Affectionately Dedicated
To My
Beloved Late Uncle Nana

— SHIVAJI

BIOCHEMICAL CHANGES IN PROTEINS AND LIPIDS DURING STORAGE OF HEAT PROCESSED GROUNDNUT (*Arachis hypogaea*, L.)

By

Shivaji Vasant Damame

B. Sc. (Agri.) First Class

A Thesis submitted to the

MAHATMA PHULE AGRICULTURAL UNIVERSITY

RAHURI, DIST:-AHMEDNAGAR

Maharashtra State, (India)

In partial fulfilment of the requirements for the degree

of

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CANDIDATE'S DECLARATION

I hereby declare that this thesis or part thereof has not been submitted by me or any other person to any other University or Institute for a Degree or Diploma

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This is to certify that the thesis entitled "Biochemical changes in proteins and lipids during storage of heat processed groundnut (*Arachis hypogaea*, L.)", submitted to the Faculty of Agriculture, Mahatma Phule Agricultural University, Rahuri, District Ahmednagar in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (Agriculture) in BIOCHEMISTRY, embodies the results of *bona fide* research work carried out by Shri S.V.Damame, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

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This is to certify that the thesis entitled "Biochemical changes in proteins and lipids during storage of heat processed groundnut (*Arachis hypogaea*, L.)", submitted to the Faculty of Agriculture, Mahatma Phule Agricultural University, Rahuri, District Ahmednagar, Maharashtra, India, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (Agriculture) in BIOCHEMISTRY, embodies the results of a piece of *bona fide* research work carried out by Shri S.V.Damame, under the guidance and supervision of Dr.J.K.Chavan, Associate Professor of Biochemistry, Mahatma Phule Agricultural University,Rahuri, Maharashtra, India, and no part of the thesis has been submitted for any other degree or diploma.

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ABSTRACT

BIOCHEMICAL CHANGES IN PROTEINS AND LIPIDS DURING STORAGE OF HEAT PROCESSED GROUNDNUT (*Arachis hypogaea*, L.)

By

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MASTER OF SCIENCE
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The present investigations were undertaken to study the influence of heat treatments and storage on the changes in quality of proteins and oil of groundnut kernels. The groundnut kernels (cv.C-1-2) of freshly harvested produce were subjected to roasting (160°C for 30 min) and frying (2 min in boiling groundnut oil) treatments and stored up to 150 days at ambient (27 ± 2°C) and cold temperature (5 ± 2°C) in sealed polythene bags. The samples were analysed after every 30 days for different quality parameters.

The heat treatments reduced the moisture content markedly and increased the protein by about 4 percent and oil by about 2 percent in the kernels. Both roasting and frying

Contd.....

treatments and, storage significantly increased the soluble proteins and decreased the methionine and tryptophan contents in the kernels. The heat treatments however, significantly decreased the pepsin hydrolysis of residual proteins. The heat treatments and storage also significantly affected the saponification value, acid value and iodine value of the kernel oil. There was an increase in both saponification value and acid value while a decrease in iodine value due to these treatments. The changes in saponification and iodine value due to heat treatments and storage were however, not of significant order. The acid value was, however, found to increase gradually during storage of raw and heated kernels up to 120 days and rapidly thereafter.

The heat treatments were found to induce detrimental changes in the quality of storage proteins and oil of the kernels and decreased their shelf-life. The frying treatment exhibited more pronounced detrimental effects on the quality of the proteins and oil as compared to roasting. The storage of raw and heated kernels at 5 $\pm$ 2°C was found to be beneficial in minimizing the deteriorative changes in the kernels. Further, investigations on the standardization of time and temperature of the heat treatments and, storage conditions to minimize the undesirable changes and, to increase the shelf-life of heat processed groundnut kernels are essential.

Chapter Opener Page

Introduction

1. INTRODUCTION

Groundnut (Arachis hypogaea,L.) is one of the important oil seed crops, widely grown in India,China, United States and the African countries. India ranks first in both area and production of groundnut in the world. India alone contributes more than 26 percent of the worlds groundnut production (FAO, 1985). Among the total oil seeds production of India, groundnut contributes more than 56 percent.

