeability of the packaging material (Nishijima *et al.,* 1976). Additives have a prominent effect on storage stability and additives like carboxy methyl cellulose, sorbitol, gluten, SSL, enhances storage life of food products. This is due to increased water binding during and after baking (Emodi, 1982).

Chapter-III

MATERIAL AND METHODS

CHAPTER -III

MATERIAL AND METHODS

The study entitled "**Dependence on humectants, Heat transfer Co-efficient and kinetics of moisture removal in deep-fried products**" was undertaken in the Department of Food Science and Nutrition, College of Home Science, CSK, Himachal Pradesh Agricultural University, Palampur during the Academic years of 2000-2001 and 2001-2002.

3.1 THE EXPERIMENT

The Experiment consisted of collection of research material (raw material for sample preparation, packaging material etc.) of required quality and specifications, interactive use of different humectants viz. sorbitol, mannitol and glycerol at various levels, calculation of densities, conductivities, specific heat, thermal diffusivity and heat transfer co-efficient, kinetics of moisture removal at different time intervals and at different temperature, kinetics of fat absorption and oil uptake ratio, product development and shelf-life studies, organoleptic evaluation and quality assurance parameters.

The experiment was divided into two major parts :-

(i) Kinetics of deep-fat-frying (densities, conductivities, specific heat, thermal diffusivity, heat transfer co-efficient, moisture loss, fat absorption and oil uptake ratio)

(ii) Shelf-life studies (Chemical analysis as affected by storage for 0, 30, 60 and 90 days).

3.2 THE EXPERIMENTAL DESIGN :

The experiment was scientifically designed according to the Completely Randomized Block Design (CRBD) and replicated three times. One treatment was kept as control for the sake of comparison and evaluation of results.

3.3 THE EXPERIMENTAL LAYOUT :

The experiment was laid out as per following details :

3.3.1 ***Locale*** **:** The major part of the experiment was conducted in the Post Graduate Research Laboratory of the Department of Food Science and Nutrition, however, the data regarding heat exchange and heat transfer parameter were collected in the Food Processing Pilot Plant of the Department. The organoleptic studies and storage of samples for shelf-life studies were also conducted in the Pilot Plant and Quality evaluation laboratory.

3.3.2 ***For Sub-Experiment I*** : Kinetics of Deep-fat-frying

Major treatments: following were the major treatments

T_0 = Control

T_1 = Sorbitol

T_2 = Mannitol

T_3 = Glycerol

Each humectant (details of humectants in Annexure IV) was used in three different levels,

Sorbitol ratios → 70 : 30 (T_1)
→ 60 : 40 (T_2)
→ 50 : 50 (T_3)

Mannitol ratios → 70 : 30 (T_4)
→ 60 : 40 (T_5)
→ 50 : 50 (T_6)

Glycerol ratios → 70 : 30 (T_7)
→ 60 : 40 (T_8)
→ 50 : 50 (T_9)

Control (To)

Sub-treatments : Following were the sub-treatments.

Each sample was deep fried in three different frying media (Annexure V) at three different temperatures:

S_1 = Shortening/Ghee

S_2 = Refined groundnut oil

S_3 = Mustard oil

Sub-sub-treatments : These consisted of frying of each sample in each frying media at three different temperatures.

$F_1 = 170^0C$

$F_2 = 180^0C$

$F3 = 190^0C$

3.3.2.1 ***Interactions :*** Different interactions against the major treatment, sub-treatment, sub-sub treatment and interactions thereof worked out as 90 (81 interaction + 9 control) replicated there times tentamouting to 270 samples each (Annexure II).

3.3.3.0 FOR SUB-EXPERIMENT II - SHELF LIFE STUDIES

Major treatments : following were the major treatments :

To = control

T1 = Sorbitol

T2 = Mannitol

T3 = Glycerol

Each humectant was used in three different level so the total major treatments were:

Sorbitol	→ 70 : 30	(T_1)
	→ 60 : 40	(T_2)
	→ 50 : 50	(T_3)
Mannitol	→ 70 : 30	(T_4)
	→ 60 : 40	(T_5)
	→ 50 : 50	(T_6)
Glycerol	→ 70 : 30	(T_7)
	→ 60 : 40	(T_8)
	→ 50 : 50	(T_9)
Control		(T_{10})

<u>Sub treatments</u> : following were the sub-treatments :-

S_1 = Shortening/ghee

S_2 = Refined groundnut oil

S_3 = Mustard oil

Each of the above ten treatments was fried in these three different frying media bringing the sample number to 30.

Sub-sub treatments : was the use of three different packaging materials for shelf-life studies.

P_1 = Craft paper

P_2 = Plastic jars

P_3 = Polyethylene bags

Each of the above 30 sub-treatments were then packed in three different packaging materials, thus bringing the sample number to 90.

3.3.3.1 ***Interactions***: Different interaction amongst major treatment sub treatment, sub-sub treatments were worked out to be as show in 3.3.2.1. Further details have been show in Appendix III.

3.3.4 SAMPLE AND SAMPLING TECHNIQUE :

Selecting sample for product evaluation perhaps is the most important step in the successful control of product quality & sample has been defined as a unit, which must be representative of the entire lot or population, and must have been selected at random. If one has to identify the true quality of a given lot, one has to adopt a statistical plan. In the present study simple random sampling techniques as proposed by Gould and Kalia,1978; Kalia, 2002 were used, the samples were selected from various locations of the lot in a manner to secure a representative sample of the lot. Urnest care was taken to minimize indeterminate type of errors, and keep the variates within control limits.

3.3.5 STANDARDIZATION OF DOUGHNUT RECIPE

Once the raw material, frying media and different humectants to be used were procured, the recipe for doughnuts was standardized in the laboratory. Initially the recipe was standardized altering the components like sugar, egg, water etc. Once the recipe was set, final trials on the different levels of humectants, which could be successfully added while replacing sugar, were tried. Starting from 5 per cent level of incorporation of sorbitol, mannitol or glycerol in place of sugar, it was tried up to a level which produced doughnuts without altering much the colour, taste, flavour, appearance and taste. A level up to 50 per cent was found acceptable. Finally, three levels i.e. 30, 40 and 50 per cent were selected for substituting sugar in doughnut formulation. The standardized recipe is given in Annexure I.

3.3.6 PREPARATION OF SAMPLE :

The samples (doughnuts) were prepared according to the standardized formulation (Annexure I). The ingredients were mixed manually so as to get uniform dough. The water absorption (amount of water used to get desired consistency of dough) and dough handling properties (whether sticky, slightly sticky or non-sticky) were recorded.

The dough was rolled out on a floured table to a thickness of about 0.8 cm and cut into round pieces of 5 cm diameter. Each doughnut was fried in three different media according to the scheme as enumerated in 3.3.2 and 3.3.3.0.

3.4 SUB-EXPERIMENT- I KINETICS OF DEEP-FAT-FRYING

3.4.1 *Frying of samples* :

Shortening, groundnut oil and mustard oil were used as frying media. The oil was heated in a frying pan to the desired temperatures by using heater (1kw). The heater was connected to Temperature Indicator-cum-Controller, which kept the temperature of the oil set according to the experiment. When the temperature of the oil exceeded the set temperature the heater switched off automatically thus keeping the temperature of oil set on one required temperature (with $\pm$ 2°C variation). The doughnuts were then dropped into the hot oil and frying was carried out at the preset temperature, the oil being constantly stirred during frying to get uniform temperature. The doughnuts were fried one at a time. The time taken for frying of doughnuts prepared from different humectants and their ratios, for each frying media was noted down using a stopwatch.

3.4.2 *Temperature during frying :*

The monitoring of temperature at a preset temperature with auto-cut out system has been considered important parameter for kinetic studies. Frying was carried out at three different temperatures i.e. 170, 180 and 190^{0}C. The temperature of the frying oil was monitored using metallic temperature probe and Temperature Indicator-cum-controller (Century Instruments, Chandigarh). These helped to keep the temperature constant during frying with temperature variation of ±2^{0}C.

3.4.3 *Temperature of the product :*

For the calculation of heat transfer co-efficient, the temperature profile of the inner portion (center) and surface of the product are important parameters. The temperature at the surface was measured immediately after frying with the help of metallic temperature probe (1.5-mm diameter). Similarly, the temperature at the center of the product was measured with the help of above probe.

3.4.4 *Thickness of the product :*

Thickness of the product required for calculation of heat transfer co-efficient varied with the level of humectant added to the doughnuts. It was measured with the help of Vernier Caliperse. The average of three values was taken for each product.

3.4.5 *Frying of samples for moisture loss studies :*

Frying of sample was done in similar way as stated under 3.4.1. The only difference was that samples were fried for 1, 2, 3 and 4 min and taken out and subjected to moisture determination immediately after cooling

3.4.6 *Heat Transfer* **Co-efficient :**

The temperature profile in the inner portion (center) and surface of the product were recorded during frying. At the end of frying a steady state was reached at the center of the product and at all the frying temperatures studied, whereas steady state was reached much earlier in the portion closer to the surface of the product. Assuming a linear boundary condition of the third kind or the convective boundary condition at the surface (Ozisik, 1987) i.e. x = s

$$-k\frac{dT}{dx} = h\,(T_S - T_\infty)$$

Where ,

h	=	Heat transfer co-efficient
k	=	Thermal conductivity
T_S	=	Surface temperature
T_∞	=	Frying oil temperature

The above equation was used to determine the heat transfer co-efficient (h). The thermal conductivity of the surface layer (k) was estimated from its proximate composition using the Empirical Parallel Model (Lewis, 1987) given by

$$K = V_S K_S + V_W K_W$$

Where,

V_S = Volume fractions of solids

K_S = Thermal conductivity of solids

V_W = Volume fraction of water

K_W = Thermal conductivity of water

$$V_s = \frac{m_s / \rho_s}{\frac{m_s}{\rho_s} + \frac{m_w}{\rho_w}}$$

Where,

m_w = Mass fraction of water

m_s = Mass fraction of solids (1- m_w)

ρ_s = Density of product

ρ_w = Density of water (1)

V_w = 1- V_s

The thermal conductivity of the solid fractions and of water are given by Miles, (1983) as K_S = 0.26 W m^2 K^{-1} and K_W = 0.600 W m^2 K^{-1} respectively.

The equation for Heat Transfer Co-efficient was simplified as:

$$\frac{-k\,(T_s - T_c)}{x} = h\,(T_S - T_\infty)$$

Where,

h	=	Heat transfer co-efficient
k	=	Thermal conductivity
x	=	Thickness of the product
T_c	=	Temperature of center
T_S	=	Surface temperature
T_∞	=	Frying oil temperature

3.4.7 *Density*

Volume of the doughnuts was determined by volume displacement of mung beans in a large container, large enough to accommodate the product. The density was calculated as mass per unit volume.

3.4.8 *Viscosity (Gould and Kalia, 1978)*

For determination of the viscosity of the fat/oil, the latter was taken into 1 ml pipette and the number of drops falling in one minute was recorded as its viscosity at 20°C

3.4.9 *Smoke point (Pang, 1970)*

The oil was heated in a frying pan till it started giving smoke and then temperature of the oil was determined by means of a high temperature thermometer.

3.4.10 *Thermal Diffusivity (Lewis, 1987)*

The thermal diffusivity 'ą' is the ratio of the thermal conductivity to the specific heat of the product multiplied by its density.

$$ą = \frac{k}{\rho C}$$

Where,

a = Thermal diffusivity (m^2s^{-1})

K = Thermal conductivity ($Wm^{-2}k^{-1}$)

ρ = Density (Kgm^{-3})

C = Specific heat ($KJ\ Kg^{-1}\ K^{-1}$)

3.4.11 *Specific heat (Lewis, 1987)*

The equation used for estimation of specific heat 'C' of food was as follows :

$$C = m_w C_w + m_s m_s$$

Where,

C = Specific heat

m_w = Mass fraction of water

C_w = Specific heat of water ($4.18\ KJ\ Kg^{-1}\ K^{-1}$)

m_s = Mass fraction of solids

m_s = Specific heat of solids ($1.46\ KJ\ Kg^{-1}\ K^{-1}$)

3.4.12 *Moisture Content (AOAC, 1990)*

Procedure : 10 g sample (either dough or doughnuts) was weighed in the moisture box and dried in oven at 105°C for 6 hrs. The sample was weighed after cooling it in a desiccator.

Calculation :

$$\textbf{Moisture (per cent)} = \frac{\textbf{Loss in weight (g)}}{\textbf{Weight of sample (g)}} \times 100$$

3.4.13 *Crude Fat (AOAC, 1990)*

Reagents used : Petroleum ether (40 - 60 °C)

Procedure : Crude fat was estimated using Soxhlet method. Took 5 g of well ground dried sample in extraction thimble. Placed the thimble in the extractor and connected weighed flask containing 100 ml petroleum ether. Connected the extractor to a reflux condenser and extracted the sample under reflux for 5-6 hours. Evaporated the petroleum ether extract to dryness on hot plate. Dried flask containing the fat residue in hot air oven at 100°C for five minutes. Cooled in desicator and weighed.

Calculation :

$$\textbf{Crude Fat (per cent)} = \frac{W_3 - W_2}{W_1} \times 100$$

Where,

W_1 = Weight (g) of sample taken

W_2 = Weight (g) of empty flask and

W_3 = Weight (g) of the flask with fat

3.4.14 *Oil Uptake Ratio (Pinthus et al., 1993)*

The oil Uptake Ratio (U_r) was calculated from the moisture content of the dough and doughnuts and the oil content of the doughnuts using the formula given by (Pinthus *et al.*, 1993).

$$U_r = \frac{\textbf{Oil Content (per cent)}}{(M_D - M_P)}$$

Where,

M_D = Moisture content of dough

M_P = Moisture content of doughnuts

3.5 SHELF-LIFE QUALITY OF DOUGHNUTS

3.5.1 *Frying of Doughnuts*

The doughnuts were prepared according to the formulation given in Annexure I. The frying media used were shortening, refined groundnut oil and mustard oil.

3.5.2 *Packaging for Storage Studies*

Three different packaging which were tested in the present investigation were :

- Craft paper

- Polyethylene bags
- Plastic jars

Plastic jars (Pearlpet made) of 1 kg capacity, craft paper envelopes of 1/2 kg capacity and polyethylene bags of 1/2 kg capacity (low density, 100 gauge, food grade) were purchased from manufacturer's authorized agents.

Washing: Plastic jars were thoroughly cleaned with mild detergent and rinsed properly with cold water. The polyethylene bags were sanitized in dilute $KMnO_4$ solution (0.05 per cent).

Drying : After washing jars and polyethylene bags were dried in hot air oven at low temperature.

Filling : The doughnuts (cooled at room temperature) were placed in jars, polyethylene pouches and craft paper envelopes.

Seaming: The plastic jars were capped air tightly. The lids were then dipped into melted paraffin wax so as to form an impermeable layer over the lid. The polyethylene bags were seamed hermetically with auto electric seamer (60°C). The craft paper envelopes were stapled.

Labeling : The packaging materials were then labeled with glass marking pencils.

Storage: The samples were kept for storage at ambient conditions (25 $\pm$ 5°C, 70 per cent RH)) for further studies.

The data regarding the mean temperature and per cent relative humidity (RH) coinciding with the storage schedule during one year was recorded and shown in Annexure VII.

3.5.3 *Chemical Analysis*

The doughnuts were evaluated for their proximate composition at zero, 30, 60 and 90 days intervals after grinding them into flour fineness in Willy Mill.

3.5.3.1 Moisture (AOAC, 1990)

Procedure same as described in 3.4.12.

3.5.3.2 Crude Fat (AOAC, 1990)

Procedure same as described in 3.4.13.

3.5.3.3 Crude Protein (AOAC, 1990)

Crude protein was determined by Microkjeldahl Method by digesting sample with concentrated sulphuric acid using copper sulphate as a catalyst to convert nitrogen to ammonia ions. Alkali (40 per cent sodium hydroxide solution) was added and the liberated ammonia distilled into an excess of boric acid solution. The distillate was liberated with hydrochloric acid to determine the ammonia absorbed in the boric acid.

Reagents:

- Sulphuric acid : Concentrated, nitrogen free.
- Hydrochloric acid : 0.01N Standardized.
- Boric acid solution : Dissolved 40 g of boric acid in distilled water and diluted to one liter.
- Sodium hydroxide solution (40 per cent): dissolved 40 g carbonate free sodium hydroxide (NaOH) in distilled water and diluted to one liter.
- Copper sulphate catalyst : mixed copper sulphate and potassium sulphate in the ratio of 1:9.
- Mixed indicator (pH 4.5) : dissolved 2 g of methyl red and 1 g of methylene blue or bromocresol green in one liter of ethanol and store in dark bottle.
- Boiling regulators : glass beads for digestion.

Procedure :

Digestion : Place few boiling regulators in the kjeldhal flask and a pinch of the catalytic salt mixture. Transferred 2 g of sample in flask. Added 20 ml sulphuric acid and mixed gently swirling the liquid. Digested the sample by boiling vigorously utill the liquid became clear and of light blue green colour. Cooled and added 50 ml of water. Mixed and allowed to cool and diluted to make 100 ml in a volumetric flask.

Distillation : Added 10 ml of the boric acid solution to 150 ml conical flask. Added 2-3 drops of mixed indicator. Put the flask in contact with the condenser, transferred 2 ml of the aliquot to distillation apparatus and stoppered the inlet. Distilled the sample and titrated the contents of the flask with 0.01N HCl. Recorded volume of HCl used. Conducted blank also.

Calculation : Crude Protein was calculated by multiplying Total Nitrogen (per cent) with a factor of 6.25.

$$\text{Total Nitrogen (per cent)} = \frac{0.00014\,(V_1 - V_2) \times \text{Volume of Aliquot made} \times 100}{\text{Volume of aliquot taken for distillation} \times W}$$

Where,

W	=	Weight (g) of sample taken
100 ml	=	Volume of aliquot made
2 ml	=	Volume of aliquot taken for distillation
V_1	=	Volume of HCl (N/100) used for titration
V_2	=	Volume of HCl (N/100) used for titration of blank

3.5.3.4 Ash (AOAC, 1990)

Procedure : Placed the requisite number of silica crucibles in a muffle furnace to heat at 550°C for 15 min. Removed the crucibles, cooled in a desicator for one hour, weighed each crucible. Weighed accurately 5 g material into each crucible. Cleared each sample on hot plate till it was charred. Placed the crucible inside the muffle furnace and ashed overnight at 550°C. When the ash became clean and white in appearance, removed in a desicator. When cooled, reweigh each crucible and ash. Calculated the weight of ash by difference.

$$\textbf{Weight of ash} = W_2 - W_1$$

$$\textbf{Ash (per cent)} = \frac{W_2 - W_1}{\textbf{Weight of sample}} \times 100$$

Where,

W_1 = Weight (g) of crucible

W_2 = Weight (g) of crucible + ash

3.5.3.5 Free Fatty Acids (AACC, 1976)

Reagents :

- Benzene
- Ethanol (95per cent)
- Phenolphthalein indicator
- 0.01 N NaOH

Procedure : Ground sample (2g) was taken to determine the free fatty acids. To the samples in the stoppered flasks, benzene (50 ml) was added and kept for 30 min with frequent shakings. After filtration, measured aliquot (10.0 ml) of supernatant liquid was added with equal amount of alcohol (95per cent) and few drops of the phenolphthalein indicator and titrated against 0.01 N NaOH till permanent pink colour persisted. Blank was also run. Results were expressed as per cent Oleic acid by using the below mentioned formula.

Calculation :

$$\text{Free Fatty Acid (\%as Oleic acid} = \frac{282 \times \text{ml of alkali used}}{\text{Weight of sample}} \times \frac{\text{Normality of alkali}}{1000} \times 100$$

3.5.3.7 Peroxide Value (AOAC, 1990)

Reagents:

- Acetic acid : Chloroform solution (3 : 2 v/v)
- Saturated potassium iodide solution
- 0.1 N Sodium thiosulphate solution
- Starch solution (1per cent) : 1 g of soluble starch was dissolved in cold distilled water to make thin paste, then boiling distilled water was added and boiled for one min, while stirring. When completely dissolved, the volume was made to 100 ml.
- Chloroform : methanol solution (2 : 1 v/v)

Procedure: Lipid content of 5 g sample was extracted by keeping the sample overnight in chloroform: methanol (2:1 v/v) mixture. Next day, the chloroform and methanol phase was evaporated and lipid phase was left in flask. Then to each flask 30 ml acetic acid: chloroform mixture was added and swirled to dissolve. After that, 0.5 ml of the saturated potassium iodide solution was added, kept exactly for one min. with occasional shaking and 30 ml of distilled water was added.

The 0.5 ml of 1per cent starch solution was added and titrated with 0.1N sodium thiosulpahte with vigorous shaking until all iodine from the chloroform layer was released and blue colour just disappeared and blank was run in similar way.

Calculation :

$$\text{Peroxide Value (meq/ Kg sample)} = \frac{S \times N \times 1000}{\text{g of sample}}$$

Where,

S = ml of sodium thiosulphate (blank corrected)

N = Normality of sodium thiosulphate solution

3.6 SHELF-LIFE STUDIES TO ASSESS CONSUMER ACCEPTABILITY

The products containing different humectants and stored in different packaging materials were subjected to organoleptic evaluation. In this perception of an individual is taken into consideration. It is useful in product improvement, quality maintenance, new product development and marketing research.

Minimum of 10 judges was selected at a random. Due consideration was given to educational background, previous experience, sex and age. Hedonic scale was used ranging from 0 - 10 (Annexure VI). Each judge was provided the set of samples, alongwith potable water for rinsing mouth after testing each sample. The samples were evaluated for quality attributes as colour, flavour, texture, taste, appearance signify 10= perfect, 9-7 = good, 6-4 = fair, 3-2 = poor, 1 =

off. The judges were asked to record the observation according to their own experience, judgment and knowledge of the state of the quality of samples. The samples were coded and panel was conducted in a blind fold manner. The data was statistically adjusted using ANOVA to determine the differences.

3.7 ECONOMICS OF THE PRODUCTS

The total costs of the products were determined by taking into consideration the cost of raw materials used in the preparation of products. It is an important parameter for the assessment of acceptability of new products to consumer/ market.

3.8 STATISTICAL ANALYSIS OF DATA

The data collected on various parameters were statistically analyzed using completely randomized block design (Gomez and Gomez, 1984) using three way factorial model. The treatments were compared at 5 per cent level of significance and results were interpreted accordingly.

Chapter-IV
RESULTS AND DISCUSSION

Chapter-IV

Results and Discussion

The study envisaged hereunder was taken up with the sole purpose of Quality Assurance, adherence to HACCP (Hazard Analysis and Critical Control points) and Codex Alimentarius as well as economics of the deep-fried foods. For the sake of uniformity, continuity and product characteristic standardization, soft cake doughnuts were prepared. The study involved experimentation with various parameters like working out of kinetics of moisture loss and oil uptake, heat transfer co-efficients, thermodynamic properties, heat and mass transfer, physico-chemical and organoleptic evaluation.

For the sake of clarity, the experiment was sub-divided into various sub-experiments as elaborated in the Chapter describing Material and Methods. The results so obtained are discussed in the following paragraphs.

4.1 Chemical characteristics of refined wheat flour

Refined wheat flour or *maida* or American flour is the white inner flour of kernel with the least amount of constituents other than starch and is particularly suited to make bread, biscuits or cakes. It is essentially the starchy endosperm and has low contents of ash and crude fibre; there is less protein than in whole-wheat flour but the proportion of gluten is higher because of segregation. Hard red winter wheat with high protein and gluten content is used for bread making, sometimes mixed with even stronger hard red spring wheat. These are not suitable for making biscuits and cakes, for which the so-called western white and soft red winter wheat is better.

The chemical characteristics of refined wheat flour used for the preparation of doughnuts are presented in Table 4.1 which reflect that the protein, fat, ash and crude fibre contents of refined wheat flour used for the preparation of doughnut samples were 10.35, 2.01, 0.62 and 0.32 per cent respectively, whereas the total carbohydrates, free fatty acids, starch and total sugars were recorded as 72.44 per cent, 0.39 per cent as oleic acid, 68.31 per cent and 0.94 per cent as glucose, respectively.

The chemical composition of the refined wheat flour used in the present study is thus suitable for preparation of cake doughnuts as it contains less protein, ash and crude fibre contents.

Various authors like Tipples *et al.*, 1978; Mok and Dick, 1991; Wang and Flore, 1999; Basman and Koksel, 1999; Hatcher and Kruger, 1997 and Hatcher *et al.*, 1999 reported wide variations in protein (9.24-13.40 per cent), fat (1.50-2.50 per cent), ash (0.36-1.52 per cent), moisture (9.40-13.00 per cent), respectively. These variations are possibly due to the variety of wheat used for the production of flour,

Table 4.1: Chemical characteristics of refined wheat flour

Parameter (S)	Refined wheat flour
Protein (N x 6.25) (%)	10.35
Fat (%)	2.01
Ash (%)	0.62
Crude fibre (%)	0.30
Total carbohydrates (%)	72.44
Free Fatty Acids (% as Oleic acid)	0.390
Starch (%)	68.31
Total sugars (% as glucose)	0.94

extraction rate/flour yield and/or agro-climatic conditions of the area where the wheat was grown.

Therefore, it can be safely stated that chemical constituents of the material under investigation were by and large within acceptable limits.

4.2 Physico-chemical characteristics of frying media

Fats and oils are water insoluble substances of plant or animal origin, which consist predominantly of glycerol esters of fatty or triglycerides. The word 'fat' is ordinarily used to refer to triglycerides that are solid or more correctly semi-solid at ordinary temperature, whereas the word 'oil' is used for triglycerides that are liquid under same conditions. The quality of fried foods depends on the quality of fat, which should meet the requirement such as having low absorption value i.e. fat should be able to penetrate and fry food easily, a high smoking point and a long frying life. It should leave the food with a dry, non-greasy surface and impart good flavour. During cooking, the oil or fat is often kept hot for long periods of time and is exposed to both moisture and oxygen. Complex chemical and physical changes occur under these conditions causing fat to deteriorate, which may reach a point where the flavour, colour, nutritional value and safety of foods may be affected.

The physical/chemical properties of fats are of practical importance for a number of reasons. Many technical applications of fatty materials, including their use in edible products, depend upon the oiliness, surface activity, solubility, melting behaviour or physical properties peculiar to the long-chain compounds. In general, the viscosity of oil decreases slightly with increase in unsaturation (more the number of double bonds, more unsaturated is the fat). However, hydrogenation is a process in which hydrogen is added to the unsaturated linkages under optimum temperature and pressure using nickel as a catalyst. Thus, the liquid fat becomes a solid fat and unsaturated fatty acid content decreases. Therefore, viscosity is increased slightly by hydrogenation. The melting point of fatty acid increases with increasing chain length and decreases as the acids become more unsaturated. On the other hand, smoke, fire and flash points of a fatty material are measures of its thermal stability when heated in contact with air.

Chemical characteristics like saponification value is a measure of free fatty acids present as esters in a given oil/fat and inversely proportional to each other. Therefore, a high saponification value indicates that the oil is made up of low molecular weight fatty acids and is helpful in detecting adulteration of fat or oil. Higher iodine value on the other hand indicates higher degree of unsaturation of fatty acids present while the peroxide value expresses the oxidative rancidity. The chief consideration in the choice of a frying fat are good flavour stability at frying temperatures and in the case of packaged products, a high resistance towards oxidation.

The data in Table 4.2 show the chemical characteristics of frying media used for deep-fat-frying of doughnuts. The peroxide value (meq/kg) observed in case of shortening, groundnut oil and mustard oil were 0.20, 0.33 and 0.30, respectively whereas the free fatty acid (per cent as oleic acid) contents were 0.05, 0.16 and 0.18, respectively. The smoke point was observed to be 262, 242 and 240°C, respectively for shortening, groundnut oil and mustard oil. Viscosity on the other hand was 102, 121 and 109, respectively.

Hence, it can be concluded that the frying media used in the present study had minimal amounts of free fatty acids and low peroxide value. Also, the smoke point was high, which is again the basic requirement for a good quality oil with high viscosity.

Chanderkanta (1989) and Anupama (1992) have also reported similar levels of peroxide values, free fatty acids, viscosity and smoke point. They further added that with subsequent frying of food material in the same media caused increase in peroxide values and free fatty acids and decrease in viscosity and smoke point. Similar findings are also reported by Yoon *et al.*, (1987).

4.3 Water absorption, dough handling and puffing characteristics of doughnuts

Milling of wheat grains using either the traditional *chakki*-grinding or by roller flour milling has a significant role to play during dough development for various end uses. *Chakki*-grinding of wheat is

Table 4.2: Physico-chemical characteristics of frying media used for deep-fat-frying

Parameter (S)	**Shortening**	**Groundnut oil**	**Mustard oil**
Peroxide value (meq/Kg)	0.20	0.33	0.30
Free fatty acids (% as Oleic acid)	0.05	0.16	0.18
Smoke point (°C)	262	242	240
Viscosity	102	121	109

rather an abrasive operation and large number of individual starch granules gets damaged. Starch granules then become exposed and an enzyme called β-amylase that is abundantly present acts on the starch to release sugar called maltose, which imparts a slight but desirable sweet taste to *chapatti*. Further, damaged starch absorbs more water, which not only conduces to the release of sugar by the enzyme, but also give a flexible non-sticky dough. Therefore, it can be safely said that protein content and damaged starch are positively correlated with water absorption. On the other hand roller mills do not grind wheat by crushing, but by gradual and gentle shearing the grain between two rolls, moving in opposite directions at different speeds.

The water absorption and dough handling characteristics of wheat flour containing different levels of sorbitol, mannitol and glycerol are depicted in Table 4.3. The percent water absorption in case of dough for control samples was 130. With the incorporation of sorbitol/mannitol/glycerol at 30, 40 and 50 per cent level, the water absorption decreased significantly. The water absorption for samples containing 30, 40 and 50 per cent sorbitol was 128, 125 and 117 and for mannitol was 129, 126 and 115. In case of glycerol, addition at 30, 40 and 50 per cent level in the doughnut formulation decreased the water absorption to 125, 118 and 109 per cent, respectively.

Regarding the dough handling properties, the dough containing 100 per cent sugar was slightly sticky. Addition of sorbitol/mannitol at different levels significantly improved the dough

Table : 4.3 Water absorption (%), dough handling and puffing characteristics of doughnuts containing different levels of humectants

Humectant /Ratio	Water absorption	Dough handling	Puffing		
			Shortening	Groundnut oil	Mustard oil
Control	130	Slightly sticky	Full	Full	Full
Sorbitol					
R1 (70:30)	128	Slightly Sticky	Full	Full	Full
R2 (60:40)	125	Slightly sticky	Full	Full	Full
R3 (50:50)	117	Non sticky	Partial	Partial	Partial
Mannitol					
R1 (70:30)	129	Slightly Sticky	Full	Full	Full
R2 (60:40)	126	Slightly sticky	Full	Full	Full
R3 (50:50)	115	Non sticky	Partial	Partial	Partial
Glycerol					
R1 (70:30)	125	Slightly sticky	Full	Full	Full
R2 (60:40)	118	Sticky	Partial	Partial	Partial
R3 (50:50)	109	Very sticky	Partial	Partial	Partial

handling properties of the dough. The dough containing 50 per cent sorbitol/mannitol was non-sticky. But the observations were reverse in case of dough containing different levels of glycerol. With increasing level of glycerol in the doughnut formulation, the dough converted from slightly sticky to sticky. The formulation containing 50 per cent level of glycerol was very sticky.

Tipples *et al.*, 1978; Mok and Dick, 1991; Wang and Flore, 1999; Basman and Koksel, 1999; Hatcher and Kruger, 1997 and Hatcher *et al.*, 1999 have also reported increase in water absorption with increase in protein content and damaged starch. The flour, which was used in the present investigation, had lower protein contents and possibly lesser amounts of damaged starch therefore, the water absorption was observed less. Various researchers have shown water absorption to range between 36.20 - 60.30 per cent in different wheat flours. These variations are due to presence of high protein contents (up to 13.40 per cent) and damaged starch in these flours, which increased the water absorption significantly. Also, the varietal differences (whether hard or soft) play a significant role in determining the water absorption capacity of the flour for preparation of dough.

The puffing was full in case of doughnuts prepared from 100 per cent sugar in all the frying media viz. shortening, groundnut oil and mustard oil. Similar observations were recorded on doughnuts containing 30 and 40 per cent sorbitol/mannitol and 30 per cent glycerol. The puffing was however, partial in doughnuts prepared from formulation containing 50 per cent sorbitol/mannitol and 40 and 50 per cent glycerol during deep-fat-frying of doughnuts in shortening, groundnut oil and mustard oil.

The flour used for preparation of doughnuts was soft flour having lesser amounts of proteins, fat, ash, fibre and damaged starch and this flour had a poor elasticity or height but is highly extensible. Sodium bicarbonate was added to assist quick chemical leavening or raising of dough for preparation of doughnuts. The puffing of doughnuts was caused when steam accumulated between the top and bottom layers of wheat. However, any break or weak point in gluten layers causes an escape of moisture and resulted in poor puffing. An even and continuous layer of dough must be present and this will depend on the power of gluten network to hold the wet flour in a continuous phase. The puffing was good in control doughnut samples. However, addition of sorbitol and mannitol @ of 50 per cent and of glycerol @ of 40 and 50 per cent level produced doughnuts with partial puffing. This may be attributed to the reason that with an increase in humectant concentration, the water holding capacity was enhanced. Thus, there was comparatively less loss of moisture because of binding of water molecules with humectants, resulting in poor puffing quality.

4.4 Time/ temperature relationship during deep-fat-frying of doughnuts

Perusal of data in Table 4.4 show the time taken in seconds for frying of doughnuts containing different levels of humectants at different temperatures. As the level of humectants and the temperature of deep-fat-frying increased, the time was found to doughnuts decrease. The time in seconds required for deep-fat-frying of control doughnut samples (without humectant) at 170, 180 and 190°C was 278, 201 and 142 in shortening, 292, 221 and 151 in groundnut oil and 312, 290 and 230 in mustard oil, respectively. After addition of sorbitol/mannitol the time required for deep-fat-frying of doughnuts decreased. The time required for deep-fat-frying doughnuts containing 30 per cent sorbitol was 220, 197 and 142 seconds, 40 per cent sorbitol was 184, 162 and 127 seconds and 50 per cent sorbitol 178, 145 and 110 seconds when fried at 170, 180 and 190°C in shortening, respectively. Also, the time required for frying decreased with increase in temperature. However, when the three media were compared, highest time was recorded for the samples deep-fat-frying in mustard oil. Similar observations for time/temperature relationship have been observed during frying of doughnuts containing various levels of glycerol. Among the three humectants used, the lowest time was observed in case of glycerol followed by mannitol and then by sorbitol.

Thus, it can be interpreted that temperature during frying significantly affected the time required for frying of doughnuts. With an

Table 4. 4 : Time taken (seconds) for frying of doughnuts containing different levels of humectants at different temperatures

Frying Media	Temperature (^oC)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170	278	220	184	178	211	172	165	200	151	147
	180	201	197	162	145	184	147	132	163	126	118
	190	142	142	127	110	130	116	99	114	102	83
Groundnut oil	170	292	247	235	210	231	220	198	214	203	180
	180	221	199	172	157	187	162	145	165	141	123
	190	151	137	134	114	126	120	105	114	105	96
Mustard oil	170	312	289	278	261	277	263	249	254	242	233
	180	290	266	257	238	248	241	222	227	221	208
	190	230	224	221	209	213	204	193	202	187	170

increase in temperature, the time required for frying of doughnuts decreased. This time temperature relationship can be better understood through mass transfer calculations used to derive an initial stimulation of frying of food based on the overall rate of loss of water, as well as the relative ease of migration of water through a dehydrating food matrix, from walls and edges. Water plays a number of roles in the transfer of heat into the food. This removal of energy from food's surface prevents charring or burning caused by excessive dehydration. The conversion from liquid water to steam as water leaves the food carries the bulk of contacting oils energy. As long as the water is leaving, the food will not char and burn. Therefore, although the temperature of the oil may be 180°C, the temperature of the frying food is only about 100°C, respectively the temperature of the change in phase from water to steam. Thus, the increased contact times transfers more heat from the oil to the food in a fixed period of time. The enhanced heat transfer (which was achieved with various humectants) caused heightened dehydration at the surface, which usually translates to the exterior of frying food. Therefore, in control samples, the initial moisture of the dough was high and thus the time required for frying was high because time was required for evaporation of all the free form of water. Increase in temperature, however, reduced the processing time, as the rate of dehydration was fast. Addition of humectants resulted in two major benefits for reducing the processing times. Firstly, the moisture content of the dough was less with increased water holding capacity thereby reducing the free form of water to be evaporated during frying. Secondly, the conductivity of the product was enhanced which resulted in increased rate of heat transfer and moisture evaporation due to decreased thermal diffusivity of food.

The results are in agreement with those reported by Pokharkar and Mahale (2001) and Diaz *et al.*, (1999) and Indira (1996). They also reported decrease in time required for frying of foods with an increase in temperature.

4.5 Specific heat during deep-fat-frying

Specific heat plays an important role in heat transfer processes during the heating and cooking of foods. It is imperative therefore, to ascertain the quantity of energy required for addition or removal. In addition to an indicative of energy costs, it has a bearing on the type and size of the equipment. Specific heat of a material is a measure of the amount of energy required to raise unit mass by unit temperature rise. It is possible to predict the specific heat of foods from the knowledge of its composition. Fore example, the specific heat of skim milk would be slightly lower than that of water because of presence of milk solids.

Effect of different levels of humectants and temperature on specific heat of doughnuts during deep-fat-frying has been summarized in Table 4.5. The specific heat (KJ Kg^{-1} K^{-1}) of the control samples (without humectants) at 170, 180 and 190°C in case of shortening was

Table: 4.5 Effect of different levels of humectants and temperature on specific heat ($KJ\ Kg^{-1}\ K^{-1}$) by doughnuts during deep-fat-frying

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170	1.935	1.954	1.901	1.888	1.968	1.992	1.878	1.913	1.880	1.816
	180	1.928	1.944	1.896	1.879	1.959	1.913	1.870	1.906	1.876	1.809
	190	1.918	1.932	1.889	1.868	1.951	1.904	1.861	1.918	1.869	1.802
Groundnut oil	170	1.945	1.945	1.893	1.862	1.949	1.881	1.846	1.899	1.868	1.809
	180	1.939	1.939	1.887	1.849	1.938	1.872	1.837	1.894	1.861	1.804
	190	1.926	1.929	1.876	1.844	1.929	1.863	1.829	1.888	1.855	1.780
Mustard oil	170	1.976	1.995	1.923	1.899	2.013	1.929	1.896	1.942	1.900	1.838
	180	1.964	1.973	1.916	1.891	2.004	1.921	1.884	1.936	1.894	1.832
	190	1.950	1.957	1.904	1.882	1.996	1.912	1.880	1.930	1.888	1.826

1.935, 1.928 and 1.918; groundnut oil 1.945, 1.939 and 1.926; and mustard oil 1.976, 1.964 and 1.950, respectively. Addition of either humectant sorbitol/mannitol/glycerol at 30, 40 and 50 per cent level produced doughnuts with lower specific heat values when compared to control. The specific heat (KJ Kg^{-1} K^{-1}) of the doughnuts containing 30 per cent sorbitol at 170, 180 and 190°C was 1.954, 1.944 and 1.932 in case of shortening; 1.945, 1.939 and 1.929 in groundnut oil; and 1.995, 1.973 and 1.957 in mustard oil, respectively. As the level of sorbitol was increased to 40 per cent level, further reduction in specific heat was observed and the values were 1.901, 1.896 and 1.889 (shortening); 1.893, 1.887 and 1.876 (groundnut oil); 1.923, 1.916 and 1.904 (mustard oil), respectively after deep-fat-frying at 170, 180 and 190°C. Temperature also had pronounced effect on specific heat and with increase in temperature, decrease in above values was observed.

Therefore, evidently the addition of humectants reduced the specific heat of doughnuts. With increase in the level of humectant and temperature during frying, further decrease in specific heat was observed, because it is dependent upon the moisture contents. Since the control doughnuts contained higher moisture contents, these resulted in reduced mass fraction of solids. Thus, the specific heat in case of control doughnuts were higher because of lower volume of solids increased the specific heat. On the contrary, with addition of humectants the moisture contents were lowered thereby, increasing the mass fraction of solids thus, reducing the specific heat of the doughnuts.

Similarly, with increase in temperature during frying, the rate of moisture loss was increased which directly affected and decreased the specific heat of doughnuts (Jha and Prasad, 1993; Yamada, 1970).

4.6 Thermal conductivity during deep-fat-frying

In most cases, it is desirable to be able to heat and cool foods as rapidly as possible. This improves the economics of the process by increasing the capacity and generally results in a better quality product. Heat transfer rates and mechanisms are very important, with heat being transferred by conduction or convection or by combination of both. The heating rate will depend upon a variety of factors such as shape, size and physical nature of material (i.e. whether it is a solid, liquid or suspension), the thermal properties of the materials (such as specific heat and thermal conductivity), the mechanism of heat transfer and temperature and the nature of the heat transfer fluid used.

Perusals of data in Table 4.6 show the effect of different levels of humectants and temperature on thermal conductivity of doughnuts during deep-fat-frying. It was observed that the addition of various levels of humectants increased the thermal conductivity, while increase in temperature decreased the thermal conductivity but the difference is non-significant. The thermal conductivities (W m^{-2} k^{-1}) of control doughnut samples during frying at 170, 180 and 190°C was 0.294, 0.293 and 0.292 in shortening; 0.296, 0.295 and 0.294 in

Table: 4.6 Effect of different levels of humectants and temperature on thermal conductivities ($Wm^{-2}k^{-1}$) of doughnuts during deep-fat-frying

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170	0.294	0.301	0.300	0.302	0.301	0.301	0.300	0.299	0.300	0.296
	180	0.293	0.300	0.299	0.301	0.300	0.301	0.299	0.298	0.299	0.294
	190	0.292	0.299	0.298	0.299	0.300	0.300	0.298	0.297	0.298	0.294
Groundnut oil	170	0.296	0.300	0.300	0.299	0.300	0.298	0.297	0.298	0.299	0.295
	180	0.295	0.300	0.299	0.298	0.300	0.297	0.296	0.297	0.298	0.295
	190	0.294	0.299	0.297	0.298	0.299	0.296	0.295	0.297	0.298	0.294
Mustard oil	170	0.297	0.303	0.302	0.302	0.306	0.302	0.302	0.301	0.301	0.298
	180	0.296	0.301	0.301	0.302	0.305	0.302	0.301	0.301	0.301	0.298
	190	0.295	0.299	0.300	0.300	0.303	0.300	0.300	0.300	0.300	0.296

groundnut oil; and 0.297, 0.296 and 0.295 in mustard oil, respectively. With the addition of sorbitol at 30, 40 and 50 per cent levels significantly increased the thermal conductivities of the doughnuts. The thermal conductivity (W m^{-2} k^{-1}) in case of samples containing 30 per cent sorbitol at 170, 180 and 190°C was 0.301, 0.300 and 0.299 in shortening; 0.300, 0.300 and 0.299 in refined groundnut oil and 0.303, 0.301 and 0.299 in mustard oil, respectively. Similar observations were found in case of doughnuts containing various levels of mannitol and glycerol.

Hence, it can be interpreted that addition of humectants increased the thermal conductivities. However, increase in the temperature during frying reduced the same. Basically thermal conductivity of a food is influenced by its composition in a similar manner to specific heat; water exerts the major influence. In many foods, water behaves as solid and immobilized within the solid matrix. This immobilized water is then responsible for heat transfer within the solids. In case of control samples, there was high moisture content in the form of free water, which was evaporated rapidly during frying and thus played relatively less role in conducting heat. However, addition of different humectants worked to hold the water in immobilized form within the food, thereby, increasing the conductivity of the doughnuts. Since, temperature had negative effect on moisture contents, so it also had negative and lowering effect on conductivities (Rao et al, 1975; Tschubik and Malslow, 1973; Wang and Brenan, 1992; Abdul, 1983)

4.7 Thermal diffusivity during deep-fat-frying

The thermal diffusivity 'a' is the ratio of the thermal conductivity to the specific heat of the product multiplied by its density. In physical terms, thermal diffusivity gives a measure of how quickly the temperature will be changed when the food is heated or cooled. Materials with high thermal diffusivity will heat or cool quickly; conversely, substances with a low thermal diffusivity will heat or cool slowly.

Data in Table 4.7 show the effect of different levels of humectants and temperature on the thermal diffusivity of doughnuts during deep-fat-frying. It is evident from the table that with addition of humectants at various levels, the thermal diffusivity decreases. On the other hand it increased with increase in temperature. The values for thermal diffusivity (m^2s^{-1}) observed in case of control (without humectant) doughnuts at 170, 180 and 190°C in case of shortening was 0.286, 0.287 and 0.289; groundnut oil 0.282, 0.283 and 0.287; and mustard oil 0.283, 0.285 and 0.286, respectively. Addition of sorbitol at 30 per cent level decreased the thermal diffusivity (m^2s^{-1}) and the observed values were 0.252, 0.254 and 0.255 in shortening; 0.247, 0.248 and 0.250 in groundnut oil; and 0.246, 0.250 and 0.251 in mustard oil, respectively during frying at 170, 180 and 190°C. Still further addition of sorbitol at 40 per cent level further reduced thermal diffusivity of doughnuts. Similar observations were found in case of samples containing different levels of mannitol and glycerol.

Table 4.7: **Effect of different levels of humectants and temperature on thermal diffusivity (m^2s^{-1}) of doughnuts during deep-fat-frying**

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170	0.286	0.252	0.229	0.215	0.255	0.230	0.217	0.243	0.222	0.210
	180	0.287	0.254	0.230	0.214	0.257	0.232	0.218	0.243	0.223	0.211
	190	0.289	0.255	0.231	0.217	0.260	0.233	0.219	0.245	0.224	0.212
Groundnut oil	170	0.282	0.247	0.228	0.213	0.250	0.231	0.216	0.240	0.221	0.208
	180	0.283	0.248	0.229	0.215	0.252	0.232	0.217	0.240	0.222	0.210
	190	0.287	0.250	0.230	0.216	0.253	0.233	0.218	0.242	0.224	0.212
Mustard oil	170	0.283	0.246	0.228	0.213	0.250	0.230	0.216	0.240	0.221	0.209
	180	0.285	0.250	0.229	0.214	0.253	0.232	0.217	0.243	0.222	0.210
	190	0.286	0.251	0.230	0.215	0.253	0.233	0.217	0.243	0.222	0.210

The inferences drawn are that addition of humectants decreased the thermal diffusivity of doughnuts while the increase in temperature increased these values. It is a well-known fact that during frying, moisture/water plays a key role in transfer of heat. The removal of water as vapour is accompanied by entrance of oil into the product. The food samples containing higher moisture contents had higher thermal diffusivity because continuous removal/evaporation of moisture as vapours heated the foods more efficiently. Addition of humectants altered the moisture content of doughnuts due to their strong water binding properties and thus available momentary moisture for heat and mass transfer during frying was less, thereby decreasing thermal diffusivity. Also, the specific heat and density of products had major impact on thermal diffusivity and higher values mean lower values of thermal diffusivity (Mathews & Halls, 1968. Rice et al., 1975).

4.8 Moisture loss during deep-fat-frying of doughnuts

During the process of frying, the water at the peripherals is initially evaporated because of intense heat. In order to replenish the loss of moisture, water molecules from the center of the product migrate towards the surface, which is called the pumping phenomena. The term "pumping" is used to describe this migration i.e. water is pumped by an imaginary machine from the interior to exterior. Therefore, it is fair to use mass transfer calculations to derive an initial stimulation for the frying of food, based on the overall rate of loss of water, as well as the relative ease of migration of water through a dehydrating food matrix, from walls and edges. These conditions define the kinetics of mass transfer of water in and from a frying food. Batters and breading apparently functioned to reduce water loss during frying. Incorporation of long fibre cellulose, methocel, curdlan (microbial polysaccharide) and other ingredients are also reported to effectively reduce the water loss and similarly alginates could be used for the same purpose.

Data on effect of different levels of humectants and temperature on the moisture content of doughnuts during deep-fat-frying are presented in Table 4.8. In the control doughnut samples, the moisture content was observed to be 18.43, 17.21 and 17.82 per cent at 170, 180 and 190°C, respectively after frying in shortening. While the moisture content in samples deep-fat-fried in groundnut oil and mustard oil were (18.83, 18.61 and 18.13 per cent) and (19.96, 19.54 and 19.05 per cent) when fried at a temperature of 170, 180 and 190°C, respectively. Addition of sorbitol/mannitol initially at 30 per cent level slightly decreased the moisture content when compared to control samples. Further addition of same humectants at 40 and 50 per cent level again significantly reduced the moisture contents to lower levels. These moisture contents were observed to be 16.17, 15.82 and 15.55 in doughnuts containing 50 per cent sorbitol at 170, 180 and 190°C temperature of mustard oil. The doughnuts containing 50 per cent mannitol and fried in groundnut oil had moisture content of 14.17, 13.85

Table 4.8: **Effect of different levels of humectants and temperature on moisture contents of doughnuts during deep-fat-frying**

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170	18.43	18.16	16.24	15.76	18.67	16.99	15.38	16.63	15.54	13.07
	180	17.21	17.77	16.01	15.38	18.34	16.68	15.06	16.41	15.26	12.81
	190	17.82	17.32	15.77	15.03	18.03	16.32	14.73	16.20	15.03	12.59
Groundnut oil	170	18.83	17.82	15.94	14.79	17.94	15.46	14.17	16.14	14.98	12.84
	180	18.61	17.59	15.71	14.32	17.58	15.11	13.85	15.93	14.75	12.61
	190	18.13	17.21	15.29	14.08	17.23	14.83	13.54	15.70	14.51	12.38
Mustard oil	170	19.96	18.87	17.04	16.17	19.33	17.24	16.01	17.70	16.16	13.88
	180	19.54	18.62	16.78	15.82	19.02	16.97	15.65	17.48	15.94	13.64
	190	19.05	18.29	16.32	15.55	19.73	16.61	15.41	17.25	15.73	13.42

and 13.54 per cent at 170, 180 and 190°C of frying temperature. Similar observations were found in case of doughnuts containing different levels of glycerol. The only difference was that initial addition of glycerol at 30 per cent level did not increased but decreases the moisture content of the doughnuts. Thus, temperature significantly reduced the moisture content of the doughnuts. The humectants significantly reduced the moisture content of the doughnuts and increase in the level of humectant in the doughnut formulation more effectively reduced the moisture contents (Fig. 1a, 1b & 1c for samples fried in shortening; Fig. 2a, 2b & 2c for samples fried in groundnut oil and Fig. 3a, 3b & 3c for samples fried in mustard oil). The samples deep-fat-fried in shortening showed lowest values of moisture content followed by groundnut oil samples and then those fried in mustard oil.

The conclusions that can be drawn from the above table are that temperatures as well as humectants were found to be effective in reducing the moisture contents of the fried foods. The basic function which water performs during frying of food is transfer of heat into the food. This water during frying migrates from the food matrix as steam thereby, carrying bulk of frying oils energy and this is the reason why foods with high initial moisture content do not burn and takes long time for frying. In case of control samples (without humectants), the moisture contents were higher. Also, steady state (when temperature of surface is nearly equal to the temperature of frying oil) was achieved much later which resulted in long processing times. In case of samples containing

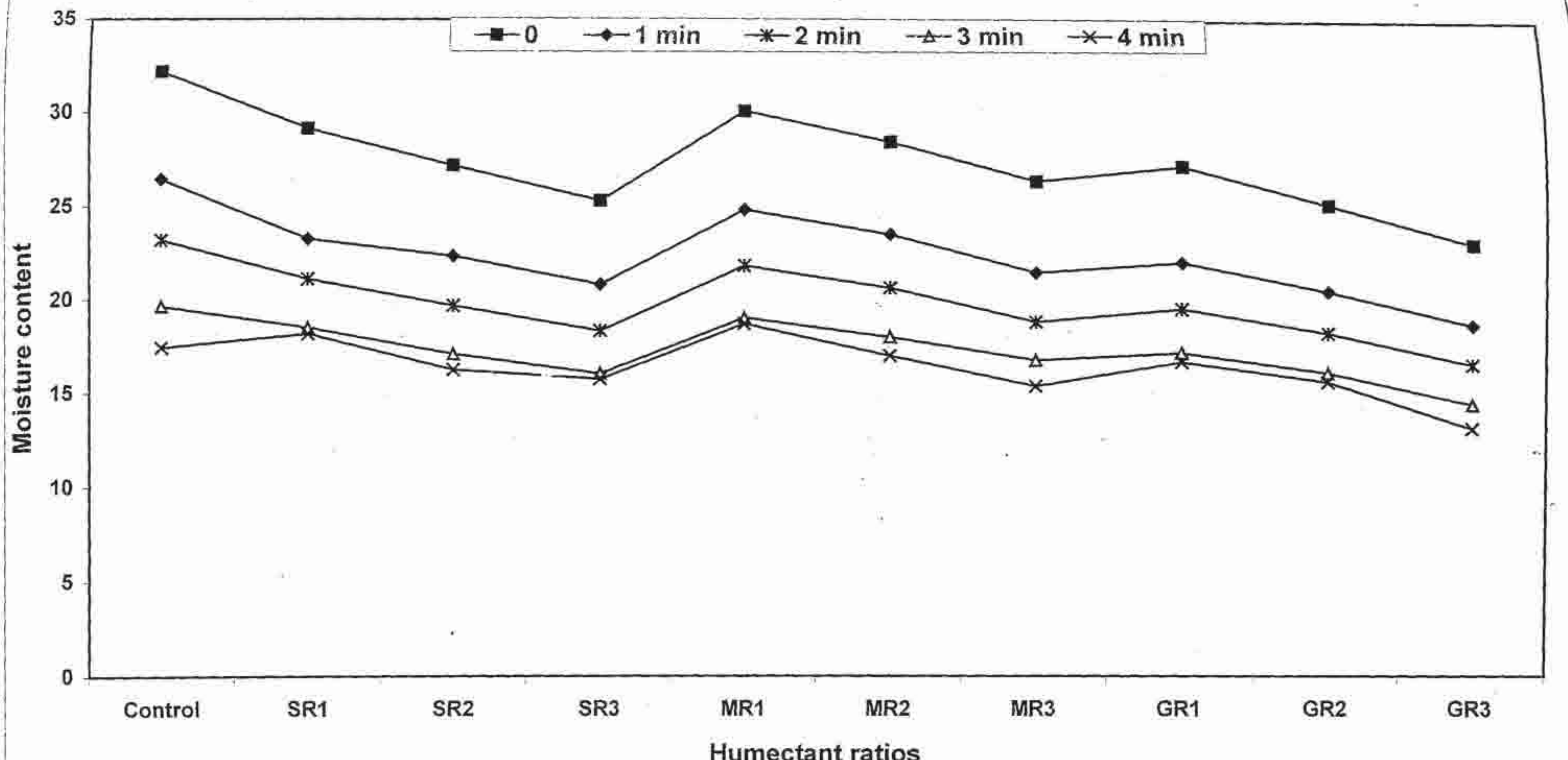


Fig :1a Moisture loss as affected by different levels of humectants during deep-fat-frying of doughnuts in shortening at 170oC

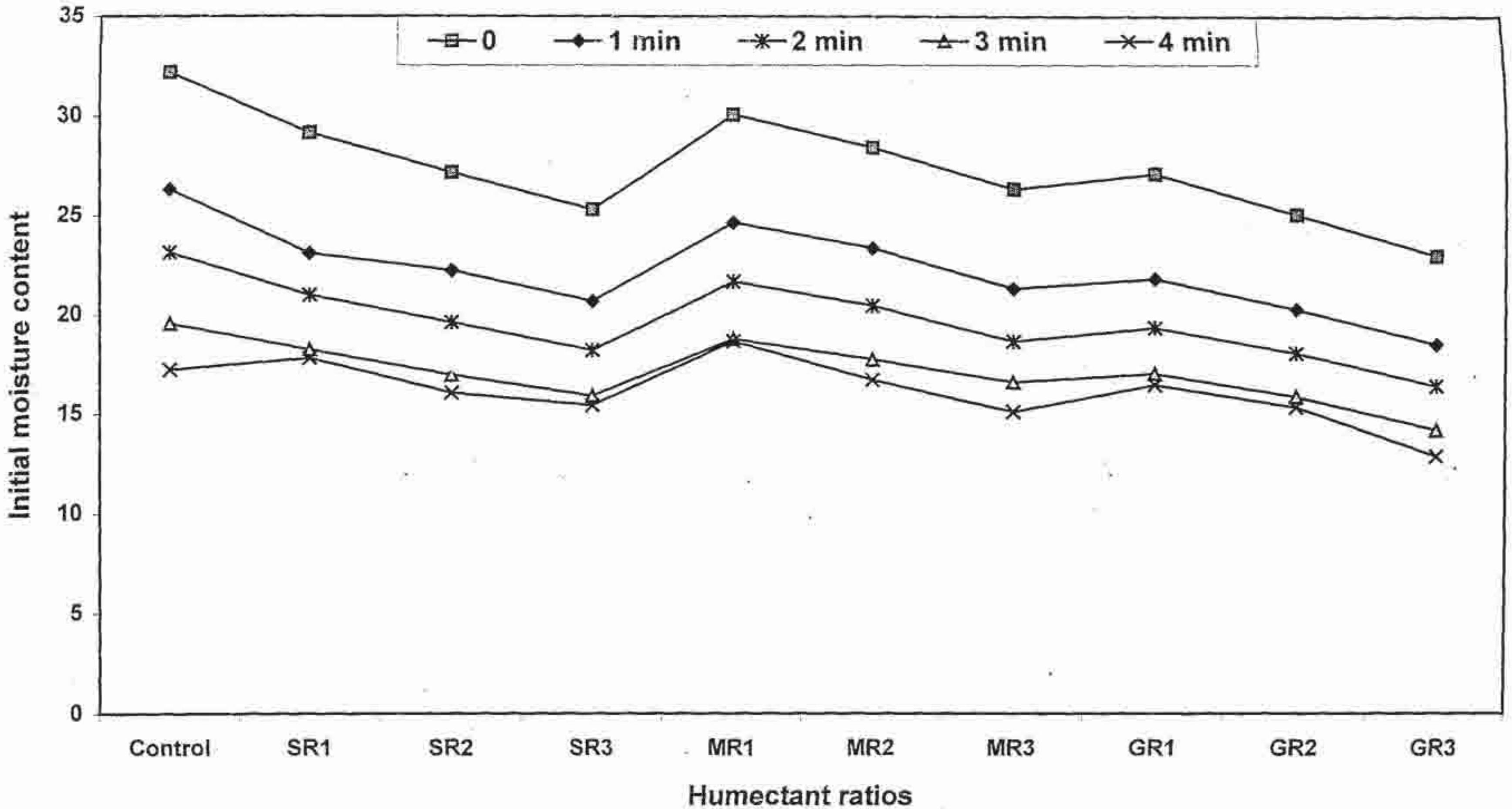


Fig :1b Moisture loss as affected by different ratios of humectants during deep-fat-frying of doughnuts in shortening at 180oC

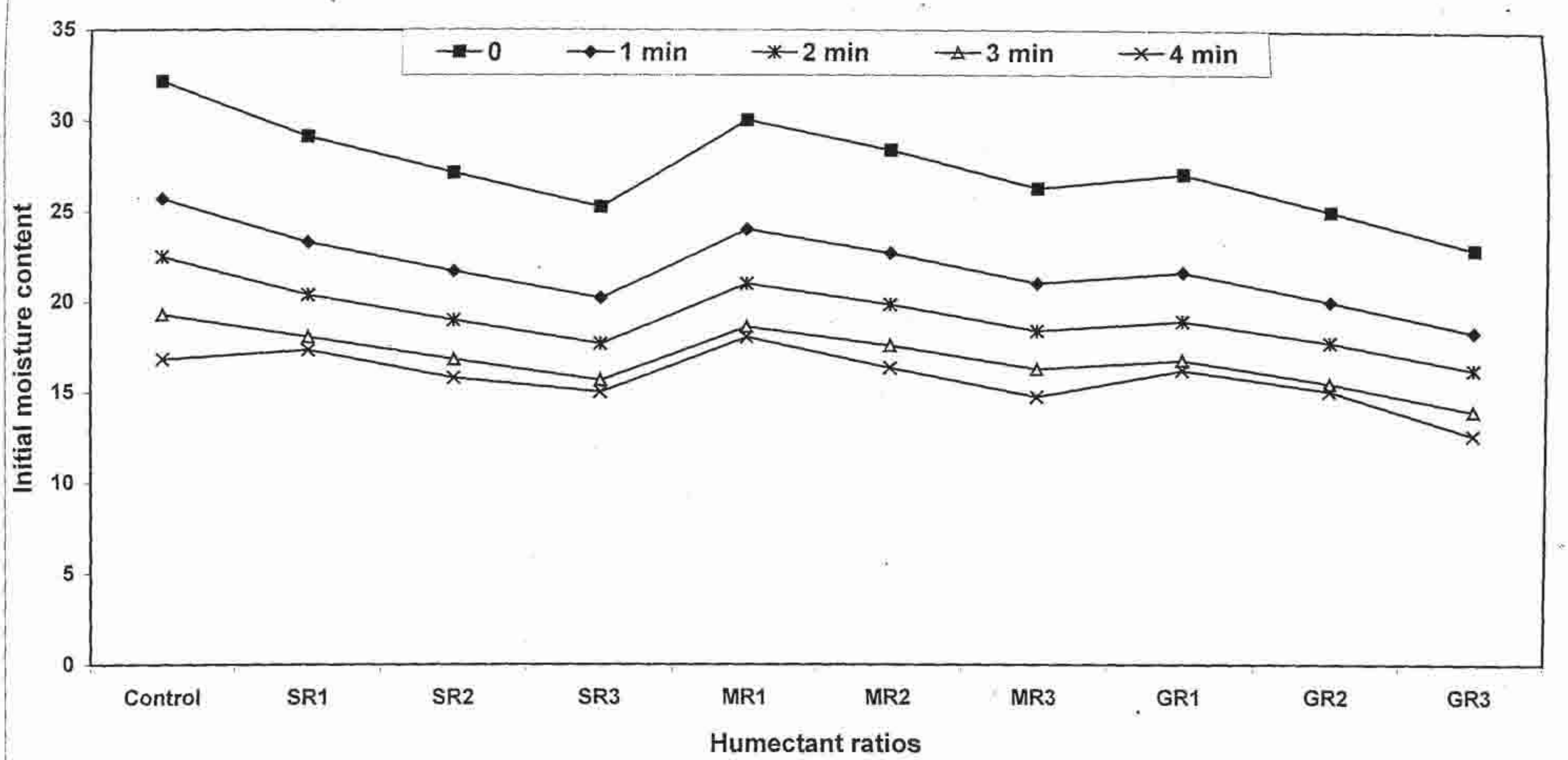


Fig :1c Moisture loss as afftected by different levels of humectants during deep-fat-frying of doughnuts in shortening at 190oC