Groundnut kernels are rich source of edible oil. It contains about 50 percent oil (Fristrom et al., 1975). The groundnut oil possesses an excellent nutritional quality. It contains large amount of unsaturated fatty acids (80 percent) of which 20 to 30 percent are polyunsaturated (St.Angelo et al., 1979). Anessential fatty acid, linoleic acid is found to be in large amount. The oleic acid and linoleic acid accounts more than 75 percent of the total fatty acids of groundnut oil (Salunkhe et al., 1982). The groundnut kernels are also a good source of dietary proteins. The full fat groundnut kernels contain about 21 to 36 percent protein (Freeman et al.,1954), while fat free seed meal contains about 43 to 63 percent protein (Cherry, 1977). The groundnut proteins are rich in acidic amino acids but low in sulphur containing amino acids (Basha and Pancholy, 1981). The lysine, methionine and tryptophan are found to be deficient amino acids in groundnut

proteins (Aykroyd and Doughty, 1964). The sucrose and starch constitute major portion of the carbohydrates in groundnut flour (Taranathan et al., 1975). Hence, it is a rich source of calories. The groundnut is also a good source of certain minerals like phosphorus, calcium, magnesium and potassium (Branch and Gaines, 1983) and, certain B-group vitamins (Woodroof,1983a).

The major portion of the peanut produced in the country is processed to extract edible oil. A significant quantity of groundnut is also utilized for direct consumption with vegetable, snacks, roasted and fried groundnuts and, in the preparation of jaggery based convenience foods. In India, 4 to 5 percent of the groundnut produce is utilized for domestic consumption, (Kapila,1982) while in the United States, a larger quantity (over 25 percent) is utilized for domestic purposes (Carley, 1978). Besides, the groundnut kernels or groundnut-meal are also used to prepare protein isolates, concentrates, dairy based products, composite flour and variety of bakery products (Rooney et al.,1972; Cater et al., 1974; Beuchat and Nail, 1978; Spadato and Pearce, 1981; McWatters and Cherry, 1983; Ory and Conkerton, 1983; Khalil and Chughtai, 1984).

Roasting of peanut kernels frequently with a little common salt is a very common practice all over the world.

The roasted peanut kernels are used as snacks, in the manufacture of confectionary and, milk and bakery based snack foods. The roasting is often carried out by applying dry heat or by frying in oil. These heat treatments reduce moisture, develop pleasant flavour and make the nuts more acceptable (Kabirullah et al., 1977). The heat treatments also induce several chemical changes in the kernels, the severity of which depends upon the nature and extent of heating. The pleasant flavour of roasted nuts is mainly due to sugar : amino acid interactions(Cobb and Swaisgood, 1971; Mason et al., 1969; Newell et al., 1967). Excessive roasting of peanut kernels is known to destroy amino acids,particularly methionine (Basha and Young, 1985), lower the nutritional quality (Sharma et al., 1983) and functional properties of peanut meal (Ahmed and Schmidt, 1979). Roasting is also known to destroy lipolytic and oxidative enzymes in the kernels. The reduction in moisture and elimination of lipoxygenase due to heat treatments is reported to prevent molding, reduce staling and rancidity (Woodroof, 1945).

The roasted and fried nuts and processed foods containing such nuts are often stored for a considerable time before consumption. The biochemical changes would continue during storage of such heat processed nuts. The storage of unprocessed nuts have been shown to exhibit decrease in starch, increase in sugars and peroxidation (Pattee et al.,

1981; St.Angelo and Ory, 1975). It is thus clear that undesirable biochemical changes occur during storage of peanuts. Considerable information is available about the influence of roasting on the amino acid composition and flavour compounds. However, reports on changes in storage proteins and oil quality are inadequate. The roasted nuts cannot be stored for prolonged time unless they become unacceptable for consumption due loss in protein and oil quality. Hence, it is essential to investigate these changes during storage of heat processed groundnut to assess their shelf-life. The present investigations were therefore undertaken with following objectives.

1. To study the effects of heat treatments on the changes in protein and oil in groundnut kernels

2. To study the effects of storage of heat processed peanuts on the protein and oil quality of groundnut.

3. To assess the shelf-life of heat processed groundnut.

Chapter Opener Page

Review of Literature

2. REVIEW OF LITERATURE

2.1 Chemical composition

Groundnut is considered as one of the most concentrated foods because of it's high protein and oil contents(Hoffpauir, 1953). Whole groundnut pods consist of about 20 to 26 percent shells and 74 to 80 percent kernels which include cotyledones (about 72%), skin (4%) and embryo (3%). The groundnut seed contains approximately 6 percent moisture, 50 percent oil, 25 percent protein, 15 percent carbohydrates, 2 percent crude fibre and 2 percent ash (Cobb and Johnson, 1973; Adsule et al., 1988). It also contains an appreciable amount of B-group vitamins. However, vitamins A, C and D are present in small quantities.