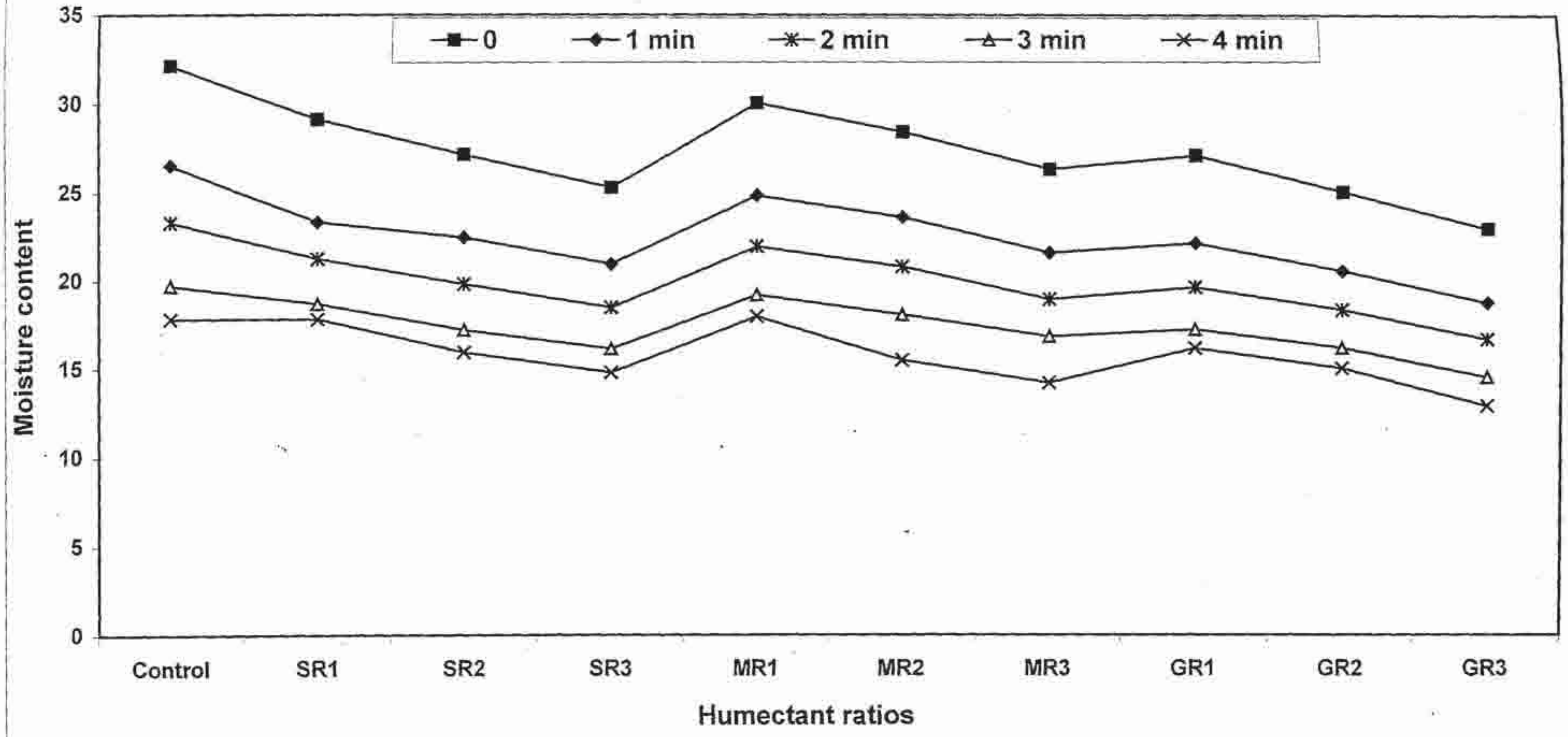


Fig :2a Moisture loss as affected by different levels of humectants during deep-fat-frying of doughnuts in refined groundnut oil at 170oC

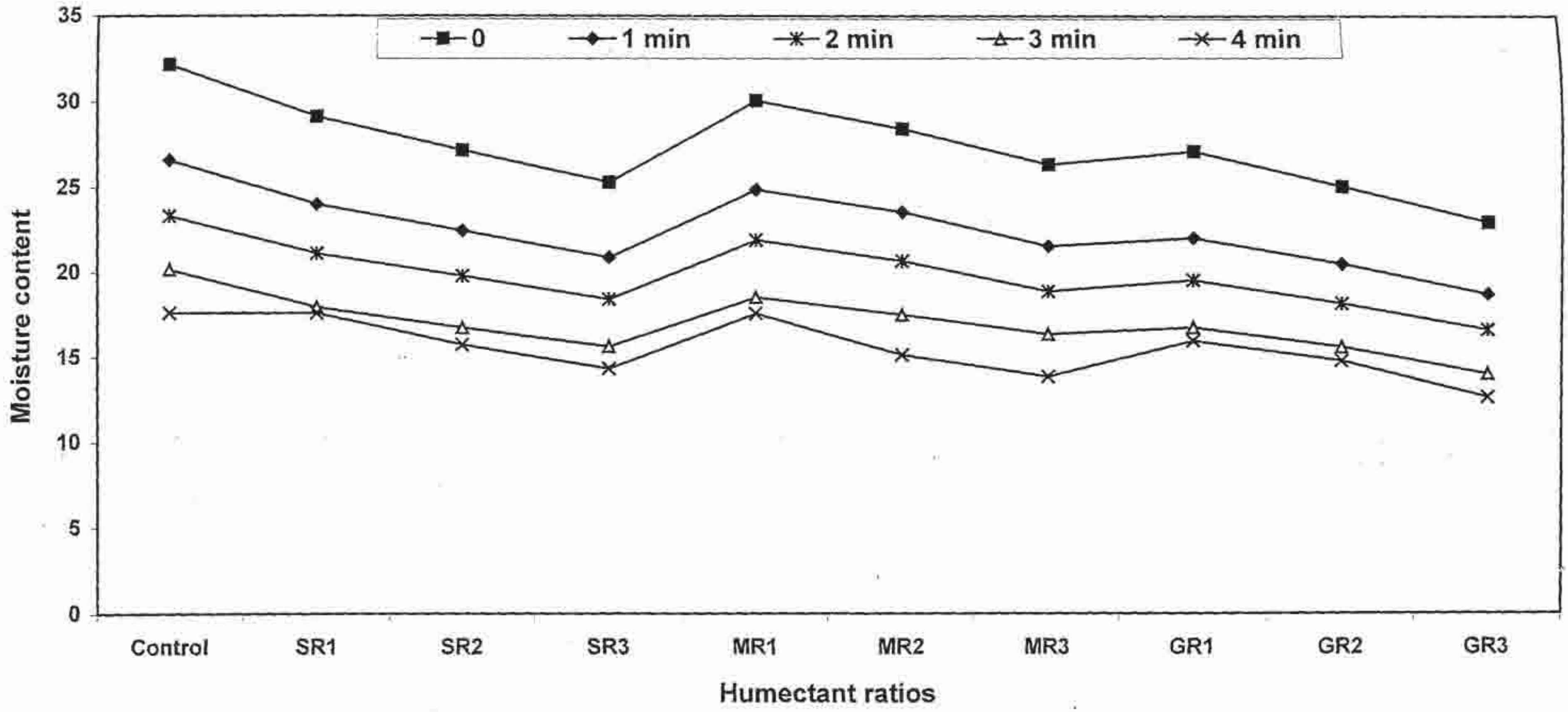


Fig :2b Moisture loss as affected by different levels of humectants during deep-fat-frying of doughnuts in refined groundnut oil at 180oC

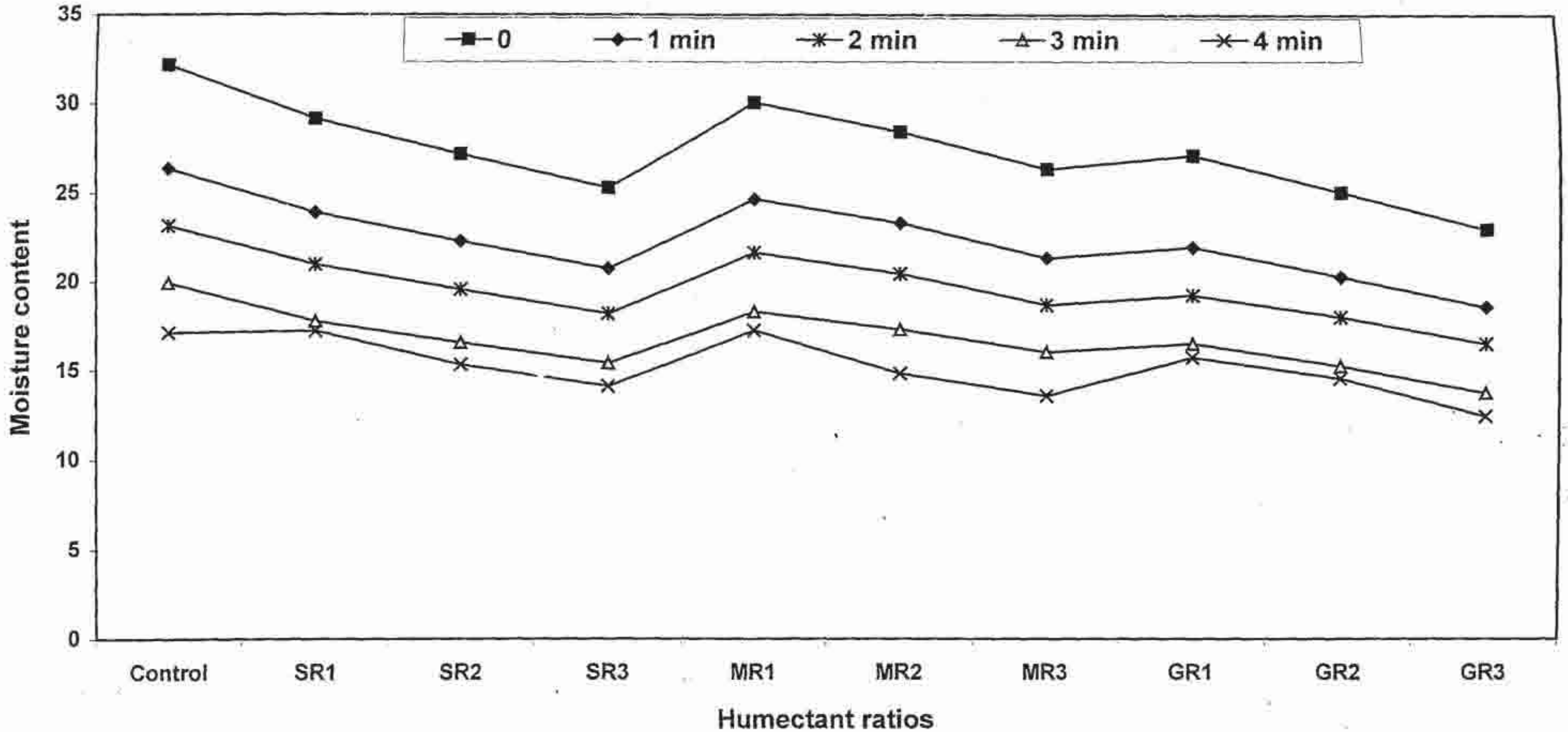


Fig :2c Moisture loss as affected by different levels of humectants during deep-fat-frying of doughnuts in refined groundnut oil at 190oC

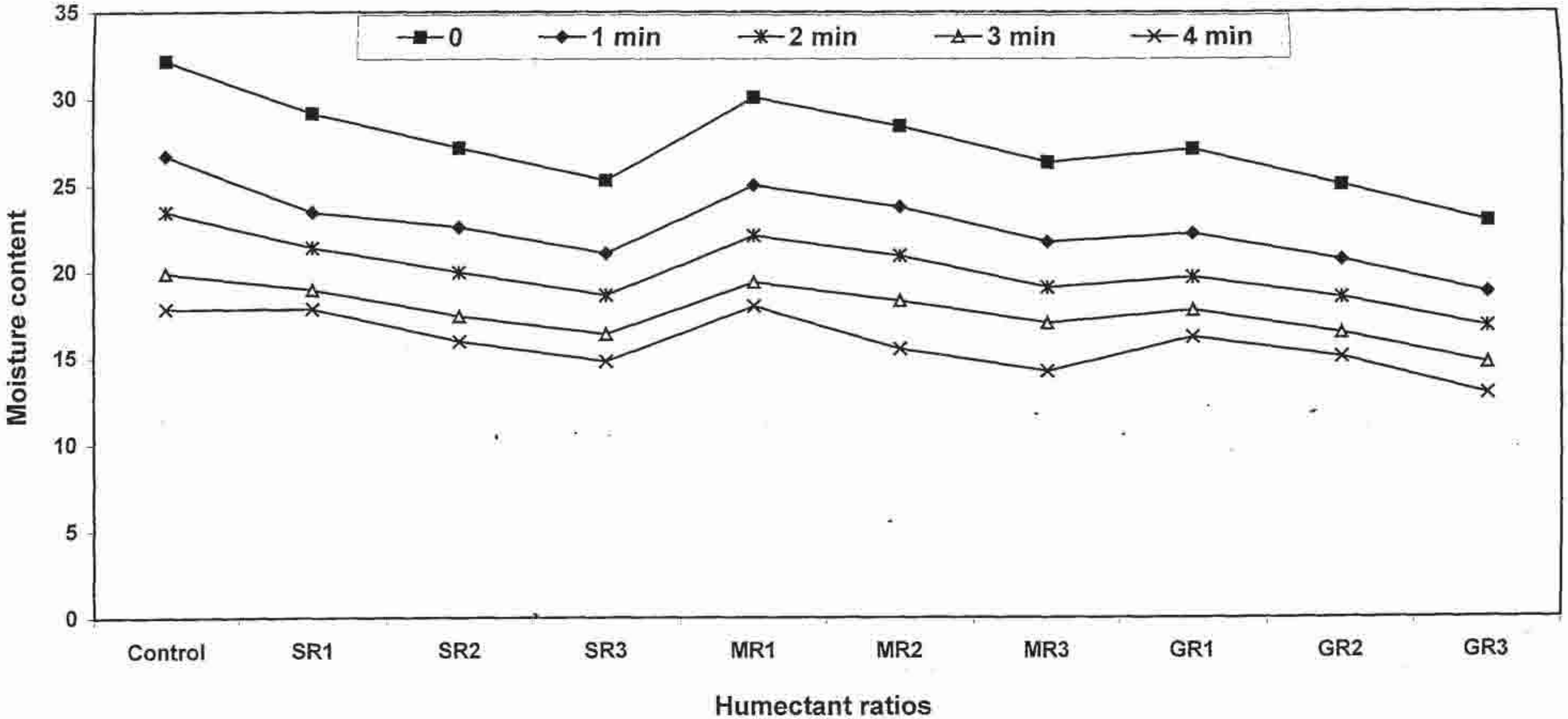


Fig:3a Moisture loss as affected by different levels of humectants during deep-fat-frying of doughnuts in mustard oil at 170oC

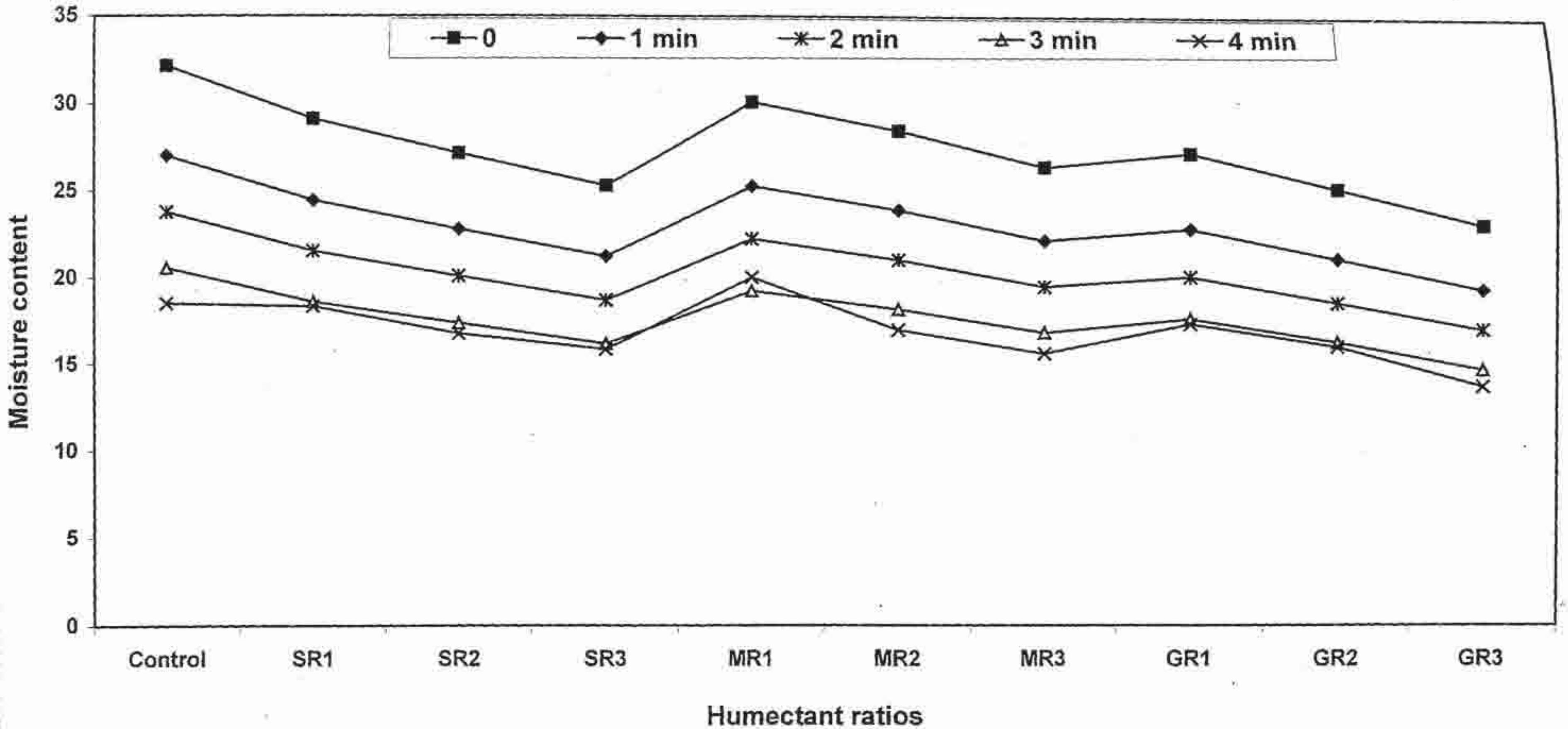


Fig :3b Moisture loss as affected by different levels of humectants during deep-fat-frying of doughnuts in mustard oil at 180oC

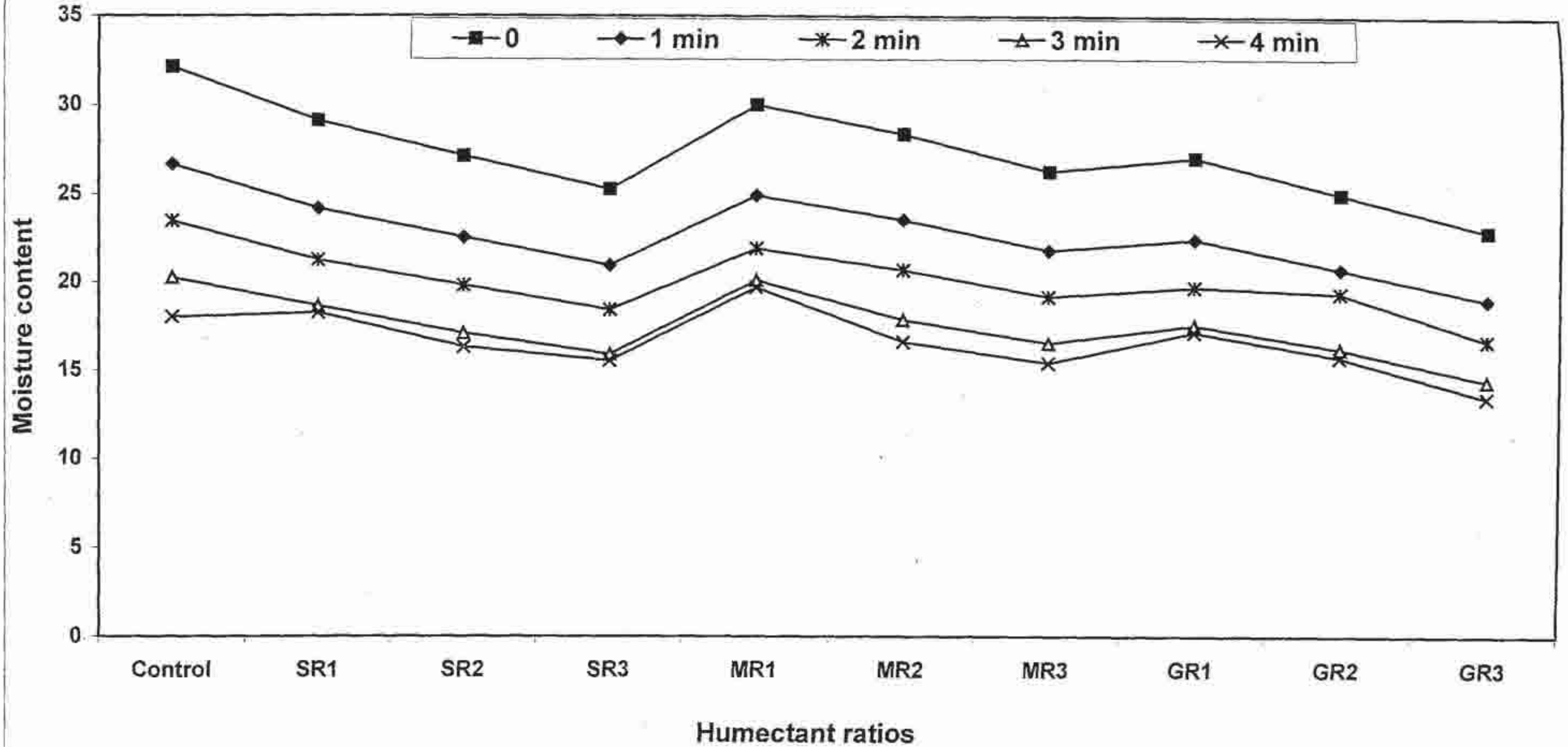


Fig :3c Moisture loss as affected by different levels of humectants during deep-fat-frying of doughnuts in mustard oil at 190oC humectants, the thermal conductivity of the product was enhanced and thus steady state was achieved much earlier. This resulted in short processing times and faster rate of evaporation of water. Since the water/moisture contents were less initially before frying, the same were observed less even after frying. This effect was basically due to increased conductivity and reduced thermal diffusivity (rate at which food can be heated or cooled) of the food materials. Humectants also functioned to increase the water holding capacity by entrapping moisture and consequently preventing moisture loss.

The results are in conformation with those of Diaz *et al.*, (1999), Indira *et al.*, (1996), Reddy and Das (1993), Sahin *et al.*, (2000), Berry *et al.*, (1999) who sated that with increase in the temperature and time during frying, moisture loss increased. Also addition of different additives like sorbitol, cellulose, methocel, carboxy methyl cellulose, curdlan etc decreased the moisture contents.

4.9 Fat/oil absorption during deep-fat-frying

The quality of the oil as a frying medium and the quality of the food produced in it are intimately bound. Oil transfer sensible heats by surface contact and then by capillary into the open pores of the surface from which steam has rushed out. The viscosity and surface tension of the oil moderate this effect. The contact between the food and oil progresses through the different stages. The residence time of food in oil can moderate absorption. During deep-fat-frying, heat transfer is accompanied by mass transfer which is characterized by the penetration of oil into the product and exit of water as vapour from product. Many factors affect oil uptake including oil quality, frying temperature and duration, product shape and its content (e.g. moisture, solids, fat, protein), porosity, pre-frying treatments (e.g. drying, blanching) and coating. Fat absorption can be significantly affected and reduced in the final product by the addition of ingredients like batters and breadings, long fibre cellulose, methocel, curdlan (microbial polysaccharide) and other ingredients

Table 4.9 represents the data on the effect of different levels of humectants and temperature on fat absorption by doughnuts during deep-fat-frying. Among the three temperatures tested for reducing the fat absorption by the doughnut samples, it was observed that with increase in the temperature, the fat absorption decreased. Also, with increase in the level of humectant in the doughnuts, the fat absorption decreased. With respect to three different frying media, the oil absorption was less in case of shortening followed by groundnut oil and then by mustard oil. In control doughnut samples, 10.98 per cent fat was observed at 170°C, while 10.46 and 10.15 per cent was observed at 180 and 190°C, respectively when fried in shortening. Addition of sorbitol at 30 per cent level reduced the fat absorption to 9.93 at 170°C, 9.70 at 180°C and 8.99 at 190°C during deep-fat-frying of doughnuts in shortening. Addition of sorbitol/mannitol still at higher levels i.e. 40 and 50 per cent

Table 4.9: Effect of different levels of humectants and temperature on fat absorption by doughnuts during deep-fat-frying

Frying Media	Temperature (^{o}C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170	10.98	9.93	9.16	8.99	10.00	9.30	9.15	8.80	8.52	8.27
	180	10.46	9.70	8.84	8.58	9.76	9.05	8.90	8.55	8.25	8.01
	190	10.15	8.99	8.72	8.51	9.50	8.72	8.64	8.30	7.99	7.75
Groundnut oil	170	11.38	10.43	9.50	9.20	10.63	9.62	9.28	9.09	9.00	8.68
	180	11.09	10.13	9.12	8.90	10.36	9.35	9.03	8.82	8.75	8.43
	190	10.84	9.90	8.80	8.45	10.13	9.10	8.79	8.56	8.49	8.17
Mustard oil	170	12.51	10.87	10.10	9.91	10.95	10.52	10.00	9.85	9.53	9.11
	180	12.20	10.65	9.83	9.65	10.70	10.39	9.90	9.60	9.26	8.85
	190	11.85	10.42	9.55	9.37	10.44	10.13	9.65	9.34	9.01	8.61

levels further significantly reduced the fat absorption. Similar observations were found in case of doughnut samples supplemented with glycerol at different levels.

On an average, it can be concluded that addition of humectants viz., sorbitol, mannitol and glycerol significantly reduced the fat absorption by the doughnuts during deep-fat-frying. This was basically because of the fact that frying of foods involves heat transfer accompanied by mass transfer, which is characterized by the penetration of oil into the product and escape of water as vapour from the product. Oil transferred sensible heat by surface contact and then by capillary into the open pores of the surface from which steam has rushed out. This effect is moderated by viscosity and surface tension of the oil and also by thermal conductivity and diffusivity of the food. The residence time of the food in oil also moderated oil absorption. Thus, in case of higher temperatures, the residence time of the food in the oil was reduced, thereby decreasing oil absorption. When doughnuts were placed in hot oil, the moisture at the surface was lost rapidly. A diffusion gradient was provided, since the outer surface was dry. The inner moisture was converted to vapour and this caused a pressure gradient. Thus, the vapour in frying doughnuts migrated from central portion to the surface and at the same time oil entered the voids left by the vapours. However, when humectants were added to the doughnut formulation, they increased the water holding capacity, thereby increasing the ability of the humectants to prevent moisture loss and thus replacement of the lost moisture by the oil. Addition of humectants moderated the oil absorption phenomena because less moisture was evaporated as vapour resulting in lesser number of voids that could be replaced by oil.

The results are in agreement with those of Indira *et al.*, (1996), Diaz *et al.*, (1999), Berry *et al.*, (1999) and Sahin *et al.*, (2000) who reported that time and temperature significantly affected the oil absorption by the samples. With increase in temperature the oil absorption decreased while with increase in time of frying of samples, the oil absorption increased. Different additives like sorbitol, cellulose, methocel, carboxy methyl cellulose, curdlan can be effectively used to reduce fat absorption by the samples.

4.10 Oil uptake ratio (Ur) during deep-fat-frying

The basic physical effect of deep-fat-frying is water replacement by oil. Formulation changes and different additives as well as various treatments, may alter the water holding capacity and consequently affect the oil uptake. As more studies compared different treatments on the basis of equal frying time rather than equal water loss, enormous conclusions can be drawn regarding the relative effectiveness of the treatment and/or the additive as an oil barrier or reducer. Hence to overcome this problem, new criterion of oil uptake ratio was used which alleviated the dependency of oil uptake on moisture. The value of Ur, expresses the weight ratio between the amount of oil uptake and water removed. The value of Ur is derived for any specific point of the frying process by considering the initial and the momentary moisture and oil contents. The value of Ur may change with frying time, different rates of oil uptake and water removal or other effects like shrinkage.

On perusal of data in Table 4.10 regarding effect of different levels of humectants on oil uptake ratio during deep-fat-frying of doughnuts, it was observed that increase in temperature significantly reduced the oil uptake ratio. The oil uptake ratio in control doughnut samples was 0.792 when fried at 170°C; while it was reduced to 0.778 and 0.719 in case of doughnuts fried at 180 and 190°C in groundnut oil. High oil uptake ratio was observed in case of doughnuts fried in mustard oil followed by groundnut oil and then by shortening. Thus, the frying media had significant effect on the oil uptake ratio. Addition of humectants at various levels significantly affected the oil uptake ratio. The oil uptake ratio was higher in doughnuts containing 50 per cent sorbitol/mannitol. The oil uptake ratio was 0.941, 0.880 and 0.827 in case of doughnuts containing 50 per cent sorbitol fried at 170, 180 and 190°C temperatures in shortening, followed by those containing 30 per cent sorbitol and then by those containing 40 per cent sorbitol. However, the samples containing glycerol and mannitol behaved differently. In case of samples containing mannitol higher oil uptake ratio was observed in samples containing 30 per cent level of mannitol with values of 0.876, 0.828 and 0.789 when fried at 170, 180

Table 4.10 : Effect of different levels of humectants and temperature on oil uptake ratio of doughnuts during deep-fat-frying

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170°C	0.744	0.941	0.834	0.902	0.877	0.814	0.836	0.841	0.902	0.842
	180°C	0.697	0.880	0.780	0.850	0.882	0.771	0.790	0.800	0.848	0.794
	190°C	0.660	0.827	0.750	0.796	0.789	0.725	0.746	0.762	0.792	0.754
Groundnut oil	170°C	0.792	0.918	0.842	0.872	0.876	0.743	0.764	0.863	0.899	0.830
	180°C	0.778	0.875	0.793	0.810	0.828	0.703	0.724	0.820	0.854	0.790
	190°C	0.719	0.827	0.738	0.753	0.789	0.670	0.688	0.777	0.810	0.752
Mustard oil	170°C	0.946	1.084	0.991	1.054	1.123	0.908	1.062	1.049	1.079	1.011
	180°C	0.892	1.018	0.941	1.008	1.062	0.865	1.000	0.996	1.024	0.957
	190°C	0.837	0.960	0.877	0.956	1.008	0.818	0.957	0.949	0.973	0.909

Treatments (A) = 0.006
Frying Media (B) = 0.004
Temperature (C) = 0.003
A x B = 0.011
A x C = 0.011
B x C = 0.006

Humectant (A) = 0.004
Ratios (B) = 0.003
A x B = 0.006
CT Vs Others = 0.005

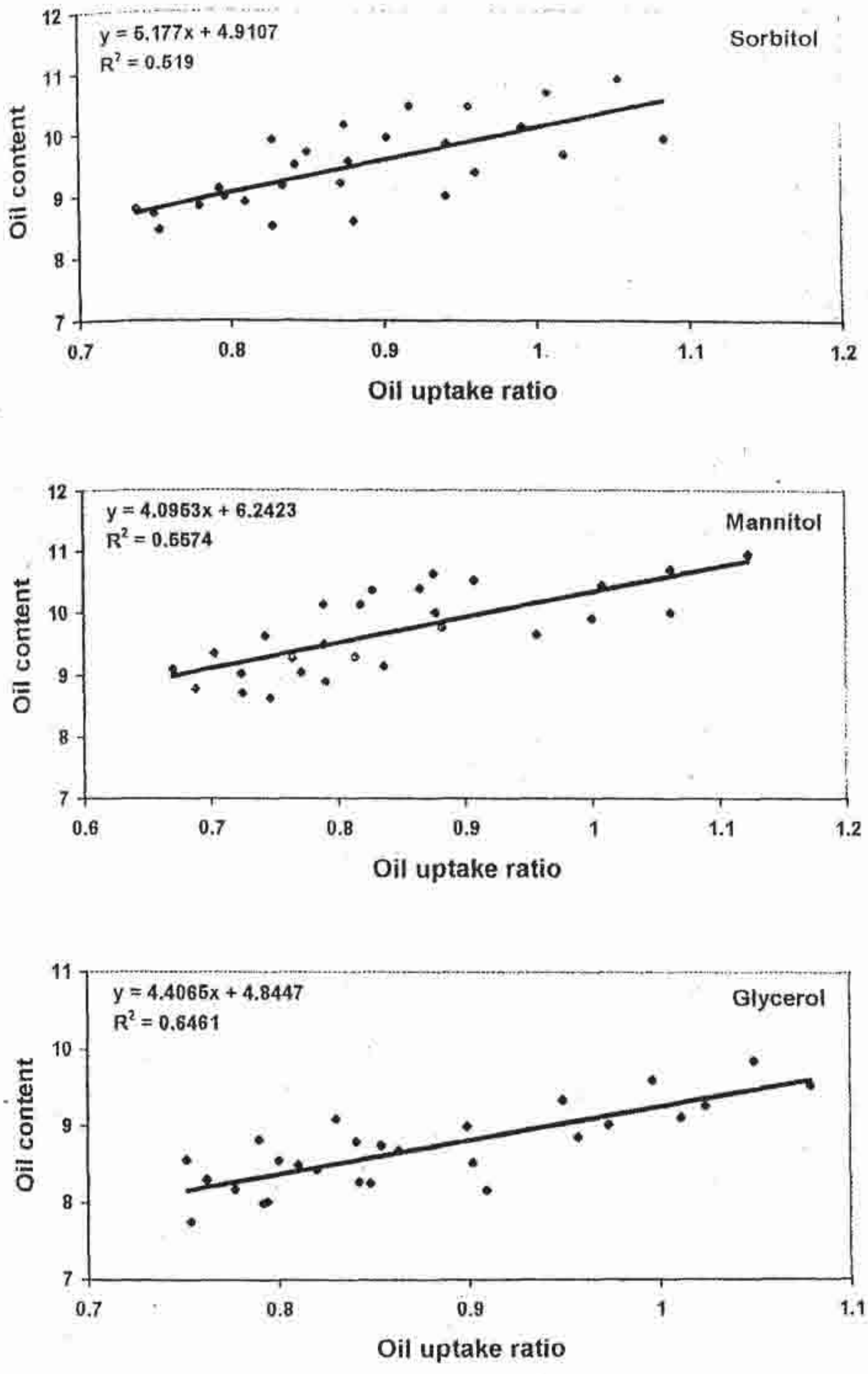


Fig. 4 Showing regression equation correlating oil uptake ratio (x) and oil content (y) for different humectants

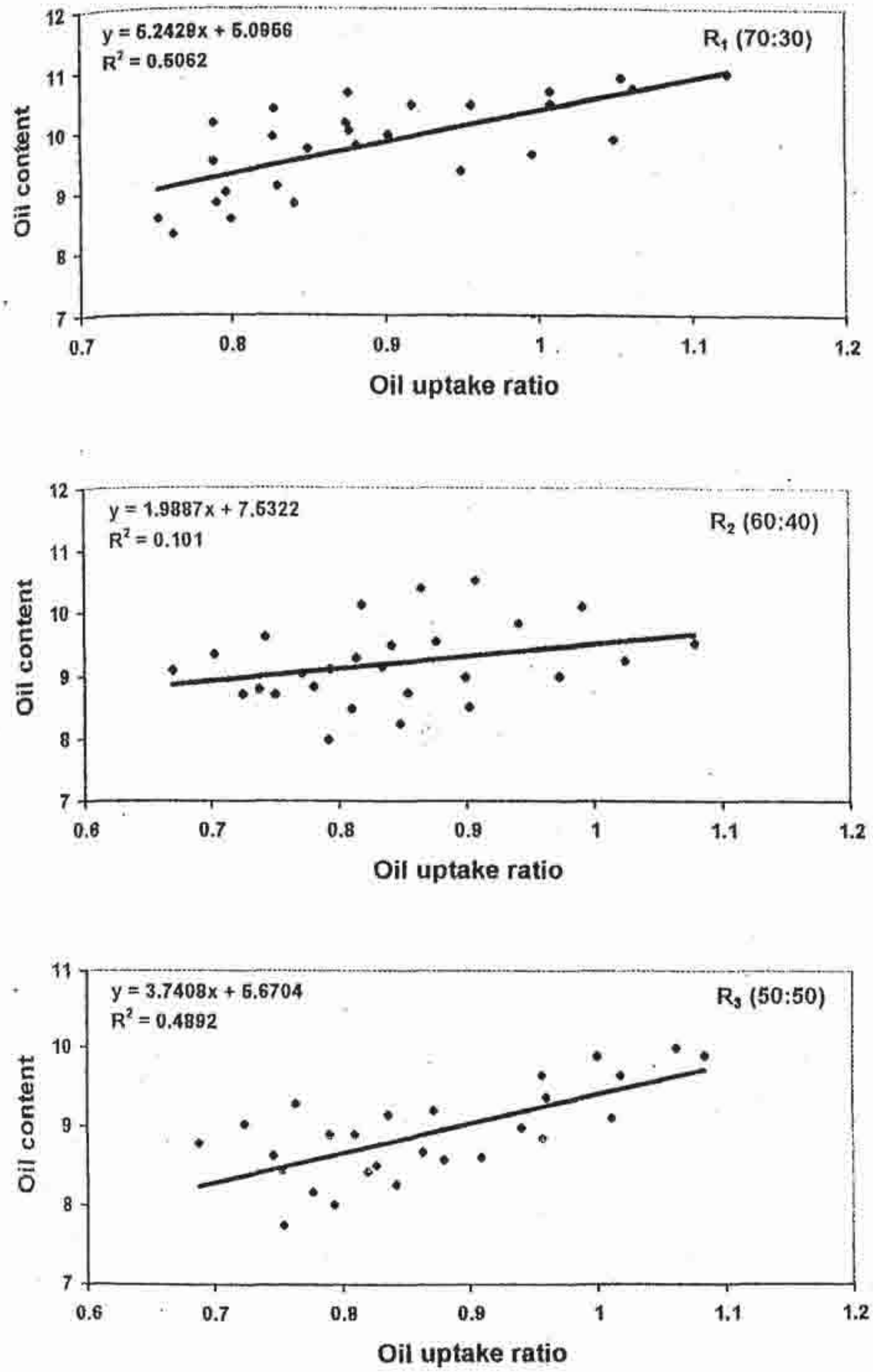


Fig. 5 **Showing regression equation correlating oil uptake ratio (x) and oil content (y) for different ratios**

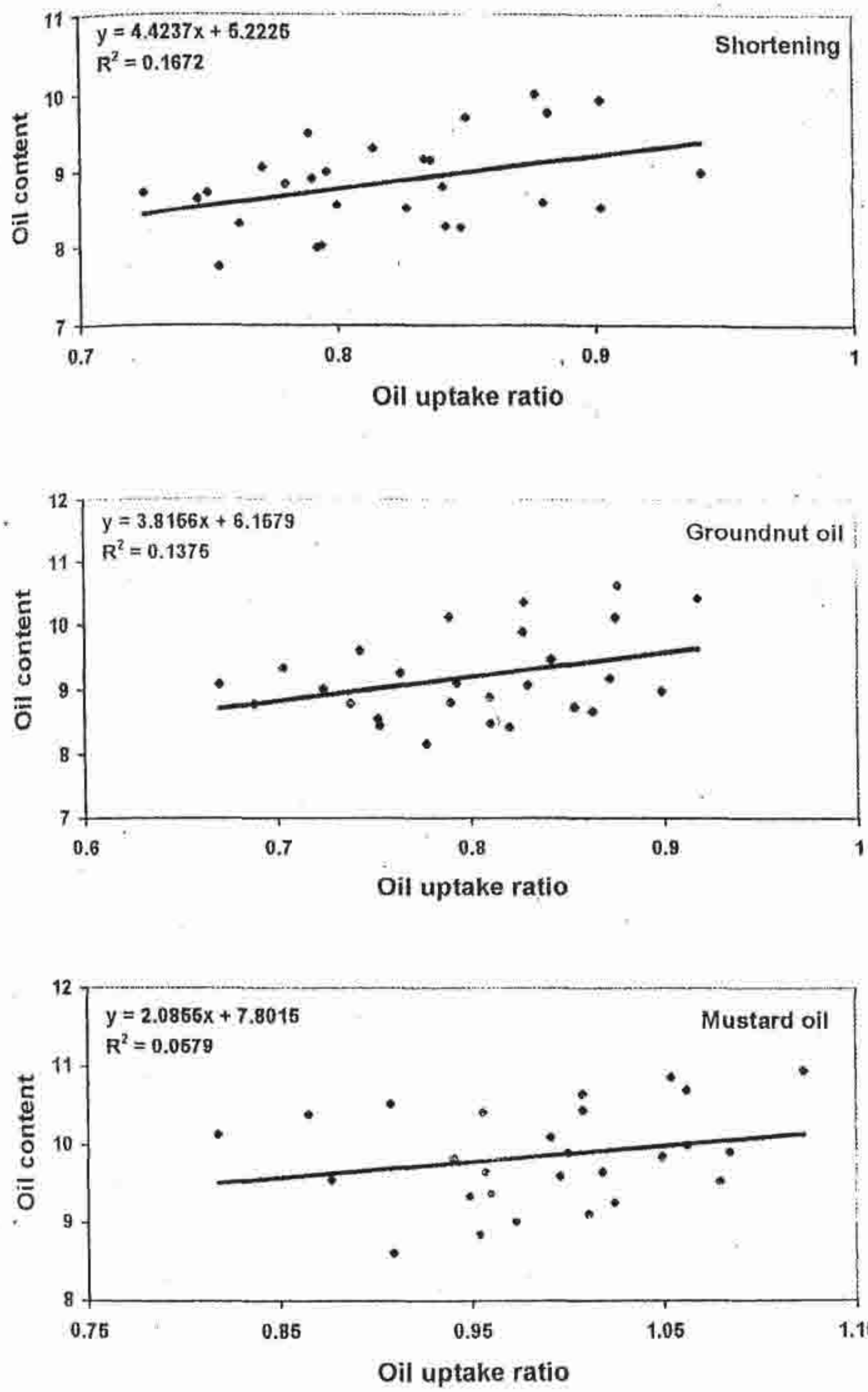


Fig. 6 Showing regression equation correlating oil uptake ratio (x) and oil content (y) for different frying medias

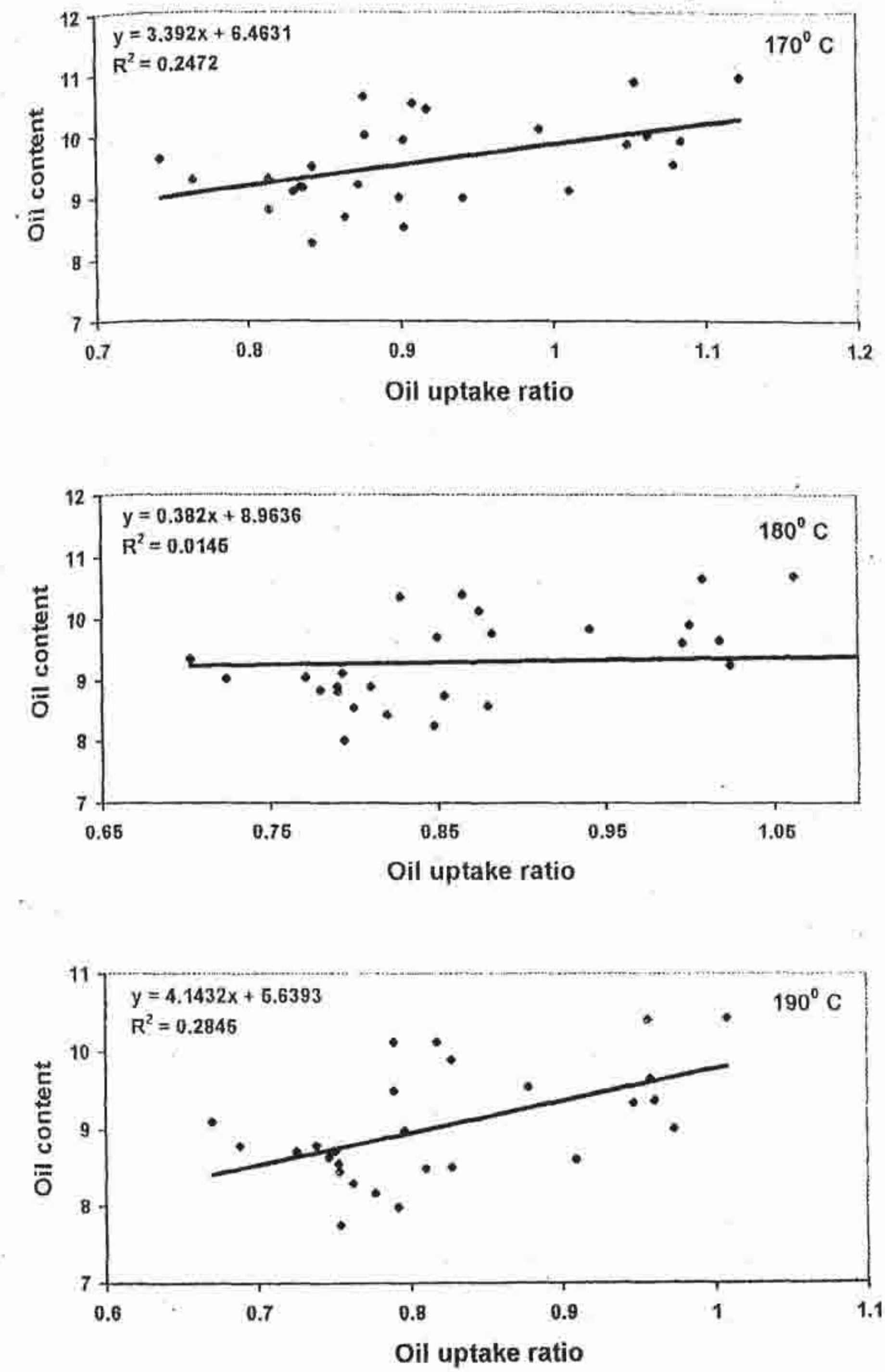


Fig. 7 Showing regression equation correlating oil uptake ratio (x) and oil content (y) for different temperatures

and 190°C in groundnut oil. These were followed by samples containing 50 per cent mannitol and then by samples containing 40 per cent mannitol. While in samples containing glycerol higher oil uptake ratio values were observed at 40 per cent level of addition with values of 1.079, 1.024 and 0.973 when fried at 170, 180 and 190°C in mustard oil. Doughnuts having 50 per cent and 30 per cent glycerol in the doughnut formulation followed the same trend.

Therefore, it was observed that various humectants used in the present investigation were effective in reducing oil uptake ratio (Ur) during deep-fat-frying of doughnuts. This effect of humectants can be attributed to their ability to decrease moisture loss thereby decreasing the oil absorption. This is the basic physical effect of frying which was altered with the use of humectants. The humectants could do so because of their enhanced water holding capacity, which consequently affected the Ur. Since Ur expresses the weight ratio between the amount of oil uptake and water removed, the initial and momentary moisture contents play a vital role in calculating the Ur of the product. With the addition of humectants, the initial moisture content of the dough was less. Also, the momentary moisture, which could be evaporated as vapours during frying, was lower. This resulted in lower fat uptake and high oil uptake ratio values (high Ur means a low moisture loss and not a large amount of oil uptake). Increase in temperature lowered Ur values because at high temperatures the moisture loss was less and thus the fat absorption was also less.

Similar observations have been reported by Pinthus *et al.*, (1993) and Shih *et al.*, (2001) who stated that addition of additives like powdered cellulose, methocel, rice flour and pre-gelatinized rice flour decreased the moisture content and fat content of the samples thereby increasing the oil uptake ratio when compared with control samples. The high values of oil uptake ratio could mean a very low moisture loss and not a large amount of oil uptake (Funami *et al.*, 1999).

4.11 Heat Transfer Co-efficient during deep-fat-frying

Cooking foods, which are more complex often, requires delivery of a large amount of energy to a core area by conduction through water and food solids. The energy flux is provided by long immersion times in hot frying oil. During frying, heat is transferred to the food by convection from the frying oil, and through the product by conduction. The rationale for studying this process is that heat transfers and mass transfer occurring during frying have a major influence on the final product quality. Heat transfer co-efficient is directly related to the conductivity of the material (food material being fried, oil or frying media etc) and the temperature of the product during and after frying and inversely proportional to the thickness of the product. Thus if the value of conductivity is less the heat transfer co-efficient is automatically less and vice versa.

From the Table 4.11 it is revealed that different levels of humectants and temperatures significantly affected the heat transfer

Table 4.11: Effect of different levels of humectants and temperature on heat transfer coefficient ($m^{-2}k^{-1}$) of doughnuts during deep-fat-frying

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170°C	553.87	943.59	1047.0	1337.6	890.47	1002.8	1284.1	1255.1	1374.2	1773.7
	180°C	461.80	826.02	892.11	1184.4	779.51	857.25	1136.9	1094.9	1170.9	1568.6
	190°C	544.79	1093.8	1209.2	1599.1	1032.8	1159.3	1537.6	1489.1	1612.3	2149.0
Groundnut oil	170°C	792.71	1437.3	1675.9	2149.4	1356.3	1589.1	2063.4	1924.5	2192.3	2346.7
	180°C	556.91	1191.0	1566.5	2227.4	1120.8	1480.9	2134.6	1632.5	1229.9	1887.9
	190°C	671.62	1509.0	1690.1	2169.9	1415.2	1604.2	2079.5	2061.4	2264.8	1766.1
Mustard oil	170°C	446.75	842.1	981.56	1463.4	799.95	936.94	1418.8	1127.8	1284.0	1738.3
	180°C	353.69	619.4	707.03	844.12	586.47	677.14	821.13	829.46	927.98	1125.5
	190°C	401.64	729.9	813.81	1060.3	691:51	775.05	1029.7	997.19	1085.1	1439.3

Treatments (A) = 108.82
Frying Media (B) = 59.60
Temperature (C) = 59.60
A x B = 188.48
A x C = NS
B x C = 103.24

Humectant (A) = 62.78
Ratios (B) = 62.78
A x B = NS
CT Vs Others = 81.05

co-efficient during deep-fat-frying of doughnuts. The heat transfer co-efficient in case of control samples was 553.87 $Wm^{-2}k^{-1}$ when fried at 170°C, this value reduced to 461.80 $Wm^{-2}k^{-1}$ when fried at 180°C, but during frying at 190°C this value increased to 544.79 $Wm^{-2}k^{-1}$. Thus, the value of heat transfer co-efficient was higher in samples fried at 170°C followed by those fried at 190°C and then by those fried at 180°C. Addition of different humectants significantly increased the heat transfer co-efficient values when compared to control samples. The heat transfer co-efficient value was 943.59 $Wm^{-2}k^{-1}$ in case of doughnuts containing 30 per cent sorbitol, 10470.00 $Wm^{-2}k^{-1}$ in 40 per cent sorbitol and 1337.60 $Wm^{-2}k^{-1}$ in case of samples containing 50 per cent sorbitol during deep-fat-frying in shortening at 170°C. Similar trend was followed by samples containing different levels of mannitol and glycerol. Among the three oils tested, the values of heat transfer co-efficients were higher in doughnuts deep-fat-fried in shortening and then by those fried in groundnut oil, respectively.

Thus, the temperature and the level of humectant had significant (CD 0.05) effect on the heat transfer co-efficients of the samples. Highest values were observed during frying of samples at 170°C followed by fried at 190 and 180°C. The increase in the level of humectant further increased the heat transfer co-efficient values this was because the conductivity of the product was increased with increased level of humectant. Also, retention of the product in the frying media for longer periods at lower temperatures helped in improving the conductivity of the product.

Rene *et al.*, (1986) have reported heat transfer co-efficient value as 900 $Wm^{-2}k^{-1}$ at oil side during frying of potato slice. The results for heat transfer co-efficient for present study are within the range 300-1800 $Wm^{-2}k^{-1}$ as suggested by Indira *et al.*, (1996). Higher values in few cases in the present study are due to higher conductivity of the humectants and effect of temperature, thereby increasing the heat transfer co-efficient values.

4.12 Effect of humectants and packaging on chemical composition of doughnuts

4.12.1 Moisture content

Table 4.12 represents the data on the effect of different levels of humectants on moisture in fresh doughnut samples. The moisture content in fresh control doughnut samples were 19.27, 18.35 and 18.36 per cent during deep-fat-frying of samples in shortening, groundnut oil and mustard oil, respectively. Addition of sorbitol initially at 30 per cent level decreased the moisture content to 18.75, 18.13 and 17.80 per cent when fried in shortening, groundnut oil and mustard oil, respectively. Further increase in the level of sorbitol up to 40 and 50 per cent again decreased the moisture content of the samples. Similar observations were found in case of samples containing mannitol at 30,

Table 4.12 : Effect of different levels of humectants on moisture (%) in fresh doughnut samples

Humectants	Frying Media		
	Shortening	Groundnut oil	Mustard oil
Control	19.27	18.35	18.86
Sorbitol			
R1 (70:30)	18.75	18.13	17.80
R2 (60:40)	17.02	16.16	15.89
R3 (50:50)	16.02	15.65	14.72
Mannitol			
R1 (70:30)	19.27	18.65	17.58
R2 (60:40)	17.24	16.95	15.33
R3 (50:50)	16.01	15.35	14.25
Glycerol			
R1 (70:30)	16.50	15.64	15.06
R2 (60:40)	15.08	14.42	13.93
R3 (50:50)	12.78	12.04	11.66

Treatments (A) = 0.229
Frying Media (B) = 0.125
A x B = 0.397
S.E. = 0.0378

Humectant (A) = 0.132
Ratios (B) = 0.132
A x B = 0.229
CT Vs Others = 0.171

Control doughnut samples (without humectants)
(1 = shortening; 2= groundnut oil; 3= mustard oil)

Doughnuts containing sorbitol fried in shortening
(1 = 70 : 30 ; 2 = 60 : 40 ; 3 = 50 : 50)

Doughnuts containing sorbitol fried in groundnut oil
(1 = 70 : 30 ; 2 = 60 : 40 ; 3 = 50 : 50)

40 and 50 per cent level. However, the samples containing glycerol at 30 per cent level behaved bit differently and the moisture contents decreased drastically, whereas, in case of sorbitol/mannitol at 30 per cent level slightly decreased the moisture contents. Further increase in the level of glycerol at 40 and 50 per cent levels further decreased the moisture contents to lower levels.

After storage of doughnuts (Table 4.13) for 30 days, the moisture contents increased. The moisture content of control doughnut samples were 16.82, 21.43 and 20.03 per cent when stored in craft paper, plastic jar and polyethylene bags after frying them in shortening. When three packaging material were compared, lowest moisture contents were observed in samples packed in craft paper followed by plastic jars and then polyethylene bag packed samples. The moisture content in the samples containing 30 per cent sorbitol fried in shortening was 16.01 per cent in craft paper, 19.23 per cent in plastic jars and 18.78 per cent when packed in polyethylene bags. As the level of sorbitol increased in the doughnuts, the moisture content decreased on storage for 30 days. Similar observations were observed in case of doughnuts containing different levels of mannitol and glycerol.

The moisture contents increased in all the packaging materials after storage for 60 days (Table 4.14) except for those packed in craft paper. In case of samples containing 30 per cent sorbitol, the moisture contents were found to be 15.35, 20.52 and 20.01 per cent, respectively in craft paper, plastic jars and polyethylene bag packed

Table 4.13: Effect of different levels of humectants and packaging on moisture (%) during storage for 30 days

Frying Media	Temperature (^{o}C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	16.82	16.01	15.34	14.76	16.20	15.44	14.86	14.07	13.84	11.64
	Plastic jar	21.43	19.23	19.06	18.57	19.42	19.36	18.66	16.33	15.70	14.50
	Polyethylene	20.03	18.78	18.34	17.85	18.88	18.44	17.95	15.63	15.49	13.52
Groundnut oil	Craft paper	16.97	16.36	16.14	15.26	16.46	16.24	15.36	13.69	13.55	11.23
	Plastic jar	21.50	19.99	19.14	18.69	20.19	20.04	18.49	17.04	16.29	14.68
	Polyethylene	20.93	19.11	19.04	18.46	19.30	19.14	18.56	16.33	15.21	13.09
Mustard oil	Craft paper	17.15	17.08	16.82	16.21	17.27	16.93	16.31	13.29	13.18	11.03
	Plastic jar	21.66	20.49	19.65	19.07	20.69	20.76	19.18	17.80	16.97	14.81
	Polyethylene	19.94	19.73	19.64	19.14	19.93	19.47	19.24	17.08	15.86	13.84

Treatments (A) = 0.012
Frying Media (B) = 0.007
Storage (C) = 0.006
A x B = 0.021
A x C = 0.022
B x C = 0.012

Humectant (A) = 0.007
Ratios (B) = 0.007
A x B = 0.012
CT Vs Others = 0.009

Table 4.14: Effect of different levels of humectants and packaging on moisture (%) during storage for 60 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	16.61	15.35	14.94	13.32	15.55	15.04	14.41	13.90	13.54	11.31
	Plastic jar	22.66	20.52	20.76	19.86	21.01	20.85	19.95	16.82	15.89	14.85
	Polyethylene	21.75	20.01	19.84	19.06	20.21	19.94	19.15	15.99	15.65	13.90
Groundnut oil	Craft paper	16.85	16.00	15.82	15.01	16.04	15.92	15.10	13.55	13.32	11.04
	Plastic jar	22.84	21.29	20.49	19.67	21.49	20.89	20.77	17.39	16.64	15.55
	Polyethylene	20.19	20.69	20.57	19.90	20.89	20.77	20.00	16.64	16.49	14.51
Mustard oil	Craft paper	16.94	16.74	16.46	15.78	16.94	16.55	15.88	13.06	12.96	10.90
	Plastic jar	22.98	21.95	21.00	20.62	22.16	22.10	21.72	18.01	17.21	15.00
	Polyethylene	20.23	21.31	21.19	20.71	21.32	21.09	20.81	17.48	17.10	14.40

Treatments (A) = 0.022
Frying Media (B) = 0.012
Storage (C) = 0.013
A x B = 0.039
A x C = 0.038
B x C = 0.021

Humectant (A) = 0.013
Ratios (B) = 0.013
A x B = 0.022
CT Vs Others = 0.017

Doughnuts containing mannitol fried in shortening
(1 = 70 : 30 ; 2 = 60 : 40 ; 3 = 50 : 50)

Doughnuts containing mannitol fried in groundnut oil
(1 = 70 : 30 ; 2 = 60 : 40 ; 3 = 50 : 50)

Doughnuts containing glycerol fried in shortening
(1 = 70 : 30 ; 2 = 60 : 40 ; 3 = 50 : 50)

Doughnuts containing glycerol fried in groundnut oil
(1 = 70 : 30 ; 2 = 60 : 40 ; 3 = 50 : 50)

samples when fried in shortening. While in case of samples containing 30 per cent mannitol the moisture content was 15.55 in craft paper packed samples, 21.01 and 20.25 in plastic jars and polyethylene bag packed samples, respectively when fried in shortening. The moisture contents of the glycerol (30 per cent) containing samples fried in the same media were recorded as 13.90, 16.82 and 15.99 per cent in craft paper, plastic jars and polyethylene bags, respectively.

After 90 days of storage (Table 4.15) the moisture content kept on increasing in plastic jars and polyethylene bags while these decreased in case of samples packed in craft paper. In case of samples containing 30 per cent sorbitol and fried in shortening, the moisture content was found to be 14.80 in craft paper, 22.05 in plastic jars while 21.19 in polyethylene bag packed samples, respectively. In samples containing 30 per cent mannitol (fried in shortening) highest moisture content was found 22.25 in plastic jar, followed by 21.39 in polyethylene bags and 15.00 in craft paper packed samples. Similar trend was observed for samples containing glycerol packed in different packaging materials.

Thus, storage had significant effect on the moisture content of the doughnut samples. The moisture content increased when stored for 30 days in plastic jars and polyethylene bags in all the samples. However, the samples when packed in craft paper showed reverse trend. There was significant fall in the moisture content of the samples. This may be attributed to the reason that the paper along with the fat

Table 4.15: Effect of different levels of humectants and packaging on moisture (%) during storage for 90 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	16.03	14.80	14.24	14.00	15.00	14.45	14.10	13.63	13.20	11.05
	Plastic jar	23.22	22.05	21.15	20.19	22.25	21.21	20.29	17.05	16.25	15.14
	Polyethylene	22.39	21.19	20.09	19.43	21.39	20.19	19.53	16.30	16.01	14.25
Groundnut oil	Craft paper	16.09	15.89	15.05	14.54	15.99	15.54	15.00	13.16	13.04	10.89
	Plastic jar	23.39	22.84	21.90	20.99	23.03	22.30	22.00	17.84	16.99	16.01
	Polyethylene	22.78	22.03	20.93	20.14	22.23	21.03	20.24	16.60	16.85	15.95
Mustard oil	Craft paper	16.20	16.21	15.89	15.25	16.42	15.99	15.35	12.89	12.63	10.59
	Plastic jar	23.50	23.04	22.40	22.05	23.63	22.50	22.15	18.25	17.65	14.45
	Polyethylene	22.80	22.59	21.33	21.06	22.79	21.43	21.35	17.75	17.43	13.89

Treatments (A) = 0.020
Frying Media (B) = 0.011
Storage (C) = 0.010
A x B = 0.034
A x C = 0.033
B x C = 0.019

Humectant (A) = 0.011
Ratios (B) = 0.012
A x B = 0.020
CT Vs Others = 0.015

absorbed the moisture thus the craft paper became impermeable to moisture gain from the surroundings.

Onyejegbu and Olerunda (1995), Kulkarni *et al.*, (1994) and Krishnankutty *et al.*, (1981) also reported increase in the moisture contents of the samples when stored in different packaging materials. Yau *et al.*, (1994) suggested that addition of sorbitol to corn tortillas decreased the moisture contents when compared with control. Manan *et al.*, (1991) also reported similar observations during packaging and storage of colocasia snack products.