2.1.1 Proteins and amino acids

The protein content in groundnut kernel has been reported to range from 21 to 36 percent (Freeman et al.,1954; Cherry et al., 1973; Cobb and Johnson, 1973; Kadam, 1979; Khalil and Chughtai, 1983). The protein content in 300 test lines grown at ICRISAT ,India was found to range from 16.2 to 28.7 percent (ICRISAT, 1985). The protein content in groundnut is influenced by genetic makeup of the cultivars (Basha and Cherry, 1976; Nagaraj et al., 1984a). The three years average protein content in 105 genotypes varied from 22.7 to 29.3 percent (Young and Hammons, 1973). Amaya et al., (1977) reported that 31 commercial varieties of groundnut

contained 22.2 to 30.4 percent protein. Other factors that influence the protein content include fertilizer application (Basha and Pancholy, 1981; Patil et al., 1986), agricultural chemicals (Wagle et al., 1985) and location (Miller, 1980; Nagaraj et al., 1984a).

The proteins in the kernels are mostly present in protein bodies (Lott and Buttrose, 1978). Arachin and conarchin (both globulins) are the major storage proteins and together comprises 87 percent of the total groundnut protein. Arachin accounts for about two third of the total proteins (Cherry et al., 1973). Boulter and Derbyshire (1978) reported that globulins contribute about 70 percent of the total seed proteins, the remaining being albumins and glutelins, in equal proportion. The conarchin is a minor globulin of groundnut (Brown, 1941).

The groundnut proteins are relatively rich in acidic amino acids and low in sulphur containing amino acids (Basha and Pancholy,1981). The methionine, lysine, threonine and tryptophan have been reported as deficient amino acids in groundnut proteins (Aykroyd and Doughty, 1964; Miller and Young, 1977). The genetic makeup significantly influence the amino acid composition in groundnut (Singh and Nath, 1981; Hovis et al., 1982). Amya et al., (1977) reported that

tryptophan content in the proteins of 37 commercial varieties of groundnut ranged from 1.1 to 1.4 percent.

The protein of raw groundnut exhibited true digestibility of 97 percent and biological value of 57.9 percent (Mitchell and Beedles, 1937). In general, the nutritive value of groundnut protein is low when compared with egg protein (FAO, 1970). This may be attributed to the deficiency of several essential amino acids in groundnut proteins. Groundnut flour supplemented with 0.3 percent methionine and 0.2 percent methionine + 0.2 percent lysine has been reported to increase protein efficiency ratio (PER) by 39 and 41 percent, respectively (Alid et al., 1981).

2.1.2 Carbohydrates

The carbohydrate content of groundnut kernels ranges from 10 to 20 percent. The defatted groundnut meal contains about 38 percent total carbohydrates. The sucrose (14.2%) and starch (12.5%) constitute major carbohydrates of the kernels. The other carbohydrate fractions like hemicellulose (4%), verbascose (4%), stachyose (1.6%) and monosaccharides (1.2%) were present in minor quantities (Taranathan et al., 1975). Gupta et al., (1982) observed that there is no appreciable difference in the reducing sugar content of 25 varieties of groundnut (1.18 to 1.78%), although there was considerable variation in the total sugar content which

ranged from 7.44 to 14.24 percent. Pattee et al., (1981) determined carbohydrate content of groundnut kernels and observed significant influence of seed size on the content of different type of sugars. These reports indicate that groundnut is rich source of dietary sugars. Crude fiber content of groundnut ranges from 1.2 to 4.3 percent. Amount of crude fiber is more in skin than in the kernels, (Hoffpauir, 1953).

2.1.3 Lipids

Groundnut contains 36 to 54 percent total lipids (Freeman et al., 1954; Sanders et al., 1982). Gupta et al., (1982) observed little variation in oil content (44.52 to 48.68%) of 325 varieties of groundnut. However, Nagaraj et al., (1984b) observed considerable variation in the oil content of 10 cultivars of groundnut. Similarly, Narashimha Char et al., (1985) reported 47 to 55 percent oil in 14 new cultivars of groundnut.

Most of the seed lipids are stored in cotyledons (Yatsu and Jacks, 1972). Groundnut oil is composed of 82 percent oleic and linoleic acids (Cobb and Johnson, 1973) which are considered as essential fatty acids. Hence groundnut oil has high nutritive value. Considerable genetic variation in the fatty acid composition between Spanish, Runner and Virginia types have been reported (Fore et al.,

1953). Because of the high proportion of unsaturated fatty acids in the oil, it has high iodine value and low stability or keeping quality (Holley and Hammons, 1968). Narashimha Ghar et al., (1985) reported that the quality parameters such as free fatty acids (0.2 to 1%), saponification value (184 to 198) and iodine value (87 to 99) show considerable genetic variation. Groundnut grown at different locations exhibited significant variation in iodine value (82.04 to 101.52), saponification value (100 to 207) and percent free fatty acids (0.3 to 2.08) (Nagaraj, 1984). Pattee et al., (1982) reported that iodine value is significantly higher in smaller seeds. Thus, it is clear that the oil quality in groundnut kernel is influence by several parameters such as genetic background, location and seed size.