4.12.2 Ash content

Data in Table 4.16 reflect the effect of different levels of humectants on ash content in fresh doughnuts samples. The ash content in fresh control doughnut samples was 0.87, 1.00 and 1.13 per cent when frying was carried out in shortening, groundnut oil and mustard oil, respectively. Addition of sorbitol initially at 30 per cent level significantly increased the ash content to 1.11, 1.20 and 1 .28 per cent, respectively during frying in shortening, groundnut oil and mustard oil respectively. However, further increase in sorbitol level at 40 and 50 per cent level in doughnut formulation significantly decreased the ash content of the samples when compared to those containing 30 per cent level of sorbitol. Addition of mannitol/glycerol at 30 per cent levels also increased the ash contents significantly but this increase was less when compared to those containing sorbitol. The samples containing 30 per

Table 4.16: **Effect of different levels of humectants on ash (%) in fresh doughnut samples**

Humectants	Frying Media		
	Shortening	**Groundnut oil**	**Mustard oil**
Control	0.87	1.00	1.13
Sorbitol			
R1 (70:30)	1.11	1.20	1.28
R2 (60:40)	1.06	1.18	1.25
R3 (50:50)	0.81	0.96	1.06
Mannitol			
R1 (70:30)	0.96	1.08	1.15
R2 (60:40)	0.90	0.95	1.04
R3 (50:50)	0.86	0.92	1.01
Glycerol			
R1 (70:30)	0.98	1.14	1.30
R2 (60:40)	0.86	0.99	1.15
R3 (50:50)	0.70	0.87	1.02

Treatments (A) = 0.036
Frying Media (B) = 0.018
A x B = 0.062
S.E. = 0.009

Humectant (A) = 0.020
Ratios (B) = 0.020
A x B = 0.359
CT Vs Others = 0.268

cent glycerol had ash content 0.98, 1.14 and 1.30 per cent during frying of samples in shortening, groundnut oil and mustard oil, respectively.

During storage of doughnuts for 30 days (Table 4.17), the ash content decreased in different packaging materials. The reduction was marked in samples packed in plastic jars and polyethylene bags. The ash content of control doughnut samples was 0.98, 0.93 and 0.96 per cent when stored in craft paper, plastic jars and polyethylene bags, respectively when fried in groundnut oil. In case of samples containing 30 per cent mannitol and fried in groundnut oil the highest ash content was found 1.05 per cent in craft paper, followed by 1.03 per cent in polyethylene bags and 1.00 per cent in plastic jar packed samples. Similarly in case of doughnuts (30per cent glycerol) prepared in groundnut oil, the ash content was 1.10 per cent in craft paper, 1.08 and 1.06 per cent in polyethylene bags and plastic jar packed samples, respectively.

After storage for 60 days (Table 4.18), the ash content again significantly decreased in different packaging materials. However, the samples packed in craft paper showed bit slower rate of decrease in ash contents of the samples. In case of samples containing 30 per cent sorbitol (fried in groundnut oil), the ash contents were found to be 1.09, 1.05 and 1.01 per cent in craft paper, plastic jars and polyethylene bags, respectively. While in case of samples containing 30 per cent mannitol, fried in groundnut oil, the ash content was 0.99 per cent in craft paper, 0.86 per cent in plastic jars and 0.88 in polyethylene bag

Table 4.17: Effect of different levels of humectants and packaging on ash (%) during storage for 30 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.87	1.09	1.06	0.79	0.91	0.87	0.85	0.97	0.84	0.70
	Plastic jar	0.82	1.03	1.00	0.74	0.86	0.82	0.81	0.92	0.80	0.65
	Polyethylene	0.86	1.06	1.03	0.77	0.88	0.85	0.84	0.95	0.82	0.68
Groundnut oil	Craft paper	0.98	1.14	1.14	0.90	1.05	0.90	0.89	1.10	0.97	0.85
	Plastic jar	0.93	1.17	1.08	0.83	1.00	0.84	0.80	1.06	0.90	0.81
	Polyethylene	0.96	1.09	1.11	0.86	1.03	0.87	0.86	1.08	0.94	0.84
Mustard oil	Craft paper	1.11	1.22	1.18	1.01	1.12	0.99	0.97	1.21	1.13	0.98
	Plastic jar	1.04	1.15	1.12	0.96	1.06	0.92	0.89	1.16	1:06	0.94
	Polyethylene	1.08	1.18	1.15	0.99	1.09	0.96	0.92	1.19	1.10	0.96

Treatments (A) = 0.008
Frying Media (B) = 0.004
Storage (C) = 0.004
A x B = 0.014
A x C = 0.014
B x C = NS

Humectant (A) = 0.005
Ratios (B) = 0.005
A x B = 0.008
CT Vs Others = 0.006

Table 4.18: Effect of different levels of humectants and packaging on ash (%) during storage for 60 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.82	1.03	0.99	0.75	0.85	0.81	0.82	0.89	0.88	0.62
	Plastic jar	0.68	0.97	0.86	0.63	0.71	0.73	0.70	0.80	0.72	0.56
	Polyethylene	0.70	0.92	0.94	0.69	0.76	0.77	0.76	0.83	0.73	0.59
Groundnut oil	Craft paper	0.91	1.09	1.08	0.84	0.99	0.86	0.85	1.03	0.92	0.78
	Plastic jar	0.78	1.05	0.95	0.72	0.86	0.70	0.76	0.95	0.87	0.72
	Polyethylene	0.84	1.01	0.97	0.74	0.88	0.74	0.81	0.98	0.91	0.76
Mustard oil	Craft paper	0.99	1.16	1.10	0.96	1.08	0.91	0.92	1.14	1.08	0.92
	Plastic jar	0.88	1.08	0.98	0.85	0.91	0.85	0.85	1.05	1.00	0.85
	Polyethylene	0.93	1.04	1.04	0.88	0.95	0.88	0.89	1.08	1.06	0.87

Treatments (A) = 0.009
Frying Media (B) = 0.005
Storage (C) = 0.004
A x B = 0.015
A x C = 0.015
B x C = NS

Humectant (A) = 0.005
Ratios (B) = 0.004
A x B = 0.009
CT Vs Others = 0.003

packed samples, respectively. Similarly the ash content of glycerol (30 per cent fried in groundnut oil) containing samples was 1.03, 0.95 and 0.98 per cent, respectively in craft paper, plastic jars and polyethylene bags.

The ash content of the samples kept on decreasing after 90 days storage (Table 4.19) in different packaging materials. However, the samples packed in craft paper again showed slower rate of decrease of ash content of the samples. Samples containing 30 per cent sorbitol, prepared in groundnut oil had ash content of 1.01 per cent in craft paper, 0.88 per cent in plastic jars and 0.93 per cent in polyethylene bag packed samples. On the other hand samples prepared in the same oil containing 30 per cent mannitol showed highest ash content 0.92 in craft paper followed by 0.76 in polyethylene bags and 0.73 in plastic jar packed samples. Similar findings were observed in case of samples containing different levels of glycerol.

Thus, the sample packed in craft paper showed comparatively less decrease in ash content when compared to those packed in plastic jars and polyethylene bags. On an average, it can be stated that storage decreased the ash content of the samples. The rate of decrease was slower in glycerol containing samples when compared with the other two humectants. Addition of different levels of humectants significantly reduced the rate of decrease of ash content when compared with control.

Table 4.19: Effect of different levels of humectants and packaging on ash (%) during storage for 90 days

Frying Media	Temperature (^oC)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.75	0.94	0.92	0.68	0.78	0.77	0.74	0.81	0.80	0.54
	Plastic jar	0.56	0.76	0.73	0.52	0.55	0.65	0.57	0.69	0.61	0.44
	Polyethylene	0.61	0.83	0.81	0.55	0.62	0.68	0.64	0.72	0.64	0.50
Groundnut oil	Craft paper	0.83	1.01	1.01	0.76	0.92	0.80	0.83	0.94	0.84	0.69
	Plastic jar	0.66	0.88	0.84	0.58	0.73	0.69	0.66	0.82	0.79	0.61
	Polyethylene	0.73	0.93	0.90	0.61	0.76	0.68	0.72	0.87	0.82	0.65
Mustard oil	Craft paper	0.91	1.08	1.02	0.89	1.02	0.84	0.92	1.05	1.02	.083
	Plastic jar	0.74	0.92	0.86	0.71	0.75	0.66	.073	0.94	0.90	0.74
	Polyethylene	0.80	0.97	0.91	0.74	0.80	0.72	0.80	0.98	0.97	0.79

Treatments (A) = 0.007
Frying Media (B) = 0.005
Storage (C) = 0.004
A x B = 0.013
A x C = 0.012
B x C = 0.007

Humectant (A) = 0.004
Ratios (B) = 0.004
A x B = 0.007
CT Vs Others = 0.005

4.12.3 *Protein content*

Data in Table 4.20 reflect the effect of different levels of humectants on protein content in fresh doughnut samples. The protein content in fresh control doughnut samples was 10.39, 10.82 and 10.28 per cent when frying was carried out in shortening, groundnut oil and mustard oil, respectively. Addition of sorbitol initially at 30 per cent level slightly increased the protein content to 10.75, 11.27 and 10.53 per cent, respectively during frying in shortening, groundnut oil and mustard oil, respectively. However, further increase in sorbitol level at 40 and 50 per cent level in doughnut formulation significantly decreased the protein content of the samples. Whereas, different observations were found in case of samples containing mannitol and glycerol. Addition of mannitol/glycerol at 30 per cent levels decreased the protein contents significantly. The samples containing 30 per cent glycerol had protein content 10.14, 10.17 and 9.68 per cent during frying of samples in shortening, groundnut oil and mustard oil, respectively.

After storage of doughnuts for 30 days (Table 4.21), the protein content decreased in different packaging materials. The reduction was marked in control samples and other samples packed in plastic jars and polyethylene bags. The protein content of control doughnut samples was 8.46, 7.91 and 8.08 per cent when stored in craft paper, plastic jars and polyethylene bags, respectively when fried in groundnut oil. In case of samples containing 30 per cent mannitol

Table: 4.20 Effect of different levels of humectants on protein (%) in fresh doughnut samples

Humectants	Frying Media		
	Shortening	Groundnut oil	Mustard oil
Control	10.39	10.82	10.28
Sorbitol			
R1 (70:30)	10.75	12.27	10.53
R2 (60:40)	10.34	10.81	9.93
R3 (50:50)	9.91	10.06	9.60
Mannitol			
R1 (70:30)	10.02	10.61	9.65
R2 (60:40)	9.60	10.08	9.24
R3 (50:50)	9.31	9.36	8.96
Glycerol			
R1 (70:30)	10.14	10.17	9.68
R2 (60:40)	9.36	9.70	9.44
R3 (50:50)	8.90	9.14	8.85

Treatments (A)	= 0.034	Humectant (A)	= 0.198
Frying Media (B)	= 0.019	Ratios (B)	= 0.198
A x B	= 0.059	A x B	= 0.034
S.E.	= 0.0008	CT Vs Others	= 0.013

Table 4.21: Effect of different levels of humectants and packaging on protein (%) during storage for 30 days

Frying Media	Temperature (^oC)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	8.14	8.64	8.65	8.31	7.80	8.15	7.91	7.40	8.20	7.90
	Plastic jar	7.54	8.31	8.46	8.11	7.89	7.95	7.61	7.49	8.19	7.79
	Polyethylene	7.86	8.47	8.89	8.38	8.00	8.40	7.98	7.61	8.39	8.10
Groundnut oil	Craft paper	8.46	9.22	8.17	7.71	7.53	7.66	7.23	7.14	7.87	7.45
	Plastic jar	7.91	8.65	8.28	7.90	7.74	7.78	7.41	7.33	8.04	7.60
	Polyethylene	8.08	8.89	8.29	8.04	8.13	7.89	7.64	8.36	8.01	7.34
Mustard oil	Craft paper	7.99	8.46	8.09	7.69	7.81	7.65	7.28	7.99	7.74	7.11
	Plastic jar	7.45	8.17	8.21	7.88	7.97	7.81	7.49	8.15	7.86	7.20
	Polyethylene	7.67	8.28	8.48	8.17	8.81	8.07	7.76	8.51	8.25	7.81

Treatments (A) = 0.020
Frying Media (B) = 0.011
Storage (C) = 0.010
A x B = 0.034
A x C = 0.034
B x C = 0.019

Humectant (A) = 0.012
Ratios (B) = 0.011
A x B = 0.020
CT Vs Others = 0.015

and fried in groundnut oil the highest protein content was found 8.13 per cent in craft paper, followed by 7.74 per cent in polyethylene bags and 7.53 per cent in plastic jar packed samples. Similarly in case of doughnuts (30per cent glycerol) prepared in groundnut oil, the protein content was 8.36 per cent in craft paper, 7.33 and 7.14 per cent in polyethylene bags and plastic jar packed samples, respectively.

During storage for 60 days (Table 4.22), the protein content again significantly decreased in different packaging materials. However the samples packed in craft paper showed bit slower rate of decrease in protein contents of the samples. In case of samples containing 30 per cent sorbitol (fried in groundnut oil) the protein contents were found to be 8.93, 7.97 and 8.03 per cent in craft paper, plastic jars and polyethylene bags, respectively. While in case of samples containing 30 per cent mannitol, fried in groundnut oil, the protein content was 8.43 per cent in craft paper, 7.47 per cent in plastic jars and 7.53 in polyethylene bag packed samples, respectively. Similarly the protein content of glycerol (30 per cent fried in groundnut oil) containing samples was 8.08, 7.64 and 7.85 per cent, respectively in craft paper, plastic jars and polyethylene bags.

After 90 days storage (Table 4.23) the protein content of the samples kept on decreasing in different packaging materials, however the samples packed in craft paper again showed slower rate of decrease of protein content of the samples. Samples containing 30 per cent sorbitol, prepared in groundnut oil had protein content of 8.54 per

Table 4.22: Effect of different levels of humectants and packaging on protein (%) during storage for 60 days

Frying Media	Temperature (^oC)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	8.05	8.48	8.13	7.95	7.98	7.73	7.55	8.09	7.72	7.17
	Plastic jar	6.80	7.65	7.67	7.43	7.15	7.37	7.03	7.63	7.49	6.82
	Polyethylene	7.19	7.88	7.95	7.55	7.38	7.55	7.15	7.81	7.67	7.00
Groundnut oil	Craft paper	8.20	8.93	8.25	8.07	8.43	7.85	7.67	8.25	8.08	7.59
	Plastic jar	7.15	7.97	8.00	7.59	7.47	7.60	7.19	7.84	7.64	7.34
	Polyethylene	7.50	8.03	8.08	7.74	7.53	7.08	7.34	8.03	7.85	7.48
Mustard oil	Craft paper	7.87	8.19	7.88	7.70	7.69	7.38	7.30	8.00	7.56	7.44
	Plastic jar	6.57	8.53	7.33	7034	7.03	6.83	6.94	7.54	7.09	7.03
	Polyethylene	6.96	7.70	7.50	7.46	7.20	7.00	7.06	7.73	7.25	7.31

Treatments (A) = 0.017
Frying Media (B) = 0.009
Storage (C) = 0.009
A x B = 0.030
A x C = 0.029
B x C = 0.017

Humectant (A) = 0.010
Ratios (B) = 0.009
A x B = 0.017
CT Vs Others = 0.013

Table 4.23: Effect of different levels of humectants and packaging on protein (%) during storage for 90 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	7.83	8.05	7.97	7.73	7.55	7.57	7.33	7.83	7.38	6.85
	Plastic jar	6.07	6.86	6.70	6.56	6.36	6.30	6.16	7.05	7.01	6.37
	Polyethylene	6.61	6.99	6.89	6.71	6.49	6.49	6.31	7.18	7.14	6.55
Groundnut oil	Craft paper	8.03	8.54	6.09	7.55	8.04	7.19	7.15	8.05	7.81	7.25
	Plastic jar	6.56	6.99	6.90	6.69	6.50	6.50	6.29	7.23	7.15	6.88
	Polyethylene	6.79	7.10	7.15	6.86	6.60	6.60	6.46	7.39	7.35	7.05
Mustard oil	Craft paper	7.73	7.80	7.69	7.13	7.30	7.30	6.73	7.65	7.23	7.09
	Plastic jar	5.88	6.70	6.48	6.40	6.20	6.20	6.00	6.91	6.74	6.64
	Polyethylene	6.30	6.74	6.61	6.53	6.24	6.24	6.13	7.07	6.92	6.83

Treatments (A) = 0.050
Frying Media (B) = 0.028
Storage (C) = 0.027
A x B = 0.087
A x C = 0.085
B x C = NS

Humectant (A) = 0.029
Ratios (B) = 0.030
A x B = 0.050
CT Vs Others = 0.038

cent in craft paper, 6.99 per cent in plastic jars and 7.10 per cent in polyethylene bag packed samples. On the other hand samples prepared in the same oil containing 30 per cent mannitol showed highest protein content 8.04 in craft paper followed by 6.60 in polyethylene bags and 6.50 in plastic jar packed samples. Similar findings were observed in case of samples containing different levels of glycerol.

Thus, the sample packed in craft paper showed comparatively less decrease in protein content when compared to those packed in plastic jars and polyethylene bags. On a whole, it can be stated that storage decreased the protein content of the samples. The rate of decrease was slower in glycerol containing samples when compared with the other two humectants. Addition of different levels of humectants significantly reduced the rate of decrease of protein content when compared with control.

4.12.4 *Fat content*

Table 4.24 represents the data on the effect of different levels of humectants on fat content in fresh doughnut samples. The fat content in control samples was 13.45 per cent in shortening, 14.06 per cent in groundnut oil and 15.66 in mustard oil, respectively. Addition of different levels of humectants significantly (CD $\leq$ 0.05) reduced the fat content of the doughnuts. Addition of sorbitol at 30 per cent level decreased the fat content to 11.19 per cent in shortening, 11.84 per cent in groundnut oil and 11.86 per cent in mustard oil, respectively.

Table 4.24: **Effect of different levels of humectants on fat (%) in fresh doughnut samples**

Humectants	Frying Media		
	Shortening	**Groundnut oil**	**Mustard oil**
Control	13.45	14.06	15.66
Sorbitol			
R1 (70:30)	11.19	11.84	11.86
R2 (60:40)	11.15	11.48	12.15
R3 (50:50)	10.85	11.10	11.72
Mannitol			
R1 (70:30)	11.32	11.80	12.12
R2 (60:40)	10.07	10.39	10.86
R3 (50:50)	9.76	9.54	10.46
Glycerol			
R1 (70:30)	9.59	9.79	10.65
R2 (60:40)	8.67	14.15	9.69
R3 (50:50)	8.31	8.79	9.04

Treatments (A) = 1.657
Frying Media (B) = NS
A x B = NS
S.E. = 1.977

Humectant (A) = 0.957
Ratios (B) = 0.957
A x B = NS
CT Vs Others = 1.236

Further increase in sorbitol level at 40 and 50 per cent level again decreased the fat content. Similarly, the same observations/trend was observed in case of doughnuts containing different levels of mannitol and glycerol. However, glycerol was found to be more effective in reducing the fat content in the samples. The values for fat content in samples containing 50 per cent glycerol was 8.31 per cent in shortening, 8.79 per cent in groundnut oil and 9.04 per cent in mustard oil, respectively. Among the three different frying media used, higher fat content was observed in case of mustard oil, followed by groundnut oil and then by shortening.

After a storage period of 30 days (Table 4.25) the fat contents decreases in all the three packaging used. Reduction in fat content was pronounced in case of samples stored in craft paper when compared to plastic jar and polyethylene bag packed samples. The fat content of control doughnut samples fried in groundnut oil were 8.55, 11.38 and 11.34 per cent after storage in craft paper, plastic jars and polyethylene bags, respectively. In case of samples containing 30 per cent sorbitol fried in groundnut oil, the fat contents were 7.98, 10.44 and 10.38 per cent when packed in craft paper, plastic jars and polyethylene bags, respectively. However, in case of mannitol (30 per cent) containing samples fried in groundnut oil, the fat content was 8.07 per cent in craft paper, 10.67 per cent in plastic jars and 10.58 per cent in polyethylene bag packed samples, respectively. Similarly, doughnuts prepared in same media with 30 per cent glycerol, the highest fat

Table 4.25: Effect of different levels of humectants and packaging on fat (%) during storage 30 for days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	8.08	7.84	7.63	7.38	7.93	7.66	7.34	7.26	7.01	6.69
	Plastic jar	10.97	9.95	9.17	9.01	10.02	9.34	9.17	8.87	8.59	8.32
	Polyethylene	10.94	9.89	9.12	8.97	9.96	9.26	9.12	8.76	8.47	8.23
Groundnut oil	Craft paper	8.55	7.98	7.78	7.53	8.07	7.80	7.50	7.54	7.49	7.20
	Plastic jar	11.38	10.44	9.51	9.20	10.67	9.66	7.28	9.17	9.07	8.80
	Polyethylene	11.34	10.38	9.46	9.15	10.58	9.57	7.23	9.04	8.96	8.63
Mustard oil	Craft paper	8.06	7.75	7.56	7.32	7.88	7.55	7.25	8.29	7.94	7.58
	Plastic jar	12.59	10.89	10.12	9.92	10.99	10.18	10.94	9.93	9.60	9.17
	Polyethylene	12.47	10.83	10.05	9.87	10.90	10.09	10.89	9.81	9.49	9.06

Treatments (A) = 0.018
Frying Media (B) = 0.010
Storage (C) = 0.031
A x B = 0.009
A x C = 0.030
B x C = 0.017

Humectant (A) = 0.010
Ratios (B) = 0.011
A x B = 0.017
CT Vs Others = 0.013

content was observed 9.07 per cent in plastic jar, 8.96 per cent in polyethylene bag and 7.49 per cent in craft paper, respectively. Similar findings were observed in other two frying media and rest of the ratios of humectants.

After storage for 60 days (Table 4.26) the fat contents again significantly decreased in different packaging materials. The samples packed in craft paper had lowest values of fat content when compared to other two packagings. In case of samples containing 30 per cent sorbitol after frying in groundnut oil, the fat contents were found to be 7.89, 10.33 and 10.25 per cent when packed in craft paper, plastic jars and polyethylene bags, respectively. While in case of samples containing 30 per cent mannitol after frying in the same media had fat content as 7.98 per cent in craft paper, 10.55 per cent in plastic jars and 10.46 per cent in polyethylene bags, respectively. Similarly in case of groundnut oil fried samples of doughnuts containing 30 per cent glycerol, the highest fat content was observed 8.96 in plastic jars, 8.82 in polyethylene bags and 7.37 in craft paper, respectively.

During storage period of 90 days (Table 4.27), again decrease in fat content of the samples packed in different packaging materials was observed. Samples containing 30 per cent sorbitol, prepared in groundnut oil had the values of 7.76 per cent in craft paper, 10.20 per cent in plastic jars and 10.13 per cent in polyethylene bags, respectively. On the other hand, samples containing 30 per cent mannitol, prepared in the same media showed highest values of 10.43

Table 4.26: Effect of different levels of humectants and packaging on fat (%) during storage for 60 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	7.95	7.73	7.52	7.29	7.85	7.59	7.28	7.14	6.92	6.61
	Plastic jar	10.81	9.88	9.07	8.88	9.90	9.22	9.08	8.73	8.47	8.19
	Polyethylene	10.77	9.76	9.02	8.84	9.83	9.14	9.00	8.61	8.36	8.11
Groundnut oil	Craft paper	8.47	7.89	7.67	7.45	7.98	7.72	7.39	7.49	7.37	7.11
	Plastic jar	11.27	10.33	9.42	9.12	10.55	9.55	9.17	9.06	8.96	8.65
	Polyethylene	11.23	10.25	9.34	9.04	10.46	9.43	9.12	8.93	8.82	8.50
Mustard oil	Craft paper	7.89	7.63	7.43	7.23	7.76	7.47	7.13	8.20	7.89	7.46
	Plastic jar	12.50	10.78	10.04	9.80	10.92	10.07	10.84	9.81	9.48	9.03
	Polyethylene	12.37	10.71	9.96	9.75	10.77	10.01	10.80	9.69	9.33	8.95

Treatments (A) = 0.018
Frying Media (B) = 0.010
Storage (C) = 0.009
A x B = 0.031
A x C = 0.031
B x C = 0.017

Humectant (A) = 0.010
Ratios (B) = 0.010
A x B = 0.018
CT Vs Others = 0.013

Table 4.27: Effect of different levels of humectants and packaging on fat (%) during storage for 90 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	7.84	7.61	7.40	7.17	7.74	7.48	7.17	7.06	6.83	6.50
	Plastic jar	10.72	9.77	8.97	9.77	9.79	9.14	8.99	8.59	8.35	8.07
	Polyethylene	10.68	9.65	8.92	9.73	9.71	9.05	8.92	8.50	8.25	7.99
Groundnut oil	Craft paper	8.38	7.76	7.55	7.40	7.89	7.59	7.26	7.37	7.31	7.02
	Plastic jar	11.16	10.20	9.25	9.00	10.43	9.42	9.05	8.97	8.83	8.52
	Polyethylene	11.07	10.13	9.22	8.95	10.34	9.33	9.02	8.82	8.69	8.37
Mustard oil	Craft paper	7.78	7.52	7.32	7.15	7.63	7.34	7.05	8.11	7.80	7.37
	Plastic jar	12.39	10.74	9.92	9.67	10.77	9.97	10.73	9.68	9.34	8.89
	Polyethylene	12.25	10.59	9.83	9.64	10.65	9.92	10.68	9.57	9.24	8.83

Treatments (A) = 0.022
Frying Media (B) = 0.012
Storage (C) = 0.012
A x B = 0.038
A x C = 0.038
B x C = 0.021

Humectant (A) = 0.012
Ratios (B) = 0.013
A x B = 0.022
CT Vs Others = 0.016

in plastic jars, followed by 10.34 per cent in polyethylene bags and 7.89 per cent in craft paper packed samples, respectively. Similar findings were observed for samples having different levels of glycerol fried in different media.

Different levels of humectants, frying media and the different packaging materials used, significantly affected the fat content. The highest fat contents were observed in case of samples fried in mustard oil followed by those fired in groundnut oil and then shortening. Addition of humectants at various levels significantly reduced the fat content of the doughnuts. The glycerol at various levels of incorporation was found to be most effective in reducing the fat content of the samples when compared with the control samples. During storage, lowest fat content was observed in case of samples packed in craft paper and this may be due to the reason that large amounts of fat was absorbed by the paper thus reducing the fat content of the samples. Highest fat content was observed in case of sampled packed in plastic jars followed by those packed in polyethylene bags and lastly by those packed in craft paper.

4.12.5 Free Fatty Acids

The data on effect of different levels of humectants on free fatty acid contents in fresh doughnuts are presented in Table 4.28. The free fatty acid contents in fresh control doughnut samples were 0.44, 0.62 and 0.54 per cent as oleic acid during frying of samples in

Table 4.28: Effect of different levels of humectants on free fatty acids (% as oleic acid) in fresh doughnut samples

Humectants	Frying Media		
	Shortening	Groundnut oil	Mustard oil
Control	0.44	0.62	0.54
Sorbitol			
R1 (70:30)	0.52	0.63	0.57
R2 (60:40)	0.43	0.58	0.51
R3 (50:50)	0.35	0.44	0.38
Mannitol			
R1 (70:30)	0.54	0.64	0.60
R2 (60:40)	0.47	0.62	0.54
R3 (50:50)	0.39	0.48	0.42
Glycerol			
R1 (70:30)	0.41	0.55	0.48
R2 (60:40)	0.38	0.48	0.43
R3 (50:50)	0.35	0.44	0.39

Treatments (A) = 0.017
Frying Media (B) = 0.009
A x B = 0.029
S.E. = 0.002

Humectant (A) = 0.009
Ratios (B) = 0.010
A x B = 0.169
CT Vs Others = 0.126

shortening, groundnut oil and mustard oil, respectively. Thus the free fatty acid contents were higher in samples fried in groundnut oil followed by those fried in mustard oil and then in shortening. Addition of sorbitol initially at 30 per cent level significantly (CD$\leq$0.05) increased the free fatty acid contents to 0.52, 0.63 and 0.57 per cent as oleic acid after frying of samples in shortening, groundnut oil and mustard oil, respectively. However, further addition of sorbitol at 40 and 50 per cent level decreased the free fatty acid contents. Similar observations were found in case of doughnuts containing 30, 40 and 50 per cent of mannitol. Whereas, in case of samples containing glycerol, initial addition upto 30 per cent does not increased the free fatty acid contents. The free fatty acid contents significantly decreased with addition of 30, 40 and 50 per cent level of glycerol. The free fatty acid content of doughnut containing 30 per cent glycerol was 0.41 per cent as oleic acid in shortening, 0.55per cent as oleic acid in groundnut oil and 0.48per cent as oleic acid in mustard oil, respectively.

After a period of 30 days (Table 4.29) marked increase in the free fatty acid contents of the samples packed in various packaging materials was observed. However in case of craft paper, this increase was lesser when compared to other two packaging. The free fatty acid contents of control doughnut samples was 0.65, 1.12 and 1.00 per cent as oleic acid when packed in craft paper, plastic jars and polyethylene bags, respectively, after frying in shortening. When the three packaging material were compared, the free fatty acid contents were highest in

Table 4.29: Effect of different levels of humectants and packaging on free fatty acids (% as oleic acid) during storage for 30 days

Frying Media	Temperature (^{o}C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.65	0.67	0.66	0.49	0.72	0.76	0.59	0.64	0.58	0.49
	Plastic jar	1.12	1.05	0.94	0.92	1.10	1.03	0.90	0.84	0.71	0.60
	Polyethylene	1.00	0.94	0.77	0.73	0.99	0.87	0.83	0.72	0.63	0.53
Groundnut oil	Craft paper	0.59	0.60	0.59	0.46	0.66	0.69	0.56	0.58	0.51	0.43
	Plastic jar	1.06	0.99	0.88	0.66	10.4	0.96	0.74	0.79	0.64	0.53
	Polyethylene	0.92	0.85	0.65	0.58	0.90	0.75	0.68	0.68	0.56	0.46
Mustard oil	Craft paper	0.51	0.54	0.51	0.40	0.60	0.60	0.50	0.53	0.46	0.38
	Plastic jar	0.97	0.90	0.72	0.62	0.95	0.80	0.70	0.69	0.59	0.49
	Polyethylene	0.84	0.78	0.59	0.53	0.83	0.69	0.62	0.61	0.51	0.42

Treatments (A) = 0.011
Frying Media (B) = 0.006
Storage (C) = 0.006
A x B = 0.019
A x C = 0.019
B x C = 0.010

Humectant (A) = 0.006
Ratios (B) = 0.007
A x B = 0.011
CT Vs Others = 0.008

plastic jar packed samples followed by polyethylene bags and then by craft paper. In sorbitol containing samples at 30 per cent level, the free fatty acid contents were 0.67 per cent as oleic acid in craft paper, 1.05 per cent as oleic acid in plastic jars and 1.00 per cent as oleic acid in polyethylene packed samples, respectively when fried in shortening. Amongst the three humectants, the rate of increase in the values of free fatty acids was slower in glycerol containing samples at various levels.

The free fatty acid contents further increased after storage for 60 days (Table 4.30) in all the samples packed in craft paper, plastic jars and polyethylene bags. Again the increase in free fatty acids was highest in samples packed in plastic jars followed by those packed in polyethylene bags and then by craft paper. In samples containing 30 per cent sorbitol fried in shortening, the free fatty acid content was 0.76 per cent as oleic acid in craft paper, 1.62 per cent as oleic acid in plastic jars and 1.37 per cent as oleic acid in polyethylene bags, respectively. While the samples containing 30 per cent mannitol and fried in shortening, highest free fatty acids were found 1.67 per cent as oleic acid in plastic jars, 1.42 per cent as oleic acid in polyethylene bags and 0.89 per cent as oleic acid in craft paper packed samples, respectively. Similar trend was observed in case of glycerol containing samples.

During storage for 90 days (Table 4.31) further increase in free fatty acid contents was observed, highest in case of plastic jar packed samples followed by those packed in polyethylene bags and

Table 4.30: Effect of different levels of humectants and packaging on free fatty acids (% as oleic acid) during storage for 60 days

Frying Media	Temperature (^{o}C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.74	0.76	0.76	0.65	0.81	0.85	0.75	0.73	0.64	0.63
	Plastic jar	1.69	1.62	1.57	0.96	1.67	1.65	1.04	1.08	0.96	0.90
	Polyethylene	1.43	1.37	1.37	0.86	1.42	1.47	0.96	0.96	0.89	0.82
Groundnut oil	Craft paper	0.71	0.73	0.70	0.60	0.76	0.80	0.70	0.70	0.59	0.56
	Plastic jar	1.44	1.37	1.42	0.77	1.42	1.50	0.85	1.00	0.89	0.81
	Polyethylene	1.29	1.23	1.30	0.70	1.28	1.40	0.80	0.90	0.82	0.77
Mustard oil	Craft paper	0.58	0.60	0.60	0.51	0.69	0.69	0.61	0.64	0.53	0.50
	Plastic jar	1.30	1.24	1.24	0.73	1.27	1.32	0.81	0.86	0.84	0.76
	Polyethylene	1.13	1.07	1.07	0.66	1.12	1.27	0.75	0.79	0.77	0.71

Treatments (A) = 0.011
Frying Media (B) = 0.006
Storage (C) = 0.006
A x B = 0.020
A x C = 0.020
B x C = 0.011

Humectant (A) = 0.007
Ratios (B) = 0.006
A x B = 0.011
CT Vs Others = 0.008

Table 4.31: Effect of different levels of humectants and packaging on free fatty acids (% as oleic acid) during storage for 90 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.90	0.91	0.90	0.88	0.96	1.01	0.88	0.82	0.74	0.75
	Plastic jar	2.18	2.11	1.84	1.38	2.16	1.92	1.46	1.70	1.57	1.39
	Polyethylene	2.09	2.02	1.73	1.24	2.08	1.83	1.34	1.46	1.44	1.31
Groundnut oil	Craft paper	0.86	0.89	0.78	0.81	0.94	0.88	0.90	0.75	0.67	0.67
	Plastic jar	1.98	1.91	1.75	1.24	1.96	1.82	1.32	1.53	1.50	1.28
	Polyethylene	1.93	1.87	1.59	1.12	1.92	1.69	1.22	1.40	1.37	1.21
Mustard oil	Craft paper	0.76	0.76	0.71	0.66	0.82	0.82	0.77	0.72	0.54	1.59
	Plastic jar	1.87	1.80	1.59	1.17	1.85	1.67	1.24	1.44	0.84	1.14
	Polyethylene	1.82	1.76	1.46	1.04	1.81	1.55	1.13	1.28	0.77	1.11

Treatments (A) = 0.011
Frying Media (B) = 0.006
Storage (C) = 0.006
A x B = 0.019
A x C = 0.019
B x C = 0.010

Humectant (A) = 0.007
Ratios (B) = 0.007
A x B = 0.011
CT Vs Others = 0.008

then by craft paper. The free fatty acid contents in case of samples containing 30 per cent sorbitol after frying in shortening was 0.91 per cent as oleic acid in craft paper, 2.11 per cent as oleic acid in plastic jars and 2.02 per cent as oleic acid in polyethylene bags. However, the samples containing 30 per cent glycerol fried in the same media had free fatty acid content as 0.82 per cent as oleic acid in craft paper, 1.70 per cent as oleic acid in plastic jars and 1.46 per cent as oleic acid in polyethylene bag packed samples of doughnuts.

Therefore, the samples containing different levels of humectants, packed in three different packaging materials viz. craft paper, plastic jars and polyethylene bags showed gradual increase in free fatty acid contents with increase in storage time. With increasing level of humectant in the doughnut formulation, the free fatty acid contents reduced when compared to control samples and the glycerol containing samples showed the lowest values. Amongst the different frying media, the free fatty acid contents were higher in fresh samples fried in groundnut oil followed by mustard oil and then by shortening. However during storage, the free fatty acid contents rapidly increased in samples fried in shortening followed by those fried in groundnut oil and then by mustard oil.

Lolos *et al.*, (1999) and Mehta et al (1985) reported increase in free fatty acids in potato chips, when fried in different media during storage. However addition of TBHQ slowed down the rate of increase of free fatty acids. Similar findings have been reported by Noor and

Augustin (1984) who used BHA and BHT to slow down the rate of increase of free fatty acids. The increase in free fatty acids in deep-fried products might be due to development of hydrolytic rancidity.

4.9.6 Peroxide value

The data on effect of different levels of humectants on peroxide value in fresh doughnuts are presented in Table 4.32. The peroxide values in fresh control doughnut samples were 0.34, 0.43 and 0.38 meq/kg during frying of samples in shortening, groundnut oil and mustard oil, respectively. Thus, the peroxide values were higher in samples fried in groundnut oil followed by those fried in mustard oil and then in shortening. Addition of sorbitol initially at 30 per cent level significantly (CD$\leq$0.05) increased the peroxide value to 0.32, 0.44 and 0.36 meq/kg after frying of samples in shortening, groundnut oil and mustard oil, respectively. However, further addition of sorbitol at 40 and 50 per cent level decreased the peroxide value. Similar observations were found in case of doughnuts containing 30, 40 and 50 per cent of mannitol. Whereas, in case of samples containing glycerol, initial addition up to 30 per cent does not increased the peroxide value. The peroxide value significantly decreased with addition of 30, 40 and 50 per cent level of glycerol. The peroxide value of doughnut containing 30 per cent glycerol were 0.26 meq/kg in shortening, 0.38 meq/kg in groundnut oil and 0.32 meq/kg in mustard oil, respectively.

Table 4.32: Effect of different levels of humectants on peroxide value (meq/kg) in fresh doughnut samples

Humectants	Frying Media		
	Shortening	Groundnut oil	Mustard oil
Control	0.34	0.43	0.38
Sorbitol			
R1 (70:30)	0.32	0.44	0.36
R2 (60:40)	0.30	0.40	0.35
R3 (50:50)	0.24	0.35	0.28
Mannitol			
R1 (70:30)	0.36	0.48	0.40
R2 (60:40)	0.32	0.44	0.38
R3 (50:50)	0.28	0.40	0.33
Glycerol			
R1 (70:30)	0.26	0.38	0.32
R2 (60:40)	0.22	0.34	0.27
R3 (50:50)	0.18	0.26	0.21

Treatments (A)	= 0.015	Humectant (A)	= 0.008
Frying Media (B)	= 0.008	Ratios (B)	= 0.009
A x B	= 0.026	A x B	= NS
S.E.	= 0.002	CT Vs Others	= 0.011

After a period of 30 days (Table 4.33) marked increase in the peroxide value of the samples packed in various packaging materials was observed. However, in case of craft paper, this increase was lesser when compared to other two packaging used. The peroxide value of control doughnut samples was 0.52, 1.73 and 1.24 meq/kg when packed in craft paper, plastic jars and polyethylene bags, respectively, after frying in shortening. When the three packaging material were compared, the peroxide value were highest in plastic jar packed samples followed by polyethylene bags and then by craft paper. In sorbitol containing samples at 30 per cent level, the peroxide value were 0.53 meq/kg in craft paper, 0.99 meq/kg in plastic jars 0.88 meq/kg in polyethylene packed samples, respectively when fried in shortening. Amongst the three humectants, the rate of increase in the values of peroxide value was slower in glycerol containing samples at various levels.

The peroxide value further increased in all the samples packed in craft paper, plastic jars and polyethylene bags after storage for 60 days (Table 4.34). Again the increase in peroxide value was highest in samples packed in plastic jars followed by those packed in polyethylene bags and then by craft paper. In samples containing 30 per cent sorbitol fried in shortening, the peroxide value was 0.84 meq/kg in craft paper, 1.70 meq/kg in plastic jars and 1.46 meq/kg in polyethylene bags, respectively. While the samples containing 30 per cent mannitol and fried in shortening, highest peroxide value was found

Table 4.33: Effect of different levels of humectants and packaging on peroxide value (meq/kg)during storage for 30 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.52	0.53	0.60	0.48	0.58	0.65	0.54	0.52	0.45	0.35
	Plastic jar	1.73	0.99	0.92	0.82	1.04	0.97	0.87	0.95	0.85	0.72
	Polyethylene	1.24	0.88	0.81	0.74	0.93	0.86	0.79	0.88	0.77	0.64
Groundnut oil	Craft paper	0.44	0.41	0.38	0.33	0.46	0.44	0.38	0.38	0.31	0.26
	Plastic jar	1.57	0.77	0.86	0.71	0.82	0.91	0.75	0.79	0.71	0.58
	Polyethylene	1.08	0.72	0.74	0.60	0.77	0.79	0.64	0.70	0.62	0.50
Mustard oil	Craft paper	0.41	0.45	0.43	0.40	0.50	0.47	0.45	0.43	0.38	0.29
	Plastic jar	1.25	0.86	0.81	0.78	0.92	0.85	0.83	0.88	0.80	0.66
	Polyethylene	0.99	0.78	0.66	0.62	0.84	0.70	0.67	0.76	0.69	0.55

Treatments (A) = 0.011
Frying Media (B) = 0.006
Storage (C) = 0.007
A x B = 0.020
A x C = 0.020
B x C = 0.011

Humectant (A) = 0.007
Ratios (B) = 0.006
A x B = 0.011
CT Vs Others = 0.009

Table 4.34: Effect of different levels of humectants and packaging on peroxide value (meq/kg)during storage for 60 days

Frying Media	Temperature (^{o}C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.78	0.84	0.74	0.65	0.89	0.77	0.68	0.64	0.59	0.45
	Plastic jar	2.58	1.70	1.49	1.27	1.74	1.53	1.31	1.28	1.07	1.04
	Polyethylene	2.17	1.46	1.32	1.40	1.50	1.36	1.44	1.24	0.98	1.00
Groundnut oil	Craft paper	0.66	0.66	0.62	0.54	0.70	0.67	0.58	0.54	0.44	0.39
	Plastic jar	2.38	1.44	1.22	1.10	1.48	1.26	1.04	1.06	0.96	0.73
	Polyethylene	1.94	1.20	1.18	1.23	1.24	1.22	1.27	0.92	0.89	0.68
Mustard oil	Craft paper	0.60	0.75	0.69	0.59	0.79	0.73	0.63	0.60	0.52	0.41
	Plastic jar	2.14	1.52	1.40	1.17	1.56	1.44	1.21	1.14	1.09	0.88
	Polyethylene	1.80	1.37	1.27	1.34	1.41	1.31	1.38	0.99	0.97	0.79

Treatments (A) = 0.011
Frying Media (B) = 0.005
Storage (C) = 0.006
A x B = 0.019
A x C = 0.018
B x C = 0.010

Humectant (A) = 0.005
Ratios (B) = 0.007
A x B = 0.011
CT Vs Others = 0.008

1.74 meq/kg acid in plastic jars, 1.50 meq/kg in polyethylene bags and 0.81 meq/kg in craft paper packed samples, respectively. Similar trend was observed in case of glycerol containing samples.

After storage for 90 days (Table 4.35), further increase peroxide value was observed, highest in case of plastic jar packed samples followed by those packed in polyethylene bags and then by craft paper. The peroxide value in case of samples containing 30 per cent sorbitol after frying in shortening was 1.02 meq/kg in craft paper, 2.53 meq/kg in plastic jars and 2.32 meq/kg in polyethylene bags. However, the samples containing 30 per cent glycerol fried in the same media had peroxide value as 0.87 meq/kg in craft paper, 2.04 meq/kg plastic jars and 1.95 meq/kg in polyethylene bag packed samples of doughnuts.

Thus, the samples containing different levels of humectants, packed in three different packaging materials viz. craft paper, plastic jars and polyethylene bags showed gradual increase in peroxide value with increase in storage time. With increasing level of humectant in the doughnut formulation the peroxide value reduced when compared to control samples and the glycerol containing samples showed the lowest values. Amongst the different frying media, the peroxide value were higher in fresh samples fried in groundnut oil followed by mustard oil and then by shortening. However during storage, the peroxide value rapidly increased in samples fried in shortening followed by those fried in mustard oil and then by groundnut oil.

Table4.35: Effect of different levels of humectants and packaging on peroxide value (meq/kg)during storage for 90 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	0.99	1.02	0.99	0.86	1.07	1.04	0.92	0.87	0.82	0.66
	Plastic jar	3.71	2.53	2.24	1.89	2.59	2.29	1.94	2.04	1.62	1.79
	Polyethylene	3.10	2.32	2.02	2.09	2.37	2.07	2.14	1.95	1.40	1.48
Groundnut oil	Craft paper	0.84	0.83	0.84	0.62	0.88	0.88	0.66	0.79	0.68	0.54
	Plastic jar	3.47	2.39	2.08	1.56	2.44	2.12	1.60	1.61	1.49	1.29
	Polyethylene	2.82	2.22	1.86	1.79	2.27	1.90	1.84	1.36	1.27	1.09
Mustard oil	Craft paper	0.76	1.01	0.94	0.78	1.06	0.99	0.82	0.86	0.77	0.60
	Plastic jar	3.11	2.41	2.16	1.74	2.46	2.21	1.79	1.72	1.66	1.47
	Polyethylene	2.64	2.30	1.96	1.99	2.35	2.02	2.04	1.44	1.40	1.20

Treatments (A) = 0.011
Frying Media (B) = 0.005
Storage (C) = 0.006
A x B = 0.019
A x C = 0.019
B x C = 0.010

Humectant (A) = 0.006
Ratios (B) = 0.006
A x B = 0.011
CT Vs Others = 0.009

Mehta *et al.*, (1985) and Lolos *et al.*, (1999) reported increase in peroxide value in potato chips when fried in different media during storage. However addition of TBHQ slowed down the rate of increase of peroxide value. Similar findings have been reported by Noor and Augustin (1984) who used BHA and BHT to slow down the rate of increase of peroxide value. Peroxide value increased gradually probably due to the auto oxidation of the oil absorbed during deep-fat-frying.

4.10 Acceptability of doughnuts

Sensory analysis is a multi disciplinary science that uses human panelists and their senses of sight, smell, taste, touch and hearing to measure the sensory characteristics and acceptability of food products, as well as many other materials. There is no instrument that can replace the human response, making the sensory evaluation component of any food study essential. Sensory analysis is applicable to a variety of areas such as product development, product improvement, quality control, storage studies and process development. The quality of food supply depends at least in the past, on the sensory effects that food have on consumers. Food acceptance is not just a marketing or product development issue; it has broad health and nutritional implications. The sensory effects of foods in making purchase decisions regarding all the food products influence consumers, including those with health benefits or risks.

Sensory research has played a key role in the development of a modern food supply and will continue to do so as long as people consume food and beverages. Numbers can be used in several scales. They can be used on a nominal scale as category labels or names. When food samples are measured in terms of categories (acceptable Vs non-acceptable, odd sample in three Vs not odd sample), the data are said to be on nominal scale. Alternatively, numbers cań denote ranks, they can be used on an ordinal scale. The score, a food sample is given on hedonic scale will depend on the judge's food habits, culture, home background personality, idiosyncratic use of hedonic scale, recent eating history, health, age etc., all these factors will interact to determine the score.

Sensory evaluation strives to predict. Fresh products are evaluated to predict shelf-life. Small panels of trained judges are used to predict the reactions of consumers. It is natural that there are many possible applications of sensory evaluations; tenderness can be more readily measured by biting, so sensory evaluation will be used where convenience is important. Accuracy may suffer, however, unless many judges are used. An important objective of sensory evaluation is to determine which characteristics of product, lead to higher acceptance. Such a model could help periodic development and knowing the relationship between the process and sensory description would provide an important link between product development and eventual acceptance. Changes amount of ingredients, amounts to moisture or temperature are likely to produce changes in many sensory characteristics.

The organoleptic evaluation of the product under study was carried out using 9 point Hedonic scale. Hedonic tests are designed to measure degree of liking for a product category scales ranging from like extremely, through neither like nor dislike, to dislike extremely with varying number of categories are used. Panelists indicate their degree of liking for each sample by choosing the appropriate category. Panelists were asked to evaluate coded samples of several products for degree of liking on a 9-point scale. More than one sample may fall within the same category. The sensory scores as affected by different levels of humectants, frying media and storage was carried out for colour, texture, appearance, taste, flavour and discussed under following sub-heads

4.10.1 Colour scores

Table 4.36 show the colour scores of fresh doughnuts as affected by different levels of humectants. In fresh control doughnut samples higher score was observed in case of samples, fried in groundnut oil (8.35) followed by shortening (8.15) and mustard oil (7.95). Addition of different humectants viz., sorbitol, mannitol and glycerol significantly reduced the colour scores of fresh doughnut samples. The colour scores were 8.05, 8.05 and 7.75 in samples containing 30 per cent sorbitol after frying in shortening, groundnut oil

Table 4.36: **Colour score of fresh doughnuts as affected by different levels of humectants**

Humectants	**Frying Media**		
	Shortening	**Groundnut oil**	**Mustard oil**
Control	8.15	8.35	7.95
Sorbitol			
R1 (70:30)	8.05	8.05	7.75
R2 (60:40)	7.95	7.95	7.65
R3 (50:50)	7.75	7.75	7.55
Mannitol			
R1 (70:30)	8.05	8.15	7.85
R2 (60:40)	7.85	7.95	7.65
R3 (50:50)	7.75	7.75	7.45
Glycerol			
R1 (70:30)	7.95	7.95	7.65
R2 (60:40)	7.80	7.85	7.55
R3 (50:50)	7.75	7.75	7.35

Treatments (A) = 0.081
Frying Media (B) = 0.044
A x B = NS
S.E. = 0.010

Humectant (A) = 0.047
Ratios (B) = 0.046
A x B = NS
CT Vs Others = 0.060

and mustard oil, respectively. While these were 8.05, 8.15 and 7.85 in case of samples containing 30 per cent mannitol and 7.95, 7.95 and 7.65 in samples containing 30 per cent glycerol when fried in shortening, groundnut oil and mustard oil, respectively. With the increasing level of humectant in doughnut formulation, the colour scores decreased. The colour scores were 7.95, 7.95 and 7.65 in samples containing 40 per cent sorbitol which reduced to 7.75, 7.75 and 7.55 in samples containing 50 per cent sorbitol after frying in shortening, groundnut oil and mustard oil, respectively.

Data in Table 4.37 show the colour scores as affected by different levels of humectants and packaging after 30 days of storage. During storage, the colour scores decreased and the differences were statistically significant. The samples packed in craft paper lost moisture and became hard in all the samples except for those containing 50 per cent glycerol. On the other hand, control samples and those containing sorbitol and mannitol up to 30 per cent level were spoiled i.e. microbial growth appeared on them. While the case was different in glycerol containing samples. The samples were not spoiled at 30, 40 and 50per cent level of glycerol. The colour scores were 6.82 and 7.35 in case of samples containing 40 per cent sorbitol when packed in plastic jars and polyethylene bags, respectively when fried in shortening. Similarly these scores were 7.33 and 7.50 in case of samples containing 50 per cent sorbitol after packaging in plastic jars and polyethylene bags, respectively. However, the colour scores for the samples containing 50

Table 4.37: Effect of different levels of humectants and packaging on colour scores of doughnuts during storage for 30 days

Frying Media	Temperature (^oC)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	7.10
	Plastic jar	Spoiled	Spoiled	6.82	7.33	Spoiled	6.96	7.16	7.43	7.45	7.58
	Polyethylene	Spoiled	Spoiled	7.35	7.50	Spoiled	7.16	7.34	7.48	7.52	7.61
Groundnut oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	7.20
	Plastic jar	Spoiled	Spoiled	7.03	7.44	Spoiled	7.14	7.35	7.69	7.51	7.41
	Polyethylene	Spoiled	Spoiled	7.55	7.67	Spoiled	7.35	7.51	7.75	7.65	7.53
Mustard oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.66
	Plastic jar	Spoiled	Spoiled	6.93	7.00	Spoiled	6.80	6.98	7.28	7.15	6.93
	Polyethylene	Spoiled	Spoiled	7.12	7.21	Spoiled	7.01	7.09	7.49	7.34	7.11

Treatments (A) = 0.028
Frying Media (B) = 0.019
Storage (C) = 0.015
A x B = 0.049
A x C = 0.040
B x C = NS

per cent glycerol after frying in shortening were 7.10, 7.58 and 7.61 in craft paper, plastic jars and polyethylene bags, respectively. The colour scores were higher in case of samples packed in plastic jars and craft papers. Also, as the level of humectant increased in the doughnut formulation, the rate of decrease of colour scores was slower.

Perusals of data in Table 4.38 show the colour scores of doughnuts containing different levels of glycerol during storage for 60 and 90 days, respectively. It is clear from the Table that with increase in the storage period, the colour scores decreased significantly and was unacceptable in few cases. The colour scores for doughnuts containing 30 per cent glyccrol was 7.02 in plastic jars and 7.14 in polyethylene bags after 60 days storage, which decreased to6.75 in plastic jars and 6.80 polyethylene bags, respectively in case of samples fried in shortening after 90 days of storage. The doughnuts containing 40 per cent glycerol scored bit higher when compared with those containing 30 per cent glycerol and the rate of decrease in the colour scores was slower. When the three media were compared, the samples fried in mustard oil showed the lowest colour scores, followed by those fried in shortening and then in groundnut oil. The colour scores for samples containing 30per cent glycerol after 90 days of storage were 6.19 in plastic jars and 6.36 in polyethylene bags, which were bit unacceptable.

The interactions between treatments and frying media, treatments and storage were found to be significant at 5 per cent level of significance.

Table 4.38: **Colour score of doughnuts containing different levels of glycerol during storage**

Frying media/ Packaging	**Storage period**					
	60 days			**90 days**		
	(70:30)	**(60:40)**	**(50:50)**	**(70:30)**	**(60:40)**	**(50:50)**
Shortening						
Plastic jar	7.02	7.20	7.34	6.75	6.85	7.02
Polyethylene bag	7.14	7.38	7.41	6.80	6.97	7.15
Groundnut oil						
Plastic jar	7.19	7.21	7.33	6.84	6.93	7.00
Polyethylene bag	7.56	7.35	7.51	6.93	7.03	7.19
Mustard oil						
Plastic jar	6.65	6.85	6.98	6.19	6.41	6.54
Polyethylene bag	6.76	6.99	7.11	6.36	6.55	6.76

Humectants (A) = 0.020
Ratio (B) = 0.017
Frying Media (C) = 0.020
Storage (D) = 0.017
A x B = 0.029
A x C = NS
B x C = 0.029

In nutshell, the colour scores of doughnuts containing different levels of humectants packed in different packaging materials, after frying in different media decreased with increase in storage time. The control samples along with those containing sorbitol and mannitol at 30 per cent level spoiled within 30 days of storage. On the other hand, the samples packed in craft paper became hard due to absorption of moisture and fat by the paper thus making them unacceptable, except for those samples, which contained glycerol at 50 per cent level. The rate of decrease of colour scores was higher in samples containing lower levels of humectants. Also, the colour scores deceased fast when packed in plastic jars as compared to those packed in polyethylene bags. Thus, the humectants helped to retain the shelf-life for longer periods when compared to control samples.

4.10.2 Flavour scores

Flavour scores of fresh doughnuts as affected by different levels of humectants are shown in Tahle 4.39. Fresh control doughnut samples scored higher for flavour when compared with those containing humectants at various levels. Higher scores for flavour were observed in case of control samples fried in groundnut oil (8.25), followed by those fried in shortening (8.05) and mustard oil (7.75), respectively. Sorbitol, mannitol and glycerol when added to the doughnut formulation at various levels, significantly reduced the flavour scores. The samples containing 30 per cent sorbitol had scores as 8.05, 8.05 and 7.75 when

Table 4.39: **Flavor score of fresh doughnuts as affected by different levels of humectants**

Humectants	**Frying Media**		
	Shortening	**Groundnut oil**	**Mustard oil**
Control	8.05	8.25	7.75
Sorbitol			
R1 (70:30)	8.05	8.05	7.75
R2 (60:40)	7.95	7.95	7.65
R3 (50:50)	7.75	7.75	7.50
Mannitol			
R1 (70:30)	8.05	8.15	7.85
R2 (60:40)	7.85	7.95	7.65
R3 (50:50)	7.75	7.75	7.45
Glycerol			
R1 (70:30)	7.95	7.95	7.65
R2 (60:40)	7.80	7.85	7.55
R3 (50:50)	7.75	7.75	7.35

Treatments (A)	= 0.080	Humectant (A)	= 0.045
Frying Media (B)	= 0.043	Ratios (B)	= 0.045
A x B	= NS	A x B	= NS
S.E.	= 0.009	CT Vs Others	= 0.060

fried in shortening, groundnut oil and mustard oil, respectively. While those containing 30 per cent mannitol had scores as 7.95, 7.95 and 7.65 when fried in shortening, groundnut oil and mustard oil, respectively. When the level of either humectant was increased in the doughnuts, the flavour scores were significantly decreased. The scores for flavour were 7.80, 7.85 and 7.55 in case of samples containing 40 per cent glycerol and these reduced to 7.75, 7.75 and 7.35 when 50 per cent glycerol was added during frying of samples in shortening, groundnut oil and mustard oil, respectively. Thus, the samples containing glycerol at various levels scored lowest for flavour followed by those containing mannitol and sorbitol. Among three the media, the samples fried in mustard oil had lowest scores.

After storage for 30 days (Table 4.40), a gradual decrease in the flavour scores of the doughnuts was observed. The control samples and other samples containing sorbitol and mannitol at 30 per cent level, after frying in shortening, groundnut oil and mustard oil when packed in different packaging materials, spoiled due to mould growth. The pre dominant species of mould was *Aspergillus spp*, which spoiled the product. The various samples when packed in craft paper were unacceptable because they became hard, except for those containing glycerol at 50 per cent level; however, the flavour scores were very less. Thus, the glycerol was more effective in retaining the colour and flavour scores of the doughnuts at 30, 40 and 50 per cent levels during 30 days storage. The flavour scores of the samples containing 40 per cent

Table 4.40: Effect of different levels of humectants and packaging on flavour scores of doughnuts during storage for 30 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	7.03
	Plastic jar	Spoiled	Spoiled	6.92	7.16	Spoiled	6.77	6.98	7.09	7.23	7.36
	Polyethylene	Spoiled	Spoiled	7.20	7.39	Spoiled	6.95	7.11	7.25	7.38	7.47
Groundnut oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	7.14
	Plastic jar	Spoiled	Spoiled	7.01	7.26	Spoiled	6.84	7.16	7.15	7.25	7.43
	Polyethylene	Spoiled	Spoiled	7.35	7.47	Spoiled	7.13	7.38	7.27	7.49	7.68
Mustard oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.95
	Plastic jar	Spoiled	Spoiled	6.59	6.83	Spoiled	6.55	6.72	7.02	7.17	7.20
	Polyethylene	Spoiled	Spoiled	6.95	7.00	Spoiled	6.78	6.86	7.11	7.26	7.33

Treatments (A) = 0.029
Frying Media (B) = 0.019
Storage (C) = 0.015
A x B = 0.050
A x C = 0.040
B x C = 0.026

sorbitol were 6.92 in plastic jars and 7.20 in polyethylene bags after frying in shortening, while these scores were higher in case of samples containing 50 per cent sorbitol with value of 7.16 in plastic jars and 7.39 in polyethylene bags, respectively. In case of samples containing mannitol, the flavour scores were less. The samples containing 50 per cent mannitol fried in shortening scored 6.98 in plastic jar packing and 7.11 in polyethylene bags, respectively. The samples containing glycerol at 50 per cent level fried in shortening scored highest for flavour with scores of 7.03 in craft paper, 7.36 in plastic jars and 7.47 in polyethylene bags.

Data in Table 4.41 show the flavour scores of the doughnuts containing different levels of glycerol during storage for 60 and 90 days, respectively. It can be interpreted from the Table that the flavour scores decreased when the storage period extended to 60 and 90 days, respectively. The flavour scores of the doughnuts fried in mustard oil became unacceptable after storage for 60 and 90 days in different packaging materials except for those containing glycerol at 50 per cent level, which were still acceptable. The flavour scores in case of doughnuts containing 30 per cent glycerol when fried in shortening was 6.75 in plastic jars and 6.91 in polyethylene bags, respectively after storage for 60 days. The samples fried in the same media scored 6.91 (plastic jars) and 7.03 (polyethylene bags) when 40 per cent glycerol was added and 7.00 (plastic jars) and 7.13 (polyethylene bags) when 50 per cent glycerol was added during storage for 60 days. Thus, it is

Table 4.41: Flavour score of doughnuts containing different levels of glycerol during storage

Frying media/ Packaging	Storage period					
	60 days			90 days		
	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening						
Plastic jar	6.75	6.91	7.00	6.52	6.62	6.70
Polyethylene bag	6.91	7.03	7.13	6.63	6.68	6.83
Groundnut oil						
Plastic jar	6.80	6.94	7.05	6.66	6.61	6.77
Polyethylene bag	7.05	7.16	7.36	6.72	6.75	6.91
Mustard oil						
Plastic jar	6.40	6.67	6.84	6.04	6.22	6.35
Polyethylene bag	6.65	6.89	6.90	6.17	6.34	6.55

Humectants (A) = 0.020
Ratio (B) = 0.017
Frying Media (C) = 0.020
Storage (D) = 0.017
A x B = 0.028
A x C = 0.035
B x C = 0.028

evident that increase in the level of glycerol slowed downs the rate of fall of flavour scores during storage. After storage for 90 days, the flavour scores further decreased and similar trend was observed as in case of samples analyzed after 60 days of storage.

The interactions between treatments and frying media, treatments and storage were found to be significant at 5 per cent level of significance.

On an average, it can be concluded that the flavour scores of the doughnuts decreased with increase in storage time but the rate of decrease varied with the type of humectant used, the frying media and the packaging material used. Control samples along with those containing 30 per cent sorbitol or mannitol spoiled within 30 days of storage, while those containing 40 and 50 per cent sorbitol or mannitol spoiled before 60 days of storage. Addition of glycerol was found most effective in decreasing the rate of fall of flavour scores. Fresh sample however, scored less for flavour scores when compared with control and those containing sorbitol and mannitol. The samples packed in polyethylene bags had higher flavour scores than those packed in plastic jars.