2.1.4 Minerals

Total minerals content in groundnut ranged from 1.8 to 3.1 percent (Freeman et al., 1954; N.A.S., 1981; Gopalan et al., 1982). The groundnut is good source of phosphorus (0.25 to 0.66%), potassium (0.5 to 1.13%), calcium (0.2 to 0.8%), magnesium (0.9 to 0.34%) and iron (18 to 1000 µg per g). The other minerals like zinc, sulphur, manganese, copper and boron are also present in appreciable amounts (Derise et al., 1974; Hullock, 1980; Gaines and Hammons, 1981; Branch and Gaines, 1983).

2.2 Processing of groundnut

A large proportion of groundnut produced in the world is industrially processed for the extraction of oil. In India, more than 80 percent groundnut produce is used for oil extraction, 12 percent for seed, 4 to 5 percent for direct consumption and 1 percent for export (Kapila, 1982). While in the United States, over 25 percent groundnut is used for domestic consumption, about 20 percent for oil extraction and 10 percent as seed (Carley, 1978).

In the developed world, a significant proportion of the produce is processed for the preparation of protein concentrates and isolates, butter and milk, fermented products, composite meal, variety of bakery products and roasted nuts. In India, the use of peanuts in the preparation of spiced vegetables is very common. Besides, the peanuts are often processed into roasted and fried nuts and used as snacks (Adsule et al.,1988).

The protein concentrates and isolates are prepared from defatted groundnut flour or flakes (Royner et al.,1970; Cater et al., 1974). Several workers have prepared protein isolates from groundnut with slight variation in extraction conditions such as flour to water ratio, pH, time and temperature (Bhatia et al., 1966; Cater et al., 1974; Natarajan, 1980; Subramanian et al., 1981; McWatters and

Cherry, 1983). The groundnut butter production process is patented by Spadato and Pearce (1981). The process involves shelling - roasting - blanching - colour sorting - initial milling - second milling and packing. Groundnut milk is traditionally prepared by soaking the kernels in one percent sodium bicarbonate for 16 to 18 hrs followed by draining the water and grinding the nuts in water. The wet mash is steeped for 4 to 5 hrs and filtered to recover the product. In India, production of tonned groundnut milk called 'Miltone' is commercial reality. Miltone consists of groundnut milk extended with buffalow milk (Swaminathan and Parpia, 1967). It is also used to prepare yoghurt like product by using lactic culture (Beuchat and Nail, 1978).

Attempts have been made to utilize the defatted groundnut meal in the preparation of bread, biscuits, cookies, cakes, muffins, doughnuts, and other bakery products (Rooney et al., 1972; Ayres and Devenport, 1977; Abdul Baki et al., 1980; Ory and Conkerton, 1983). The groundnut is also used to prepare some traditional products like laddu, chikki. The roasted and fried skin-free cotyledones are mixed with thick and hot jaggery syrup. Small portion of the mixture are pressed with hand to obtain balls or laddu. When the mixture is spread on tray with uniform thickness of 1 to 1.5 cm, after cutting it gives chikki (Adsule et al., 1988).

The roasting of groundnut frequently with a little common salt is a very common practice all over the world. Groundnuts are roasted either by applying dry heat or in some vegetable oil (frying). Dry roasted groundnuts are used in the preparation of butter, confectionery or bakery products. The dry roasting is carried out by two ways; batch type and continuous type roaster (Woodroof, 1983b). In batch type and continuous roasting, temperature is about 138 to 143°C and roasting is finished within 3 to 10 min. Traditionally, roasting is carried out in hot pan or in hot sand, where temperature is kept about 200°C and roasting is finished within 15 min. The salted groundnuts are obtained by dipping in 20 percent brine solution for 5 to 10 min and then oven drying or 2 percent salt by weight is sprinkled on dry defatted groundnut.

2.3 Effects of processing on the quality of groundnut products

2.3.1 Oil

The groundnut oil used for frying is subjected to oxidative and hydrolytic changes. This results in decrease in functional, sensory and nutritive properties of oil (Melnick, 1957; Rice et al., 1960). These changes are reflected in increase in viscosity, foaming property, free fatty acids, refractive index and decrease in iodine value

(Sulthana and Sen, 1979). Murthi et al., (1979) observed that during continuous commercial frying of '*Sev*' with a turnover rate of 13 hrs, free fatty acids and peroxide number increased considerably and colour of oil changed to very dark. Significant losses were also observed in polyunsaturated fatty acids and iodine value of oil during 12 hrs intermittent frying of *puree* at 200°C (Rai and Narayanan, 1984). During frying of groundnut oil, there was loss of tocopherol upto 55 percent (Duplesis et al., 1981).