4.10.3 Texture Scores

Table 4.42 show the texture scores of fresh doughnuts as affected by different levels of humectants. In fresh control doughnut samples, higher score was observed in case of samples fried in

Table 4.42: **Texture score of fresh doughnuts as affected by different levels of humectants**

Humectants	Frying Media		
	Shortening	**Groundnut oil**	**Mustard oil**
Control	8.05	8.15	7.95
Sorbitol			
R1 (70:30)	7.95	8.05	7.95
R2 (60:40)	7.85	7.95	7.80
R3 (50:50)	7.75	7.75	7.35
Mannitol			
R1 (70:30)	8.03	8.05	7.95
R2 (60:40)	7.85	7.95	7.85
R3 (50:50)	7.75	7.80	7.55
Glycerol			
R1 (70:30)	7.95	7.95	7.75
R2 (60:40)	7.70	7.80	7.75
R3 (50:50)	7.55	7.65	7.55

Treatments (A) = 0.082
Frying Media (B) = 0.045
A x B = 0.143
S.E. = 0.009

Humectant (A) = 0.047
Ratios (B) = 0.046
A x B = NS
CT Vs Others = 0.062

groundnut oil (8.15) followed by shortening (8.05) and mustard oil (7.95). Addition of different humectants viz., sorbitol, mannitol and glycerol significantly reduced the texture scores of fresh doughnut samples. The texture scores were 7.95, 8.05 and 7.95 in sample containing 30 per cent sorbitol after frying in shortening, groundnut oil and mustard oil, respectively. While these were 8.03, 8.05 and 7.95 in case of samples containing 30 per cent mannitol and 7.95, 7.95 and 7.75 in samples containing 30 per cent glycerol when fried in shortening, groundnut oil and mustard oil, respectively. With the increasing level of humectant in doughnut formulation, the texture scores decreased. The texture scores were 7.85, 7.95 and 7.80 in samples containing 40 per cent sorbitol which reduced to 7.75, 7.75 and 7.35 in samples containing 50 per cent sorbitol after frying in shortening, groundnut oil and mustard oil, respectively.

Data in Table 4.43 show the texture scores as affected by different levels of humectants and packaging after 30 days of storage. During storage, the texture scores decreased and the differences were statistically significant. The samples packed in craft paper lost moisture and became hard in all the samples except for those containing 50 per cent glycerol. On the other hand, control samples and those containing sorbitol and mannitol up to 30 per cent level spoiled i.e. microbial growth appeared on them. While the case was different in glycerol containing samples the samples did not spoiled at 30, 40 and 50 per cent level of glycerol. The texture scores were 7.24 and 7.44 in case of

Table 4.43: Effect of different levels of humectants and packaging on texture scores of doughnuts during storage for 30 days

Frying Media	Temperature (^{o}C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.33
	Plastic jar	Spoiled	Spoiled	7.24	7.13	Spoiled	6.94	6.80	7.39	7.21	7.14
	Polyethylene	Spoiled	Spoiled	7.44	7.29	Spoiled	7.25	7.11	7.46	7.33	7.28
Groundnut oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.52
	Plastic jar	Spoiled	Spoiled	7.36	7.27	Spoiled	7.07	7.02	7.51	7.31	7.10
	Polyethylene	Spoiled	Spoiled	7.55	7.40	Spoiled	7.36	7.26	7.72	7.56	7.41
Mustard oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.20
	Plastic jar	Spoiled	Spoiled	7.17	6.81	Spoiled	6.96	6.70	7.28	7.17	7.01
	Polyethylene	Spoiled	Spoiled	7.34	7.19	Spoiled	7.08	6.88	7.36	7.20	7.32

Treatments (A) = 0.029
Frying Media (B) = 0.019
Storage (C) = 0.015
A x B = 0.050
A x C = 0.040
B x C = 0.026

samples containing 40 per cent sorbitol when packed in plastic jars and polyethylene bags, respectively when fried in shortening. Similarly, these scores were 7.13 and 7.29 in case of samples containing 50 per cent sorbitol after packaging in plastic jars and polyethylene bags, respectively. However, the texture scores for the samples containing 50 per cent glycerol after frying in shortening were 6.33, 7.14 and 7.28 in craft paper, plastic jars and polyethylene bags, respectively. The texture scores were higher in case of samples packed in polyethylene bags and craft papers. The texture scores were higher in case of samples containing lower levels of humectants.

Perusals of data in Table 4.44 show the texture scores of doughnuts containing different levels of glycerol during storage for 60 and 90 days, respectively. It is evident from the Table that with increase in the storage period, the texture scores decreased significantly and was unacceptable in few cases. The texture scores for doughnuts containing 30 per cent glycerol when fried in shortening was 7.09 in plastic jars and 7.42 in nolyethylene bags after 60 days, which decreased to 6.63 in plastic jars and 7.06 polyethylene bags, respectively after 90 days of storage. The doughnuts containing 40 per cent glycerol scored lower when compared with those containing 30 per cent glycerol. When the three media were compared, the samples fried in mustard oil showed the lowest texture scores, followed by those fried in shortening and then in groundnut oil. The texture scores for samples

Table 4.44: **Texture score of doughnuts containing different levels of glycerol during storage**

Frying media/ Packaging	**Storage period**					
	60 days			**90 days**		
	(70:30)	**(60:40)**	**(50:50)**	**(70:30)**	**(60:40)**	**(50:50)**
Shortening						
Plastic jar	7.09	6.87	6.82	6.63	6.50	6.32
Polyethylene bag	7.42	7.17	7.01	7.06	6.71	6.61
Groundnut oil						
Plastic jar	7.20	6.90	6.93	6.75	6.49	6.43
Polyethylene bag	7.44	7.22	7.12	7.09	6.81	6.80
Mustard oil						
Plastic jar	6.96	6.71	6.75	6.71	6.53	6.35
Polyethylene bag	7.18	7.04	6.83	6.88	6.69	6.47

Humectants (A) = 0.020
Ratio (B) = 0.016
Frying Media (C) = 0.020
Storage (D) = 0.017
A x B = 0.029
A x C = 0.035
B x C = NS

containing 30per cent glycerol after 90 days of storage were 6.35 in plastic jars and 6.47 in polyethylene bags, which were bit unacceptable.

The interactions between treatments and frying media, treatments and storage were found to be significant at 5 per cent level of significance.

Thus, the texture scores of doughnuts containing different levels of humectants packed in different packaging materials, after frying in different media decreased with increase in storage time. The control samples along with those containing sorbitol and mannitol at 30 per cent level spoiled within 30 days of storage. The rate of decrease of scores was higher in samples containing lower levels of humectants. Also, the texture scores deceased fast when packed in plastic jars when compared to those packed in polyethylene bags. Thus, the humectants helped to retain the shelf-life for longer periods when compared to control samples.

4.10.4 Appearance sco-es

Appearance scores of fresh doughnuts as affected by different levels of humectants are shown in Table 4.45. Fresh control doughnut samples scored higher for appearance when compared with those containing humectants at various levels. Higher scores for appearance were observed in case of control samples fried in groundnut oil (8.05), followed by those fried in shortening (7.95) and mustard oil (7.95), respectively. Sorbitol, mannitol and glycerol when

Table 4.45: Appearance score of fresh doughnuts as affected by different levels of humectants

Humectants	Frying Media		
	Shortening	**Groundnut oil**	**Mustard oil**
Control	7.95	8.05	7.95
Sorbitol			
R1 (70:30)	7.85	7.95	7.75
R2 (60:40)	7.85	7.95	7.75
R3 (50:50)	7.65	7.75	7.65
Mannitol			
R1 (70:30)	7.85	7.95	7.75
R2 (60:40)	7.75	7.75	7.45
R3 (50:50)	7.35	7.55	7.25
Glycerol			
R1 (70:30)	7.75	7.85	7.65
R2 (60:40)	7.60	7.65	7.55
R3 (50:50)	7.25	7.35	7.25

Treatments (A)	= 0.081	Humectant (A)	= 0.046
Frying Media (B)	= 0.044	Ratios (B)	= 0.046
A x B	= NS	A x B	= 0.081
S.E.	= 0.010	CT Vs Others	= 0.061

added to the doughnut formulation at various levels, significantly reduced the appearance scores. The samples containing 30 per cent sorbitol had scores as 7.85, 7.95 and 7.75 when fried in shortening, groundnut oil and mustard oil, respectively. While those containing 30 per cent mannitol had scores as 7.85, 7.95 and 7.75 when fried in shortening, groundnut oil and mustard oil, respectively. When the level of either humectant was increased in the doughnuts, the appearance scores were significantly decreased. The scores for appearance were 7.60, 7.65 and 7.55 in case of samples containing 40 per cent glycerol and these reduced to 7.25, 7.35 and 7.25 when 50 per cent glycerol was added during frying of samples in shortening, groundnut oil and mustard oil, respectively. Thus, the samples containing glycerol at various levels scored lowest for appearance followed by those containing mannitol and sorbitol. Among three the media, the samples fried in mustard oil had lowest scores.

After storage for 30 days (Table 4.46), a gradual decrease in the appearance scores of the doughnuts was observed. The control samples and other samples containing sorbitol and mannitol at 30 per cent level, after frying in shortening, groundnut oil and mustard oil when packed in different packaging materials, spoiled due to mould growth. The pre dominant species of mould was *Aspergillus spp*, which spoiled the product. The various samples when packed in craft paper were unacceptable because they became hard, except for those containing glycerol at 50 per cent level; however, the appearance scores were very

Table 4.46 : Effect of different levels of humectants and packaging on appearance scores of doughnuts during storage for 30 days

Frying Media	Temperature (^{o}C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	7.25
	Plastic jar	Spoiled	Spoiled	7.30	7.37	Spoiled	6.90	7.07	6.83	7.05	7.33
	Polyethylene	Spoiled	Spoiled	7.50	7.62	Spoiled	7.02	7.28	6.98	7.12	7.47
Groundnut oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	7.39
	Plastic jar	Spoiled	Spoiled	7.45	7.54	Spoiled	7.06	7.24	7.05	7.21	7.58
	Polyethylene	Spoiled	Spoiled	7.60	7.76	Spoiled	7.21	7.46	7.20	7.34	7.66
Mustard oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	7.32
	Plastic jar	Spoiled	Spoiled	7.19	7.30	Spoiled	6.88	7.10	6.74	7.13	7.40
	Polyethylene	Spoiled	Spoiled	7.45	7.53	Spoiled	7.17	7.34	6.87	7.20	7.53

Treatments (A) = 0.028
Frying Media (B) = 0.019
Storage (C) = 0.015
A x B = 0.049
A x C = 0.040
B x C = 0.026

less. Thus, the glycerol was more effective in retaining the colour and appearance scores of the doughnuts at 30, 40 and 50 per cent levels during 30 days storage. The appearance scores of the samples containing 40 per cent sorbitol were 7.30 in plastic jars and 7.50 in polyethylene bags after frying in shortening, while these scores were higher in case of samples containing 50 per cent sorbitol with value of 7.37 in plastic jars and 7.62 in polyethylene bags, respectively. In case of samples containing mannitol, the appearance scores were less. The samples containing 50 per cent mannitol fried in shortening scored 7.07 in plastic jar packing and 7.28 in polyethylene bags, respectively. The samples containing glycerol at 50 per cent level fried in shortening scored highest for appearance with scores of 7.25 in craft paper, 7.33 in plastic jars and 7.47 in polyethylene bags.

Data in Table 4.47 show the appearance scores of the doughnuts containing different levels of glycerol during storage for 60 and 90 days, respectively. It can be interpreted from the Table that the appearance scores decreased when the storage period extended to 60 and 90 days, respectively. The appearance scores of the doughnuts fried in mustard oil became unacceptable after storage for 60 and 90 days in different packaging materials except for those containing glycerol at 50 per cent level, which were still acceptable. The appearance scores in case of doughnuts containing 30 per cent glycerol when fried in shortening was 6.72 in plastic jars and 6.83 in polyethylene bags, respectively after storage for 60 days. The samples

Table 4.47: **Appearance score of doughnuts containing different levels of glycerol during storage**

Frying media/ Packaging	Storage period					
	60 days			90 days		
	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening						
Plastic jar	6.72	7.01	7.17	6.42	6.61	6.86
Polyethylene bag	6.83	7.11	7.28	6.55	6.72	6.95
Groundnut oil						
Plastic jar	6.90	7.00	7.13	6.61	6.83	6.90
Polyethylene bag	7.05	7.15	7.25	6.84	6.89	6.99
Mustard oil						
Plastic jar	6.65	6.84	7.00	6.19	6.44	6.51
Polyethylene bag	6.76	6.96	7.18	6.27	6.49	6.63

Humectants (A) = 0.020
Ratio (B) = 0.016
Frying Media (C) = 0.020
Storage (D) = 0.016
A x B = 0.029
A x C = 0.035
B x C = 0.028

fried in the same media scored 7.01 (plastic jars) and 7.11 (polyethylene bags) when 40 per cent glycerol was added and 7.00 (plastic jars) and 7.17 (polyethylene bags) when 50 per cent glycerol was added during storage for 60 days. Thus, it is evident that increase in the level of glycerol slowed downs the rate of fall of appearance scores during storage. After storage for 90 days, the appearance scores further decreased and similar trend was observed as in case of samples analyzed after 60 days of storage.

The interactions between treatments and frying media, treatments and storage were found to be significant at 5 per cent level of significance.

On an average, it can be concluded that the appearance scores of the doughnuts decreased with increase in storage time but the rate of decrease varied with the type of humectant used, the frying media and the packaging material used. Control samples along with those containing 30 per cent sorbitol or mannitol spoiled within 30 days of storage, while those containing 40 and 50 per cent sorbitol or mannitol spoiled before 60 days of storage. Addition of glycerol was found most effective in decreasing the rate of fall of appearance scores. Fresh sample however, scored less for appearance scores when compared with control and those containing sorbitol and mannitol. The samples packed in polyethylene bags had higher appearance scores than those packed in plastic jars.

4.10.5 *Taste Scores*

Table 4.48 show the taste scores of fresh doughnuts as affected by different levels of humectants. In fresh control doughnut samples, higher score was observed in case of samples fried in groundnut oil (8.15) followed by shortening (8.05) and mustard oil (7.75). Addition of different humectants viz., sorbitol, mannitol and glycerol significantly reduced the taste scores of fresh doughnut samples. The texture scores were 7.95, 7.95 and 7.75 in sample containing 30 per cent sorbitol after frying in shortening, groundnut oil and mustard oil, respectively. While these were 7.95, 7.95 and 7.65 in case of samples containing 30 per cent mannitol and 7.85, 7.85 and 7.45 in samples containing 30 per cent glycerol when fried in shortening, groundnut oil and mustard oil, respectively. With the increasing level of humectant in doughnut formulation, the taste scores decreased. The taste scores were 7.65, 7.75 and 7.45 in samples containing 40 per cent sorbitol which reduced to 7.45, 7.55 and 7.35 in samples containing 50 per cent sorbitol after frying in shortening, groundnut oil and mustard oil, respectively.

Data in Table 4.49 show the taste scores as affected by different levels of humectants and packaging after 30 days of storage. During storage, the taste scores decreased and the differences were statistically significant. The samples packed in craft paper lost moisture and became hard in all the samples except for those containing 50 per cent glycerol. On the other hand, control samples and those containing

Table 4.48: Taste score of fresh doughnuts as affected by different levels of humectants

Humectants	Frying Media		
	Shortening	Groundnut oil	Mustard oil
Control	8.05	8.15	7.75
Sorbitol			
R1 (70:30)	7.95	7.95	7.75
R2 (60:40)	7.65	7.75	7.45
R3 (50:50)	7.45	7.55	7.35
Mannitol			
R1 (70:30)	7.95	7.95	7.65
R2 (60:40)	7.75	7.75	7.45
R3 (50:50)	7.25	7.35	6.95
Glycerol			
R1 (70:30)	7.85	7.85	7.45
R2 (60:40)	7.50	7.60	7.15
R3 (50:50)	7.15	7.25	6.95

Treatments (A) = 0.082
Frying Media (B) = 0.045
A x B = NS
S.E. = 0.010

Humectant (A) = 0.047
Ratios (B) = 0.047
A x B = 0.082
CT Vs Others = 0.061

Table 4.49: Effect of different levels of humectants and packaging on taste scores of doughnuts during storage for 30 days

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.81
	Plastic jar	Spoiled	Spoiled	6.93	6.76	Spoiled	6.80	6.63	7.24	7.05	6.85
	Polyethylene	Spoiled	Spoiled	7.22	7.05	Spoiled	7.15	6.94	7.33	7.24	7.09
Groundnut oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.92
	Plastic jar	Spoiled	Spoiled	7.04	7.12	Spoiled	6.89	6.85	7.34	7.11	7.03
	Polyethylene	Spoiled	Spoiled	7.39	7.31	Spoiled	7.24	7.11	7.42	7.24	7.15
Mustard oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.33
	Plastic jar	Spoiled	Spoiled	6.85	6.56	Spoiled	6.66	6.37	6.97	6.83	6.41
	Polyethylene	Spoiled	Spoiled	7.00	6.74	Spoiled	6.84	6.52	6.78	6.66	6.30

Treatments (A) = 0.029
Frying Media (B) = 0.019
Storage (C) = 0.015
A x B = 0.050
A x C = 0.041
B x C = NS

sorbitol and mannitol up to 30 per cent level spoiled i.e. microbial growth appeared on them. While the case was different in glycerol containing samples the samples did not spoiled at 30, 40 and 50 per cent level of glycerol. The taste scores were 6.93 and 7.22 in case of samples containing 40 per cent sorbitol when packed in plastic jars and polyethylene bags, respectively when fried in shortening. Similarly, these scores were 6.76 and 7.05 in case of samples containing 50 per cent sorbitol after packaging in plastic jars and polyethylene bags, respectively. However, the taste scores for the samples containing 50 per cent glycerol after frying in shortening were 6.81, 6.85 and 7.09 in craft paper, plastic jars and polyethylene bags, respectively. The taste scores were higher in case of samples packed in polyethylene bags and craft papers. The taste scores were higher in case of samples containing lower levels of humectants.

Perusals of data in Table 4.50 show the taste scores of doughnuts containing different levels of glycerol during storage for 60 and 90 days, respectively. It is evident from the Table that with increase in the storage period, the taste scores decreased significantly and was unacceptable in few cases. The texture scores for doughnuts containing 30 per cent glycerol when fried in shortening was 6.85 in plastic jars and 6.93 in polyethylene bags after 60 days, which decreased to 6.50 in plastic jars and 6.58 polyethylene bags, respectively after 90 days of storage. The doughnuts containing 40 per cent glycerol scored lower when compared with those containing 30 per

Table 4.50: Taste score of doughnuts containing different levels of glycerol during storage

Frying media/ Packaging	Storage period					
	60 days			90 days		
	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening						
Plastic jar	6.85	6.59	6.43	6.50	6.31	6.16
Polyethylene bag	6.93	6.72	6.55	6.58	6.42	6.27
Groundnut oil						
Plastic jar	6.77	6.68	6.61	6.41	6.45	6.40
Polyethylene bag	6.88	6.82	6.80	6.59	6.52	6.47
Mustard oil						
Plastic jar	6.23	6.11	6.12	5.80	5.74	5.61
Polyethylene bag	6.54	6.43	6.31	6.07	5.89	5.83

Humectants (A) = 0.019
Ratio (B) = 0.015
Frying Media (C) = 0.020
Storage (D) = 0.016
A x B = 0.027
A x C = 0.037
B x C = 0.028

cent glycerol. When the three media were compared, the samples fried in mustard oil showed the lowest taste scores, followed by those fried in groundnut oil and then in shortening. The taste scores for samples containing 30per cent glycerol after 90 days of storage were 5.80 in plastic jars and 6.07 in polyethylene bags, which were bit unacceptable.

The interactions between treatments and frying media, treatments and storage were found to be significant at 5 per cent level of significance.

Thus, the taste scores of doughnuts containing different levels of humectants packed in different packaging materials, after frying in different media decreased with increase in storage time. The control samples along with those containing sorbitol and mannitol at 30 per cent level spoiled within 30 days of storage. The rate of decrease of scores was higher in samples containing lower levels of humectants. Also, the taste scores deceased fast when packed in plastic jars when compared to those packed in polyethylene bags. Thus, the humectants helped to retain the shelf-life for longer periods when compared to control samples.

4.10.6 Overall acceptability scores

Table 4.51 shows the overall acceptability scores of fresh doughnuts as affected by different levels of humectants. The overall acceptability scores for control fresh samples were 8.05, 8.19 and 7.83 when fried in shortening, groundnut oil and mustard oil, respectively.

Table 4.51: **Overall acceptability score of fresh doughnuts as affected by different levels of humectants**

Humectants	**Frying Media**		
	Shortening	**Groundnut oil**	**Mustard oil**
Control	8.05	8.19	7.83
Sorbitol			
R1 (70:30)	7.97	8.01	7.79
R2 (60:40)	7.85	7.91	7.66
R3 (50:50)	7.67	7.71	7.48
Mannitol			
R1 (70:30)	7.99	8.05	7.81
R2 (60:40)	7.81	7.87	7.61
R3 (50:50)	7.57	7.63	7.33
Glycerol			
R1 (70:30)	7.89	7.91	7.63
R2 (60:40)	7.68	7.75	7.51
R3 (50:50)	7.49	7.55	7.29

Treatments (A)	= 0.89	Humectant (A)	= 0.057
Frying Media (B)	= 0.051	Ratios (B)	= 0.051
A x B	= NS	A x B	= 0.092
S.E.	= 0.020	CT Vs Others	= 0.069

With the addition of humectants like sorbitol, mannitol and glycerol, the overall acceptability scores decreased significantly, lowest in case of samples containing 50 per cent level followed by 40 and then by 30 per cent level of addition of humectant. These scores in case of samples containing 30 per cent sorbitol were 7.97, 8.01 and 7.79 when fried in shortening, groundnut oil and mustard oil, respectively. These decreased to 7.85, 7.91 and 7.66 in case of samples containing 50 per cent sorbitol after frying in shortening, groundnut oil and mustard oil, respectively. Similar trend was observed when mannitol and glycerol were added at 30, 40 and 50 per cent levels. Lowest overall acceptability scores were observed in case of samples added with glycerol at various levels. Also, frying of samples in mustard oil significantly reduced these scores when two other media were compared.

After storage for 30 days (Table 4.52), significant reduction in the overall acceptability scores were observed in all the samples packed in different packaging materials. It is obvious from the Table that samples (control) and those containing sorbitol and mannitol at 30 per cent level spoiled within 30 days of storage. The samples packed in craft paper were very hard, however, samples containing glycerol showed different trend and did not spoiled. Also, the samples containing glycerol at 50 per cent level when packed in craft paper were not hard during 30 days of storage. The overall acceptability scores for samples containing 40 per cent sorbitol and 40 per cent mannitol when

Table 4.52: Effect of different levels of humectants and packaging on overall acceptability of doughnuts during storage for 30 days

Frying Media	Temperature (^oC)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.90
	Plastic jar	Spoiled	Spoiled	7.05	7.14	Spoiled	6.85	6.95	7.19	7.19	7.25
	Polyethylene	Spoiled	Spoiled	7.32	7.39	Spoiled	7.07	7.19	7.30	7.32	7.38
Groundnut oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	7.03
	Plastic jar	Spoiled	Spoiled	7.23	7.28	Spoiled	7.04	7.08	7.35	7.28	7.31
	Polyethylene	Spoiled	Spoiled	7.47	7.54	Spoiled	7.26	7.34	7.47	7.46	7.49
Mustard oil	Craft paper	Spoiled	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	6.69
	Plastic jar	Spoiled	Spoiled	6.86	6.98	Spoiled	6.69	6.85	7.06	7.09	6.99
	Polyethylene	Spoiled	Spoiled	7.10	7.21	Spoiled	6.89	7.02	7.12	7.13	7.12

Treatments (A) = 0.029
Frying Media (B) = 0.021
Storage (C) = 0.017
A x B = 0.051
A x C = 0.043
B x C = 0.028

fried in shortening were 7.14 and 6.95 in plastic jars and 7.39 and 7.19 in polyethylene bags, respectively. Thus the overall acceptability scores were higher in samples packed in polyethylene bags when compared to plastic jars. Similar trend was observed in case of samples containing 50 per cent glycerol when fried in shortening with overall acceptability scores of 6.90 in craft paper, 7.25 in plastic jars and 7.38 in polyethylene bags.

Table 4.53 shows the overall acceptability scores of doughnuts as affected by different levels of glycerol, packaging materials used and storage for 60 and 90 days. Similar observations were observed as in case of samples evaluated after 30 days storage except for those containing sorbitol and mannitol, which could not be stored for 60 days as they were spoiled due to microbial growth. The overall acceptability scores for doughnuts containing 30 per cent glycerol, when fried in shortening after storage for 60 days were 7.09 and 7.23 in plastic jars and polyethylene bags, respectively. Whereas, these scores were 6.92 and 7.08 in samples containing 40 per cent glycerol and 6.75 and 6.89 in samples containing 50 per cent glycerol, respectively. The samples fried in mustard oil scored less than those fried in groundnut oil and shortening. Similar observations for overall acceptability scores were observed after storage for 90 days.

Thus, the control samples and samples containing 30 per cent sorbitol or mannitol had shelf-life below one month. While those containing sorbitol or mannitol at 40 and 50 per cent level had shelf-life

Table 4.53: **Overall acceptability score of doughnuts as affected by different levels of humectants**

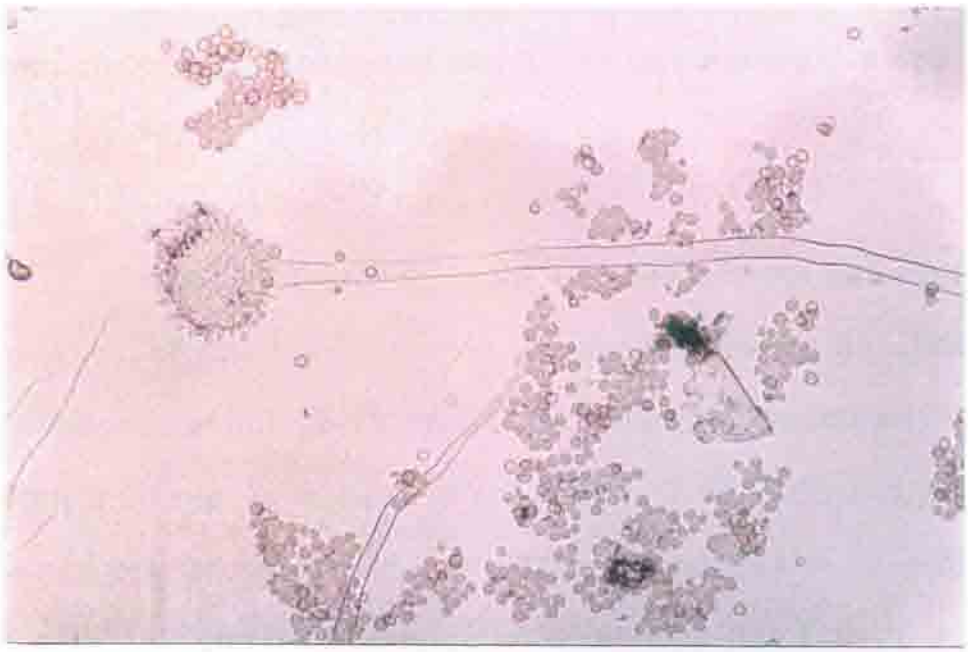
Frying media/ Packaging	Storage period					
	60 days			90 days		
	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening						
Plastic jar	7.09	6.92	6.75	6.74	6.58	6.43
Polyethylene bag	7.23	7.08	6.89	6.91	6.70	6.57
Groundnut oil						
Plastic jar	7.10	6.95	6.89	6.77	6.67	6.59
Polyethylene bag	7.29	7.14	7.12	6.95	6.80	6.75
Mustard oil						
Plastic jar	6.80	6.64	6.51	6.38	6.27	6.08
Polyethylene bag	6.98	6.86	6.67	6.58	6.39	6.22

Humectants (A) = 0.22
Ratio (B) = 0.017
Frying Media (C) = 0.022
Storage (D) = 0.018
A x B = 0.036
A x C = 0.029
B x C = NS

of below two months and the samples containing glycerol at various levels remained well up to three months with gradual decrease in overall acceptability scores.

4.11 Spoilage of doughnuts

In general, doughnuts have very short shelf-life until and unless they are packed in appropriate packaging materials to enhance the same. Present aimed at addition of various levels of humectants to judge its impact on shelf-life characteristics of doughnuts. Sorbitol/mannitol and glycerol were added to the doughnut formulation at 30, 40 and 50 per cent levels. The prepared doughnuts were packed in craft paper, plastic jars and polyethylene bags. In case of control samples and those containing sorbitol/mannitol at 30 per cent levels gained moisture considerable during storage for 30 days. This moisture gain favoured growth of mould, which appeared before 30 days of storage. However, in case of samples containing 40 and 50 per cent levels sorbitol/mannitol became unacceptable within 60 days of storage. The case was different in glycerol containing doughnut samples. Addition of glycerol at various levels produced doughnuts with very low moisture content. Also, the gain of moisture during storage up to 90 days was slow (below 19 per cent after 90 days of storage) and thus did not favoured growth of mould. So, the shelf-life of doughnuts was up to 90 days whereas, the samples packed in craft paper lost moisture



Microscopic view of organism (*Aspergillus* spp) responsible for spoilage of doughnuts rapidly rendering them hard and unacceptable. The predominant mould held responsible for spoilage of doughnuts was *Aspergillus* spp.

4.12 Economics of products

Perusals of data in Table 4.53 reveals the economics of the products as affected by different levels of humectants. The cost of production of control 12-15 doughnuts (without humectants) was 6.93, 6.91 and 6.90 rupees in case of shortening, 7.04, 7.03 and 7.01 rupees in case of groundnut oil and 7.07, 7.05 7.03 rupees in case of mustard oil at 170, 180 and 190°C. Addition of various humectants at different levels sharply increased the cost of production of doughnuts. The highest cost was recorded in case of doughnuts containing mannitol, followed by those containing sorbitol and lastly by those containing glycerol at various levels. The cost for production of doughnuts containing 50 per cent glycerol was 30.39, 30.38 and 30.37 rupees, for mannitol was 51.13, 51.12 and 51.11 rupees, for sorbitol was 48.65, 48.63 and 48.63 rupees at 170, 180 and 190°C temperature of shortening when used as frying media. Among the three different frying media, highest cost was observed in case of doughnuts deep-fried in mustard oil followed by those fried in groundnut oil and shortening.