2.3.2 Cake and meal

The groundnut cake and meal are obtained as a by products after extraction of oil. Groundnut cake and meal are mostly used as manure or animal feed (Natarajan, 1980). The defatted meal contains 43 to 65 percent proteins and 6 to 20 percent oil according to method of oil extraction (Cherry, 1977). The defatted meal has higher PER, Net protein utilization (NPU) and digestibility than full fat groundnut meal (Kabirullah et al., 1977). Heat processed groundnut meal has been reported to be equally limiting in lysine, methionine and threonine (McOsker, 1962). Prasannappa et al., (1972) reported slight improvement in PER of heat treated groundnut meal based food products - Indian multipurpose food (IMPE) and *Balahar*.

2.3.3 Protein concentrates and isolates

In recent years, efforts have been made to process groundnut cake to obtain protein concentrates and isolates and, blend it with other flours. The protein concentrates contain 70 to 85 percent proteins (Cater et al., 1974; Royner et al., 1970). During preparation of concentrates, off flavour compounds, trypsin inhibitor, aflatoxin and flatulence causing sugars are usually removed (Cherry, 1983). The groundnut protein isolates contain more than 90 percent protein. It has potential application in several food products. It is reported that 80 percent of milk solids can be replaced by protein isolates without much change in flavour, colour and overall acceptability of artificial milk (Chandrashekhara et al., 1971). The protein isolates can be used at a level of 8 percent in wheat flour as a replacement for the preparation of breads (Khan and Lawhon, 1980).

2.3.4 Butter and milk

The groundnut butter prepared from roasted and blanched kernel contains 25.2 percent protein, 50.2 percent fat and 18.8 percent carbohydrates. It also contains significant amount of minearls and niacin (Considine and Considine, 1982). The groundnut butter flavour is a major factor in determining acceptability of the product. The groundnut milk prepared from kernels can be used to prepare curd, miltone, and yoghurt

(Swaminathan and Parpia, 1967). Bucker et al., (1979) tested 19 lactic acid cultures and reported that 6 cultures could produce lactic acid in groundnut milk.

2.3.5 Fermented products

The groundnut cake or meal fermented by using certain mold, are readily digestible, tasty and nutritious. In general, fermented products of groundnut, 'Oncom' contains protein (10 to 30%), carbohydrates (6 to 22%), oil (3 to 9%) and moisture (54 to 70%) (Van Veen et al., 1968; Winarno, 1979). Worthington and Beuchat (1974) reported elimination of raffinose and stachyose during first 24 hrs of fermentation of the groundnut with Neurospora intermedia. There was essentially no changein the fatty acid composition (Beuchat and Worthington, 1974) and practically no change in protein content during fermentation of groundnut (Van Veen et al., 1968). During fermentation, large molecular weight globulins such as arachin are hydrolysed to smaller components (Beuchat et al., 1975) as a result, nitrogen solubility profile of groundnut proteins at various pH values changes drastically (Quinn et al., 1975). Protein efficiency ratio's (PER) of fermented groundnuts are however not increased over the non-fermented materials (Van Veen and Steinkraus, 1970; Quinn and Beuchat, 1975).

2.3.6 Composite flours

The groundnut flour can be used for the preparation of composite flours with higher protein content and better nutritive value. Whole wheat and maize flour supplemented with 10, 20, 30 percent level of 1:1 mixture of groundnut and cowpea flour increased protein content by 20 to 61 percent. It also significantly increased chemical score, lysine and proximate constituents of the composite product. A supplementation level of 20 percent was considered adequate to achieve a desirable nutritive benefits (Khalil and Chughtai, 1984).

2.3.7 Bakery products

Attempts have been made to utilize the defatted groundnut meal in the preparation of bread, biscuits, cookies, cakes, muffins, doughnuts and other bakery products. Rooney et al., (1972) found that blend of unheated groundnut and wheat flour at 17.5 and 20 percent protein level produced breads with good characters and improved its protein quality. Ayres and Devenport (1977) prepared yeast raised doughnuts from defatted groundnut flour as a replacement of non-fat milk solids and partial replacement of egg in the doughnut formula. High protein groundnut flour (50 to 60%) can be used to replace upto 100 percent wheat flour for the preparation of muffins (Ory and Conkerton, 1983). Bread making properties of flour produced by solvent extraction procedure was studied.

It was found that defatted groundnut flour (1%) can be substituted upto 15 to 20 percent level, which increased protein percentage of bread without affecting the flavour (Khan et al., 1978).