Table: 4.54 Effect of different level of humectants on economics of doughnuts*

Frying Media	Temperature (°C)	Treatments									
		Control	Humectants								
			Sorbitol			Mannitol			Glycerol		
			(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)	(70:30)	(60:40)	(50:50)
Shortening	170	6.93	31.97	40.29	48.65	33.46	42.28	51.13	20.98	25.68	30.39
	180	6.91	31.96	40.27	48.63	33.45	42.27	51.12	20.97	25.67	30.38
	190	6.90	31.92	40.27	48.63	33.44	42.25	51.11	20.96	25.66	30.37
Groundnut oil	170	7.04	32.07	40.38	48.74	33.57	42.37	51.21	21.07	25.78	30.48
	180	7.03	32.05	40.36	48.72	33.55	42.35	51.20	21.06	25.76	30.47
	190	7.01	32.04	40.35	48.70	33.55	42.34	51.29	21.04	25.75	30.45
Mustard oil	170	7.07	32.06	40.39	48.74	33.56	42.39	51.22	21.08	25.78	30.48
	180	7.05	32.05	40.37	48.73	33.55	42.38	51.21	21.07	25.76	30.46
	190	7.03	32.04	40.36	48.72	33.53	42.37	51.20	21.06	25.75	30.45

*** Cost per 12-15 doughnuts with out processing charges**

Chapter-V

SUMMARY

CHAPTER – V

SUMMARY AND CONCLUSIONS

Despite a great deal of volume of fried products consumed throughout the world, aspects related to management of the frying processes have till date been the subject of relatively little research particularly when compared to other production parameters. Research and development efforts so far have been concentrated on oil deterioration kinetics during frying. Little attention has been paid to the effect of the variability of the raw material on its frying behaviour and the physicochemical properties of the final products. Keeping these factors in view the present study was aimed at comparing the behaviour of soft-cake doughnuts with or without humectants (sorbitol or mannitol or glycerol) during deep-fat-frying in various media. Investigations included at characterizing the behaviour of humectants during frying in terms of effect on densities, conductivities, heat transfer co-efficients, kinetics of moisture loss, fat absorption and the oil uptake ratios. Physico-chemical properties such as moisture contents, protein, fat, ash, free fatty acids and peroxide values were also measured in fresh as well as in case of samples stored in craft paper, plastic jars and polyethylene bags after storage (25 $\pm$ 3°C; 76 $\pm$ 5 per cent RH) for 30, 60 and 90 days, respectively. In addition to physico-chemical, microbial and apparent appearance attributes, the acceptability of the fresh as physico-chemical, microbial and apparent appearance attributes, the acceptability of the fresh as well as stored samples was also ascertained by sensory evaluation. Following inferences and conclusions have been drawn from the study :

1. The chemical composition of the refined wheat (Laxmi Mills, Kangra) flour used in the present investigation was by and large upto to the expected limits. It contained less protein, ash and crude fibre contents and such flours are recommended for preparation of cakes, doughnuts and biscuits.
2. Humectants viz. sorbitol, mannitol and glycerol were used as they are the substances that absorb moisture and are used to maintain the water content of materials like baked products. Mannitol EP (D- mannitol) and sorbitol EP (D- sorbitol) used in the investigation were of Sd Fine chemical Ltd. They are recommended as food stabilizer. Glycerol on the other hand, had minimum assay of 98 per cent and recommended to be used as a humectant or sweetener.
3. Three frying media viz. shortening or ghee (Gagan), Refined groundnut oil (Sundrop) and Mustard oil (Mayur) were tested for deep-fat-frying properties. The peroxide values and free fatty acids were within desirable range, indicating negligible oxidative rancidity and/or adulteration of fat/oil. The smoke point was high in all the frying media, highest being in shortening followed by groundnut oil and mustard oil. It is one of the important

4. The water absorption was positively correlated with protein and the amount of damaged starch present in the flour. Initial addition of sorbitol, mannitol and glycerol at 30 per cent level decreased the water absorption. Further addition upto 40 and 50 per cent levels again significantly decreased water absorption.
5. The dough prepared in case of control doughnut samples was slightly sticky with addition of sorbitol and mannitol at 30, 40 and 50 per cent levels, the dough changed from slightly sticky to non-sticky. However, addition of glycerol had reverse effect and the dough became very sticky with addition of 50 per cent glycerol.
6. Full puffing was observed in case of control and those containing sorbitol/mannitol (30 and 40 per cent) and glycerol (30 per cent). However, the puffing was partial in samples containing 50 per cent sorbitol and mannitol and those containing 40 and 50 per cent levels of glycerol.
7. Time : temperature relationship during deep-fat-frying has an important role to play in the process standardization. Temperature significantly affected the time taken by the doughnuts for optimum frying and with increase in the temperature, the time taken by the doughnuts decreased. With addition of humectants at various levels, negative effect on time was observed and it further decreased with increase in temperature. Among the three humectants tested, the doughnuts containing glycerol followed by those containing mannitol and then sorbitol required the lowest

time. When the three media were compared, maximum time was recorded for samples fried in mustard oil, followed by those fried in groundnut oil and lastly by shortening. The samples fried at 180^0C were evenly fried both from inside and outside.

8. Addition of either humectant sorbitol/mannitol/glycerol @ of 30, 40 and 50 per cent level produced doughnuts with lower specific heat values when compared with control. With increase in the level of humectant, the specific heat further decreased. Amongst the three humectants used, lowest specific heat was observed in doughnuts containing various levels of glycerol. The effect of frying media was also appreciable and the samples fried in mustard oil had lowest specific heat values. Temperature also had pronounced effect and with increase in temperature, decrease in specific heat was observed.

9. Thermal conductivity of foods is basically affected by its composition and addition of various humectants at different levels significanlty increased the thermal conductivities of the doughnuts. While increase in temperature during frying decreased the same. The samples containing sorbitol at various levels scored highest for thermal conductivity values. Also, the samples fried in mustard oil had higher thermal conductivity values.

10. Thermal diffusivity is a measure of how quickly the temperature changes when a food is heated or cooled. With addition of humectants viz., sorbitol, mannitol and glycerol @ of 30, 40 and

50 per cent level in the doughnuts formulation, the thermal diffusivity decreased. On the other hand, it increased with increase in temperature.

11. Temperature and processing times have a major effect on moisture content. During frying, water migrates from the central portion radially outward to the walls and edges to replace that which is lost by dehydration of the exterior surface. During frying of doughnuts, with increase in temperature, the rate of moisture loss was fast. Higher moisture contents were found in case of samples fried in mustard oil followed by those fried in groundnut oil and shortening. Addition of sorbitol or mannitol at 30 per cent level decreased the moisture contents because the water absorption was also decreased. However, further addition of the same humectant again decreased the moisture contents. The case was same in glycerol containing samples, where moisture contents decreased at 30, 40 and 50 per cent level of addition. Among the three humectants, glycerol was most effective in lowering the moisture contents of the doughnuts.

12. A positive correlation between the weight of the oil uptake and the weight of water removed was observed during deep-fat-frying of doughnuts. The oil uptake ratio (U_r) decreased with increase in temperature during frying and highest values were recorded in samples fried in mustard oil followed by those fried in groundnut oil and shortening, because same sequence was observed in case

of moisture and fat absorption and U_r is dependent on these two variables. The samples containing 30 per cent level of humectant had highest U_r values followed by those containing 50 per cent level and lastly by 40 per cent level of any of humectant U_r values were recorded lowest in case of samples containing glycerol.

13. During deep-fat-frying loss of moisture occurs and oil diffuses into the food sample and to lower oil uptake during frying have focused on ingredient and cooking technology. The fat absorption was higher in control samples and with increase in temperature, the fat absorption decreased significantly. Significant reduction in fat absorption was also observed with the addition of various humectants and as the level of humectant increased, the fat absorption decreased. So humectants correlated the with fat absorption Glycerol was most effective in reducing fat absorption by the doughnuts. The samples fried in mustard oil absorbed more oil followed by those fried in groundnut oil and then by those fried in shortening.

14. Heat is transferred from the oil to the food sample during frying and there are both conduction and convection modes of heat transfer. In addition to heat transfer, mass transfer also takes place. The heat transfer co-efficient was very less in case of control samples. Addition of various humectants significantly increased the heat transfer co-efficient. And as the level of humectant increased in the doughnuts, the heat transfer co-

efficient also significantly increased. Temperature had detrimental effect on heat transfer co-efficient values, the values being recorded highest in samples fried at 170^{0}C, followed by those fried at 190^{0}C and then by those fried at 180^{0}C. The samples fried in groundnut oil had highest heat transfer co-efficient values followed by those fried in shortening.

15. Addition of various humectants at different levels significantly affected the moisture contents of the doughnuts and these decreased with increasing levels of humectants. Lowest moisture contents were observed in samples containing glycerol at 30, 40 and 50 per cent levels. After storage for 30, 60 and 90 days, increase in moisture contents of the doughnuts was observed. Packaging had a marked effect with lowest moisture contents observed in case of doughnuts packed in craft paper followed by those packed in polyethylene bags and plastic jars of previously described specifications. The samples packed in craft paper had lower moisture content because the paper absorbed moisture.

16. Regarding the ash contents, significant increase was observed after addition of different levels of humectants in the fresh doughnut samples. However, with storage for different duration's, these decreased significantly after packing in different packaging materials. Pronounced decrease in ash contents was observed when doughnuts were packed in plastic jars followed by those packed in polyethylene bags and craft paper. Rate of decrease in

ash contents was slower in doughnuts containing different humectants.

17. Protein contents of the doughnuts containing different levels of sorbitol/mannitol/glycerol significantly decreased in different packaging materials during storage. Lowest values were observed in case of samples packed in plastic jars, followed by those packed in polyethylene bags and craft paper. Addition of humectants, however helped to slow down the rate of decrease of protein contents.

18. Fat contents in case of fresh doughnut samples were significantly reduced after addition of various levels of humectants when compared to control samples. The samples fried in mustard oil showed highest fat contents. Among the three humectants, glycerol was most effective in reducing the fat contents. During storage for 30, 60 and 90 days, significant reduction in fat contents was observed. The samples packed in craft paper had lowest fat contents as most of the fat was absorbed by the paper used for packaging of doughnuts, followed by those packed in polyethylene bags and plastic jars.

19. Free fatty acids and peroxide values in case of fresh doughnut samples decreased with increasing level of humectants when compared with control (without humectants) and samples containing glycerol scored the lowest. However, significant increase in free fatty acids and peroxide values was observed in

case of samples packed in craft paper, plastic jars and polyethylene bags during storage. Also, the samples packed in craft paper had lowest free fatty acid and peroxide values followed by those packed in polyethylene bags and plastic jars. This increase in values can be attributed to oxidative and hydrolytic rancidity.

20. Regarding acceptability of the doughnuts, the control samples (without humectants) and those containing 30 per cent sorbitol and mannitol spoiled before one month of storage in different packaging materials used due to microbial growth. However, doughnuts containing sorbitol/mannitol @ of 40 and 50 per cent level could last long upto one and half month only. But, those containing glycerol remained well upto entire storage period (90 days). The samples packed in craft paper became hard due to loss of moisture thus rendering them unacceptable.

21. The colour, flavour and appearance scores of fresh doughnuts containing different levels of humectants were higher in case of samples containing lower levels of humectants. With increasing level of the same, these scores decreased. However, during storage for 90 days in different packaging materials, higher colour, flavour and appearance scores were observed in case of samples containing 50 per cent level of humectant. The samples packed in craft paper scored higher when compared to the doughnuts packed in plastic jars.

22. Taste and texture scores were recorded higher in case of fresh doughnuts containing lower levels of humectants (sorbitol or mannitol or glycerol). When the level of humectant was increased in the doughnut formulation, the scores for taste and texture significantly decreased. During storage for 30, 60 and 90 days, these scores decreased and higher taste and texture scores were observed in samples containing lower levels of humectants. The samples packed in craft paper were hard and thus discarded. However, the samples packed in polyethylene bags scored highest when compared to those packed in plastic jars.

23. Overall acceptability of the fresh doughnuts was highest in samples containing humectants @ of 30 per cent level. With increasing level of humectant, the overall acceptability decreased. But, during storage for three months, the overall acceptability scores decreased and the scores were highest in samples containing humectant @ of 50 per cent level. Amongst the different packing material used, the samples packed in polyethylene bags scored the highest.

Therefore it can be sufficed from the above mentioned inferences that addition of various humectants viz., sorbitol, mannitol and glycerol significantly altered the deep-fat-frying characteristics of the doughnuts in different frying media. With addition of various humectants, the time taken for frying of doughnuts, the moisture contents, fat absorption, specific heat and thermal diffusivity of the doughnuts was markedly affected and reduced when compared with control samples. On the contrary the oil uptake ratio, thermal conductivity and heat transfer co-efficients were increased with addition of different humectants which are function of temperature, moisture loss, fat absorption and density changes during deep-fat-frying of doughnuts. On a whole, addition of humectants shortened the processing time thereby decreasing the duration of exposure to higher temperature during frying, moisture loss and fat absorption. This called for cost benefit achievement and process standardization for frying of doughnuts. The media groundnut oil and shortening gave best results at 180°C temperature of frying, however, mustard oil produced doughnuts with higher oil pickup as the processing time was higher. Addition of humectant also called for longer shelf-life of the doughnuts after packing in craft paper, plastic jars and polyethylene bags. The control samples (without humectants) and those containing 30 per cent sorbitol/mannitol had shelf-life below 30 days while, those containing 40 and 50 per cent level of the above humectants remained well upto one and half month of storage. Whereas, the samples containing various levels of glycerol remained well upto three months of storage. The spoilage encountered was basically due to the growth of mould (*Aspergillus* spp.). Also, the samples packed in craft paper lost moisture and fat rapidly during storage making them hard. The protein, fat, and ash contents deceased during storage for 30, 60 and 90 days while, moisture, free fatty acids and peroxide values increased during storage. Regarding the acceptability of the doughnuts, the scores for colour, texture, appearance, flavour, taste and overall acceptability were higher in fresh doughnuts with lower levels of humectants and these decreased with storage. The samples packed in polyethylene bags had higher overall acceptability as compared to those packed in plastic jars and proved to be the best packaging material among the three packaging tested for storage of doughnuts.

It can thus be safely concluded that based on the enthalpy parameters and thermodynamic properties, a fried food is possible which is safe, nutritious and economic to produce with relatively longer shelf-life to enable better marketing and distribution

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LITERATURE CITED

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APPENDICES

Annexure - I

Formulation for the preparation of doughnuts

Ingredient (g)	Control	Sample
Refined Wheat Flour	246.50	246.50
Sugar	90	90 (substituted at 30,40 and 50 % levels with sorbitol or mannitol or glycerol)
Baking powder	3.25	3.25
Salt	3.00	3.00
Sodium-bi-carbonate	2.25	2.25
Egg	50	80
Water	Optimum	Optimum

Annexure - II

Interaction between major treatments, sub-treatments and their interactions

Experiment-1 (Kinetic Studies)

C- Control

Humectants	**Ratios**
H_1 - Sorbitol	R_1 - 70:30
H_2 -.Mannitol	R_2 - 60:40
H_3 - Glycerol	R_3 - 50:50
Temperatures	**Frying media**
T_1 - 170 ^{o} C	F_1 - Shortening
T_2 - 180 ^{o} C	F_2 - Groundnut oil
T_3 - 190 ^{o} C	F_3 - Mustard oil

Interactions

CF_1T_1	CF_2T_1	CF_3T_1
CF_1T_2	CF_2T_2	CF_3T_2
CF_1T_3	CF_2T_3	CF_3T_3
$H_1R_1F_1T_1$	$H_1R_1F_2T_1$	$H_1R_1F_3T_1$
$H_1R_1F_1T_2$	$H_1R_1F_2T_2$	$H_1R_1F_3T_2$
$H_1R_1F_1T_3$	$H_1R_1F_2T_3$	$H_1R_1F_3T_3$
$H_1R_2F_1T_1$	$H_1R_2F_2T_1$	$H_1R_2F_3T_1$
$H_1R_2F_1T_2$	$H_1R_2F_2T_2$	$H_1R_2F_3T_2$
$H_1R_2F_1T_3$	$H_1R_2F_2T_3$	$H_1R_2F_3T_3$
$H_1R_3F_1T_1$	$H_1R_3F_2T_1$	$H_1R_3F_3T_1$
$H_1R_3F_1T_2$	$H_1R_3F_2T_2$	$H_1R_3F_3T_2$
$H_1R_3F_3T_3$	$H_1R_3F_2T_3$	$H_1R_3F_3T_3$
$H_2R_1F_1T_1$	$H_2R_1F_2T_1$	$H_2R_1F_3T_1$
$H_2R_1F_1T_2$	$H_2R_1F_2T_2$	$H_2R_1F_3T_2$
$H_2R_1F_1T_3$	$H_2R_1F_2T_3$	$H_2R_1F_3T_3$
$H_2R_2F_1T_1$	$H_2R_2F_2T_1$	$H_2R_2F_3T_1$
$H_2R_2F_1T_2$	$H_2R_2F_2T_2$	$H_2R_2F_3T_2$
$H_2R_2F_1T_3$	$H_2R_2F_2T_3$	$H_2R_2F_3T_3$
$H_2R_3F_1T_1$	$H_2R_3F_2T_1$	$H_2R_3F_3T_1$
$H_2R_3F_1T_2$	$H_2R_3F_2T_2$	$H_2R_3F_3T_2$
$H_2R_3F_3T_3$	$H_2R_3F_2T_3$	$H_2R_3F_3T_3$
$H_3R_1F_1T_1$	$H_3R_1F_2T_1$	$H_3R_1F_3T_1$
$H_3R_1F_1T_2$	$H_3R_1F_2T_2$	$H_3R_1F_3T_2$
$H_3R_1F_1T_3$	$H_3R_1F_2T_3$	$H_3R_1F_3T_3$
$H_3R_2F_1T_1$	$H_3R_2F_2T_1$	$H_3R_2F_3T_1$
$H_3R_2F_1T_2$	$H_3R_2F_2T_2$	$H_3R_2F_3T_2$
$H_3R_2F_1T_3$	$H_3R_2F_2T_3$	$H_3R_2F_3T_3$
$H_3R_3F_1T_1$	$H_3R_3F_2T_1$	$H_3R_3F_3T_1$
$H_3R_3F_1T_2$	$H_3R_3F_2T_2$	$H_3R_3F_3T_2$
$H_3R_3F_3T_3$	$H_3R_3F_2T_3$	$H_3R_3F_3T_3$

Annexure - III

Interaction between major treatments, sub-treatments and thei interactions

Experiment-2 Shelf-life studies

C- Control

Humectants

H_1 - Sorbitol

H_2 - Mannitol

H_3 - Glycerol

Frying media

F_1 - Shortening

F_2 - Groundnut oil

F_3 - Mustard oil

Ratios

R_1 - 70:30

R_2 - 60:40

R_3 - 50:50

Packaging

T_1 - craft paper

T_2 - Plastic jar

T_3 - Polyethylene bag

Interactions

CF_1T_1	CF_2T_1	CF_3T_1
CF_1T_2	CF_2T_2	CF_3T_2
CF_1T_3	CF_2T_3	CF_3T_3
$H_1R_1F_1T_1$	$H_1R_1F_2T_1$	$H_1R_1F_3T_1$
$H_1R_1F_1T_2$	$H_1R_1F_2T_2$	$H_1R_1F_3T_2$
$H_1R_1F_1T_3$	$H_1R_1F_2T_3$	$H_1R_1F_3T_3$
$H_1R_2F_1T_1$	$H_1R_2F_2T_1$	$H_1R_2F_3T_1$
$H_1R_2F_1T_2$	$H_1R_2F_2T_2$	$H_1R_2F_3T_2$
$H_1R_2F_1T_3$	$H_1R_2F_2T_3$	$H_1R_2F_3T_3$
$H_1R_3F_1T_1$	$H_1R_3F_2T_1$	$H_1R_3F_3T_1$
$H_1R_3F_1T_2$	$H_1R_3F_2T_2$	$H_1R_3F_3T_2$
$H_1R_3F_3T_3$	$H_1R_3F_2T_3$	$H_1R_3F_3T_3$
$H_2R_1F_1T_1$	$H_2R_1F_2T_1$	$H_2R_1F_3T_1$
$H_2R_1F_1T_2$	$H_2R_1F_2T_2$	$H_2R_1F_3T_2$
$H_2R_1F_1T_3$	$H_2R_1F_2T_3$	$H_2R_1F_3T_3$
$H_2R_2F_1T_1$	$H_2R_2F_2T_1$	$H_2R_2F_3T_1$
$H_2R_2F_1T_2$	$H_2R_2F_2T_2$	$H_2R_2F_3T_2$
$H_2R_2F_1T_3$	$H_2R_2F_2T_3$	$H_2R_2F_3T_3$
$H_2R_3F_1T_1$	$H_2R_3F_2T_1$	$H_2R_3F_3T_1$
$H_2R_3F_1T_2$	$H_2R_3F_2T_2$	$H_2R_3F_3T_2$
$H_2R_3F_3T_3$	$H_2R_3F_2T_3$	$H_2R_3F_3T_3$
$H_3R_1F_1T_1$	$H_3R_1F_2T_1$	$H_3R_1F_3T_1$
$H_3R_1F_1T_2$	$H_3R_1F_2T_2$	$H_3R_1F_3T_2$
$H_3R_1F_1T_3$	$H_3R_1F_2T_3$	$H_3R_1F_3T_3$
$H_3R_2F_1T_1$	$H_3R_2F_2T_1$	$H_3R_2F_3T_1$
$H_3R_2F_1T_2$	$H_3R_2F_2T_2$	$H_3R_2F_3T_2$
$H_3R_2F_1T_3$	$H_3R_2F_2T_3$	$H_3R_2F_3T_3$
$H_3R_3F_1T_1$	$H_3R_3F_2T_1$	$H_3R_3F_3T_1$
$H_3R_3F_1T_2$	$H_3R_3F_2T_2$	$H_3R_3F_3T_2$
$H_3R_3F_3T_3$	$H_3R_3F_2T_3$	$H_3R_3F_3T_3$

Annexure - IV

Details of humectants

Humectant 1	:	**Sorbitol (D-sorbitol)**
Grade	:	IP
Manufacturer	:	Sd. Fine Chemicals Pvt. Ltd.
Uses	:	Recommended as food stabilizer
Cost (Rs)	:	953 per Kg
Humectant 2	:	**Mannitol (D-mannitol)**
Grade	:	IP
Manufacturer	:	Sd. Fine Chemicals Pvt. Ltd.
Uses	:	Recommended as food stabilizer with reducing sugar 0.2%
Cost (Rs)	:	998 per kg
Humectant 3	:	**Glycerol (Purified glycerol)**
Grade	:	IP
Manufacturer	:	Sd. Fine Chemicals Pvt. Ltd.
Uses	:	Recommended as food sweetener and humectant with 98% minimum assay
Cost (Rs)	:	500 per Kg

Annexure - V

Details of frying media

Frying media	:	**Shortening/Ghee**
Brand	:	Gagan
Manufacturer	:	Amrit Banaspati Co. Ltd., GT Road, Ghaziabad (UP)
Cost	:	Rs 45 per Kg
Frying media	:	**Refined Ground Nut Oil**
Brand	:	Sundrop
Manufacturer	:	Agro Tech Foods Ltd., Industrial Area Jaipur
Cost	:	Rs 53 per Kg
Frying media	:	**Mustard Oil**
Brand	:	Mayur
Manufacturer	:	Himachal Tilhan Udyog, Assoc. GT Road Damtal (HP)
Cost	:	Rs 50 per Kg

Annexure - VI

Proforma for sensory evaluation of doughnuts

mple ______________________________
te ________

	Perfect	Good			Fair			Poor		Off	Remarks
mples	10	9	8	7	6	5	4	3	2	1	

TE: Make check mark in columns corresponding to your rating of samples en scoring on factor. However, when scoring 2 factors, write in the owing letter in the corresponding column or columns: (C) Colour, (F) vour, (T) Texture, (S) Consistency, (O) Off Flavour

Signature ______________________

ANNEXURE- VII

DAILY AGROMETEROLOGICAL DATA FOR THE MONTH OF SEPTEMBER- 2001

Date	Temperature (^{o}C)		Rainfall (mm)	Relative humidity (%)	
	Max.	Min.		Max.	Min.
1.	27.5	18.0	16.2	69	74
2.	27.5	18.0	0.7	81	87
3.	27.8	18.5	7.3	79	71
4.	28.5	18.0	0.0	76	71
5.	27.4	18.0	23.2	61	63
6.	27.8	14.5	0.0	68	66
7.	27.2	17.8	0.0	66	71
8.	26.2	18.4	0.0	73	66
9.	27.5	17.6	0.0	67	77
10.	27.0	17.6	5.2	74	87
11.	26.8	17.0	9.5	60	66
12.	27.5	15.4	0.0	47	59
13.	27.5	17.2	0.0	54	61
14.	27.2	14.0	5.4	60	89
15.	26.0	14.0	0.0	51	58
16.	26.0	14.0	0.0	59	45
17.	26.5	16.2	0.0	66	58
18.	27.2	16.8	0.0	65	49
19.	27.2	16.8	0.0	41	53
20.	27.0	17.0	0.0	59	67
21.	28.0	17.0	0.0	49	50
22.	28.0	16.6	0.0	57	55
23.	28.3	17.0	0.0	57	52
24.	28.0	16.0	0.0	67	55
25.	28.0	17.0	0.0	58	75
26.	29.0	17.5	0.0	60	55
27.	28.0	15.5	0.0	57	65
28.	28.5	15.5	0.0	64	66
29.	28.5	14.0	0.0	64	71
30.	28.5	15.5	0.0	57	71

DAILY AGROMETEROLOGICAL DATA FOR THE MONTH OF OCTOBER- 2001

Date	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	
	Max.	Min.		Max.	Min.
1.	24.5	12.0	0.0	81	74
2.	24.5	12.0	0.0	76	63
3.	26.0	14.0	0.0	79	60
4.	26.5	14.0	1.6	63	68
5.	26.5	14.0	0.0	65	57
6.	27.0	11.0	0.0	69	62
7.	27.0	11.0	0.0	67	32
8.	27.0	11.0	0.0	44	66
9.	27.0	11.0	0.0	69	54
10.	26.5	10.0	0.0	74	49
11.	27.0	10.0	0.0	72	48
12.	27.0	14.0	0.0	47	39
13.	27.5	11.5	0.0	44	37
14.	26.5	11.5	0.0	63	74
15.	21.5	11.5	0.0	46	33
16.	25.5	11.5	0.0	37	28
17.	25.6	13.0	0.0	47	41
18.	24.5	13.0	0.0	52	47
19.	25.6	13.0	0.0	40	35
20.	26.4	14.0	0.0	70	51
21.	26.0	14.3	0.0	67	49
22.	27.0	15.0	0.0	64	66
23.	26.4	14.5	0.0	42	42
24.	25.8	14.8	0.0	64	39
25.	25.5	14.4	0.0	53	41
26.	25.5	14.4	0.0	61	43
27.	25.8	14.4	0.0	71	40
28.	25.8	14.4	0.0	60	43
29.	25.2	14.3	0.0	65	56
30.	25.2	14.0	0.0	63	60
31.	25.2	14.2	0.0	68	55

Annexure VII Cont.....

DAILY AGROMETEROLOGICAL DATA FOR THE MONTH OF NOVEMBER- 2001

Date	Temperature (^{o}C)		Rainfall (mm)	Relative humidity (%)	
	Max.	Min.		Max.	Min.
1.	25.4	14.5	0.0	46	68
2.	26.8	15.0	0.0	52	27
3.	28.2	17.0	0.0	50	56
4.	22.5	10.9	0.1	60	18
5.	23.4	12.5	0.0	52	48
6.	22.6	10.5	1.2	61	46
7.	22.5	9.0	0.0	44	32
8.	22.8	9.4	0.0	35	26
9.	22.4	9.5	0.0	31	29
10.	22.6	9.0	0.0	30	27
11.	22.5	9.5	0.0	37	34
12.	22.5	10.0	0.0	34	44
13.	23.8	11.0	0.0	24	35
14.	22.0	10.5	0.0	41	24
15.	22.5	10.0	0.0	44	40
16.	23.0	10.0	0.0	49	38
17.	22.0	10.0	0.0	48	36
18.	22.6	10.0	0.0	57	39
19.	22.0	9.0	0.0	57	46
20.	22.3	9.5	0.0	45	40
21.	23.0	9.5	0.0	58	45
22.	23.2	9.5	0.0	52	40
23.	21.5	9.8	0.0	42	49
24.	21.3	9.4	0.0	34	44
25.	21.4	9.0	0.0	60	64
26.	21.8	9.5	0.0	45	44
27.	21.8	9.5	0.0	45	44
28.	21.8	8.6	0.0	44	46
29.	18.5	9.2	0.0	60	44
30.	19.5	7.4	0.0	62	58

CURICULUM VITAE

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Educational Qualifications

Examination	Year	Board
10+2	1994	CBSE , DELHI
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M Sc (Food Science and Nutrition	1999	HPKV PALAMPUR
Ph D (Food Science and Nutrition)	2003	HPKV PALAMPUR

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Advisors:

M Sc: Dr YS Dhaliwal (Chairman); Dr SR Malhotra; Dr CR Sharma; Dr RAK Aggarwal

PhD: Dr Manoranjan Kalia (Chairman); Dr SR Malhotra; Dr CR Sharma; Dr KK Dogra

Title of Thesis

MSc: " Effect of incorporation of legume fortifiers on the acceptability and nutritional quality of different Indian leavened breads"

PhD: "Dependence on humectants, heat transfer co-efficient and Kinetics of moisture removal in deep- fried products"

Publications

- J Dogra, Dhaliwal YS and Manoranjan Kalia. 2001 Effect of soaking, germination, heating and roasting on chemical composition and nutritional quality of soybean and its Utilization in various Indian leavened products Journal of Food Science and Technology 38(5):453-457
- J Dogra, Dhaliwal YS and Manoranjan Kalia. 2001 Effect of soaking, germination, heating and roasting on chemical composition and nutritional quality of fababean and its utilization in various Indian leavened products Journal of Dairying, Foods and Home Sciences(In Press)
- J Dogra, Dhaliwal YS and Manoranjan Kalia. 2001 Effect of addition of treated soybean flour in preparation of Indian leavened products Paper accepted for presentation at 88th Indian Science Congress held at IARI Delhi from 3rd to 7th Jan ,2001
- J Dogra and Dhaliwal YS. 2001 Effect of soaking, germination, heating and roasting on mineral contents of soybean and fababean Himachal Journal of Agricultural Research 26:220-224
- YS Dhaliwal and J Dogra. 2000 Maize : Processing and utilization. Paper presented at National seminar on Science Industry interface on Maize production, processing and utilization. Organized by Indian Society of Agricultural Biochemists (Palampur chapter) on 3rd -4th November 2000
- J Dogra, Dhaliwal YS and B Singh. Effect of soaking, germination, heating and roasting on fibre contents of soybean and fababean Journal of Food Science and Technology (Submitted)
- J Dogra, Dhaliwal YS and HR Sharma. Effect of soaking, germination, heating and roasting on biological quality of soybean and fababean Journal of Human Ecology (Submitted)

Title of the Thesis	:	**" Dependence on humectants, heat transfer co-efficient and kinetics of moisture removal in deep-fried products"**
Name of the student	:	**JULIE DOGRA**
Admission No.	:	H-99-40-01
Major subject	:	Food Science and Nutrition
Minor subjects	:	Biochemistry Microbiology
Month and year of submission of thesis	:	November, 2002
Total pages in thesis	:	213
No of words in abstract	:	231
Major Advisor	:	**Dr. Manoranjan Kalia**

Abstract

Addition of various humectants viz., sorbitol, mannitol and glycerol significantly altered the deep-fat-frying characteristics of the doughnuts in different frying media and the time taken for frying of doughnuts, the moisture contents, fat absorption, specific heat and thermal diffusivity of the doughnuts was markedly affected and reduced when compared with control samples. On the contrary the oil uptake ratio, thermal conductivity and heat transfer co-efficients were increased with addition of different humectants On a whole, addition of humectants shortened the processing time thereby decreasing the duration of exposure to higher temperature during frying, moisture loss and fat absorption. Addition of humectant also called for longer shelf-life of the doughnuts after packing in craft paper, plastic jars and polyethylene bags. The control samples (without humectants) and those containing 30 per cent sorbitol/mannitol had shelf-life below 30 days while, those containing 40 and 50 per cent level of the above humectants remained well upto one and half month of storage. Whereas, the samples containing various levels of glycerol remained well upto three months of storage. The protein, fat, and ash contents deceased during storage for 30, 60 and 90 days while, moisture, free fatty acids and peroxide values increased during storage. Regarding the acceptability of the doughnuts, the scores for colour, texture, appearance, flavour, taste and overall acceptability were higher in fresh doughnuts with lower levels of humectants and these decreased with storage.

Julie Dogra 18th Nov 02

(Signature of the Student)

(Signature of Major Advisor)

Sumati Rai

Head of Department 18/11/02

Dean
Post Graduate Studies

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Julie Dogra

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