2.3.8 Roasted peanuts

The roasting of nuts by dry heat is reported to induce several chemical changes in the kernels. These changes usually include change in moisture, colour, aroma, texture and chemical composition. The roasting reduces moisture content, develop pleasant flavour and makes nuts or meal more acceptable for human consumption (Kabirullah et al., 1977). The aroma of fresh roasted peanuts depends on roasting time and temperature. At 130 to 150°C, reflects change in ratio of carbonyl derivatives to pyrazines. The decrease in carbonyl and increase in pyrazines is important for good flavour (Buckholz and Daun, 1981). Some sulphur compounds contribute a roasted or nutty flavour to roasted nuts. However, the compounds like hydrogen sulphide, methane thiol and carbonyl sulphide formed during roasting are known to induce off flavour in the nuts (Watkins and Young, 1987).

The roasting of unshelled groundnut at 77°C for 30 min in oven found to decrease moisture (Derise et al., 1974). The reduction in moisture content prevents molding, staling and rancidity (Woodroof, 1945).

The roasting of groundnut at 120°C for 1 hr caused protein denaturation (Balogun and Koch, 1979). Excessive heating during roasting lowered the nutritional quality of groundnut proteins (Sharma et al., 1985). Khalil and Chughtai (1983) reported that roasting of groundnut at 150°C for 30 min increased the protein content and decreased the contents of methionine. Ahmed and Schmidt (1979) observed that heat treatment of groundnut (104°C for 20 min) did not influence protein solubility or emulsifying capacity but decreased foaming capacity and foam stability of groundnut protein. Heating of groundnut at 60°C for 30 min increased the solubility of protein, nitrogen to protein conversion factor and destroyed the lipoxygenase activity completely (Noor, 1980). The dry heat treatment (120°C for 60 min) has been reported to increase the PER value (Neucere et al., 1972).

The lipoxygenase responsible for lipid oxidation in raw groundnut is usually destroyed in the roasting process. After roasting, however, lipid oxidation is primarily catalysed by non-enzymatic catalysis. The minor constituents such as metals, metalloproteins and salts are possible catalysts of lipid peroxidation in roasted nuts (St.Angelo et al., 1979).

2.3.9 Fried peanuts

The seeds of groundnut are usually fried in the groundnut or other edible oils. The frying of groundnut kernels

decreases typical flavour precursors by 57 percent and remaining decreases slightly (Oupadissakoon and Young, 1984). Evolution of H_2S during roasting believed to be related to roasting flavour (Basha and Young, 1985).

Considerable genetic variation in relation to change in protein content during frying of kernels has been reported. There was significant decrease in methionine rich proteins due to frying treatment (Basha and Young, 1985). Walradt et.al. (1971) suggested that amino acids released from methionine rich polypeptides are involved in the development of flavour via Millard reaction. Oil roasting at 147°C for 4 min decrease majority of free amino acids (Oupadissakoon and Young, 1984).

2.4 Effects of storage on the quality of groundnut and its products

2.4.1 Raw groundnut

The groundnuts are generally stored in the form of unshelled pods in the containers such as earthen pots, mud bins, bamboo baskets, metal bins and gunny bags. The groundnuts are semi-perishable and become unedible under unsuitable storage conditions. The spoilage may be due to molds, insects, discolouration, absorption of foreign odours, staleness and rancidity. The high temperature of summer causes faster deterioration in groundnut. Schewfelt and

Young (1979) suggested that cultivation, harvesting and moisture content are the most critical factors in regard to storage stability. High moisture content is possibly the cause of more deterioration than any other single factor (Woodroof, 1983c).

Several chemical and biochemical changes take place during storage of groundnut. Starch content decreases with corresponding increase in the content of reducing and non-reducing sugars. The vitamins like thiamin and niacin are lost to a considerable extent (Pushpamma et al., 1981). Storage time upto 9 months was reported to significantly affect the level of fructose, glucose, inositol, sucrose and stachyose but not of raffinose and ribose.

The oil in stored nuts undergo oxidative and lipolytic changes. The most likely catalyst of lipid oxidation in raw groundnut is the enzyme lipoxygenase. Apparently, the enzyme is sufficiently active at 4°C to promote oxidation of oil for period of several months. The raw groundnuts stored for 5 months at 4°C showed appreciable peroxidation. However, the rate of peroxidation was found higher in raw than roasted nuts when the storage exceeded beyond 5 months (St.Angelo and Ory, 1975).

The storage of unshelled groundnut at 10°C and 70 percent relative humidity (RH) or at 5°C and 60 percent RH

resulted in essentially unchanged acid and perioxide number for 12 months. Similarly storage at 10°C and 60 percent RH for 12 months did not influence the oleic, linoleic and palmatic acid content of unshelled groundnut oil. (Uematsu and Ishii, 1981). Pattee et al., (1982) reported that storage of groundnut did not affect the iodine value.

2.4.2 Processed groundnut

The processed groundnut products such as butter, bakery products, protein concentrates, isolates, defatted meal, fermented foods, roasted and fried nuts are often stored under different environmental conditions. However, the information on the changes in the quality of such products during storage is meagre. The groundnut immersed in hot water (79°C) for 90 sec and stored under non-refrigerated conditions showed lower peroxide value, free fatty acids and lipoxygenase activity (Branch et al., 1987). Protein isolates prepared by spray drying exhibited no effect on protein solubility during 24 months storage. However, the protein solubility was found to decrease after 30 months of storage of the products (Ahmed and Schmidt, 1979). Storage of the groundnut cake over a period of 8 to 11 months resulted in about 60 percent loss in oil, increase in fatty acids and unsaponifiable matter and, poor hydrogenation characteristics of oil (Sabale et al., 1975). Dry roasted groundnut stored in different atmospheric conditions showed decrease in

percent oleic acid from initial to 8 months of storage while, percent linoleic acid decreased markedly from 8 to 12 months (How and Young, 1986). In roasted groundnut, the peroxide value increased at faster rate than raw groundnut (St.Angelo and Ory, 1975). The roasted groundnut oxidised relatively rapidly during storage. Prevention of O_2 access helped to inhibit the decrease in peroxide value. The surface oil from granular samples of dry roasted groundnut was more rapidly oxidised than from oil roasted one. It is suggested that treatment of raw groundnut with aqueous solution of H_2O_2(1%) could inhibit the oxidation of groundnut after roasting (Yuki et al., 1978).

Since the heat treatments such as roasting and/or frying induce desirable flavour, destroy antinutrients and improve the acceptability of nuts, these processing are very common practices. The reports indicate that considerable biochemical changes in storage proteins and oil occur in kernels due to heat treatment and storage of such products of groundnut. These changes are likely to affect the shelf-life of products prepared from such heat processed groundnut. The information on these aspects is however, scanty.

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Material and Methods

3. MATERIAL AND METHODS

3.1 Material

3.1.1 Seeds

The pods of groundnut, variety C-1-2 were obtained from the Groundnut Breeder, Mahatma Phule Agricultural University, Rahuri. The pods were shelled manually, the kernels cleaned, dried at 50°C for 8 hrs and stored in plastic bags at 4°C until used for processing and analysis.

3.1.2 Chemicals

Most of the chemicals used in the present study were of analytical grade (BDH, Sarabhai M. Chemicals or E.Merk). DL-Methionine, L-tryptophan and Folin-Ciocalteu's reagents were obtained from Sisco Research Laboratory, Bombay. Bovine serum albumin and pepsin were obtained from Romali, American Preparate.

3.2 Methods

An experiment in factorial completely randomized block design (F-CRD) was planed to investigate the effects of heat treatments and storage of heat processed kernels at two storage temperatures and six storage periods. The treatment details were as below :

<u>Heat treatments</u> - 5

i. Control
ii. Roasting
iii. Soaking + roasting
iv. Frying
v. Soaking + frying

Storage temperatures - 2

i. $5 \pm 2^{o}C$

ii. $27 \pm 2^{o}C$

Storage periods - 6

0, 30, 60, 90, 120, 150 days.

3.2.1 Heat processing

The clean healthy 1 kg kernels were roasted in hot air oven at $160^{o}C$ for 30 min. Similarly, 1 kg kernels were deep fried in refined boiling groundnut oil (Postman brand) for 2 min. For presoaking treatments, 2 kg of the kernels were soaked in 20 percent sodium chloride solution for 4 hrs at ambient temperature and drained. The soaked kernels were later dried at $50^{o}C$ for 6 hrs and either roasted or fried in oil as described above.

The processed kernels were packed in polythene bags (200 grams in each bag). The bags were sealed and stored at $27 \pm 2^{o}C$ and at $5 \pm 2^{o}C$. After appropriate storage period, the kernels were dehulled manually to remove the red skin and ground to fine powder. The moisture and crude oil were estimated from full fat meal while crude protein, soluble proteins, methionine, tryptophan and *in vitro* protein digestibility were estimated from completely defatted meal. The crude oil was extracted from the samples in petroleum

ether and used for determination of different fat constants. All analyses were performed in triplicate.

3.2.2 Chemical analyses

The moisture, crude oil and crude protein (N x 5.46) were determined according to standard procedures of A.O.A.C. (1980).

3.2.3 Effects on protein quality

The effects of heat treatments and storage on the changes in storage proteins of groundnut kernels were studied in relation to changes in soluble proteins, limiting amino acids such as methionine, and tryptophan and, succeptibility of storage proteins to pepsin digestion (*In vitro* protein digestibility).

3.2.3.1 Soluble proteins

The defatted groundnut flour was extracted in water (1:20 w/v) for 60 min,centrifuged at 10,000 x g for 30 min and the soluble proteins in supernatants were determined by the colorimetric procedure of Lowry et al., (1951) using bovine serum albumin (100 µg/ml) as standard.

3.2.3.2 Methionine

This was estimated by the chemical method based on McCarthy and Paille (1959).

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Reagents

1. Hydrochloric acid, 2 N
2. Sodium hydroxide, 10%
3. Sodium nitroprusside, 10%
4. Sodium hydroxide, 10 N
5. Glycine, 3%
6. Concentrated ortho phosphoric acid
7. Standard methionine solution : The DL - methionine (100 mg) was dissolved in 2 ml of 20 percent hydrochloric acid and further diluted to 100 ml with water. This solution contained 1 mg DL-methionine/ml.

Methionine extraction

Methionine was extracted according to the method described by Gupta and Das (1955). Two grams of defatted sample was autoclaved with 25 ml of 2N HCl at 15 lbs pressure for one hr. The hydrolysate was treated with a pinch of activated charcoal to get rid of the colour, heated to boiling and filtered. The charcoal was washed 3 to 4 times with hot water quickly and the washings were collected. The colour free extract was neutralized with 10 N NaOH to bring the pH to about 6.5. The volume was made to 100 ml.

Colour development

The colour was developed according to the method described by McCarthy and Paille (1959).

The extract (50 ml) was taken in 250 ml conical flask and 6 ml of 10 percent NaOH were added. This was followed by addition of 0.3 ml of sodium nitroprusside and contents were kept for 10 min with occasional shaking. After 10 min, 2 ml of glycine were added, shaken well and allowed to stand for 10 min. Then, 4 ml of concentrated orthophosphoric acid were added, shaken vigorously and after 10 min colour intensities were measured on spectronic-20 colorimeter at 540 nm.

Standard curve and calculations

For a standard curve, different concentrations of methionine (2, 4, 6 and 8 mg) were taken in duplicate and 25 ml of 2N HCl was added. The remaining procedure was similar as used for samples. The methionine content of samples was calculated from standard curve and expressed as percent on moisture free basis in meal and g per 16 g N.

3.2.3.3 Tryptophan

Tryptophan in the samples was determined by the colorimetric method of Spice and Chambers (1949).

Reagents

1. Sulphuric acid - 19 N and 20.4 N
2. Sodium nitrite - 0.045%
3. P-dimethyl aminobenzaldehyde
4. Standard tryptophan : L-tryptophan (20mg) was dissolved in 100 ml water (2 drops of 10 percent NaOH were

added to facilitate solubilization of tryptophan). This solution contained 200 µg L-tryptophan/ml.

Tryptophan in sample

The ground defatted samples (40 mg) were taken in 50 ml conical flasks in triplicate and 30 mg of P-dimethyl aminobenzaldehyde were added to each flask. The third flask in each experiment was kept for blank. Then, 10 ml of 19 N sulphuric acid were added to all the flasks. After keeping the flasks in dark for 20 hrs at 30°C, 0.1 ml of 0.045 percent of sodium nitrite was added to each flask except in blanks, shaken gently and kept for 30 min for colour development. The contents were filtered through glass wool and the colour intensities were read at 600 nm on spectronic-20 colorimetry.

Standard curve

The standard tryptophan solution (0 to 120 µg) was taken in 50 ml conical flasks in triplicate. The water was added to make up volume to 0.6 ml in each flask. Then 9.4 ml of 20.4 N sulphuric acid were added to each flask in order to make 19 N as final strength of the acid. The P-dimethyl aminobenzaldehyde (30 mg) was then added to each flask. The flasks were kept in dark for 20 hrs at 30°C. Rest of the procedure was same as described for samples. The tryptophan content was determined from the standard curve after making the necessary corrections for the blank values of each sample.

The tryptophan was expressed as percent on moisture free basis in meal and as g per 16 g N.

3.2.3.4 *In vitro* protein digestibility (IVPD)

The defatted samples were ground to 80 mesh. The IVPD was determined by the method of A.O.A.C. (1980).

Reagents

1. Hydrochloric acid, 0.075 N
2. Pepsin solution (0.2 percent pepsin in 0.075 N hydrochloric acid).

Procedure

The powdered meal (200 mg) was incubated with 50 ml of pepsin solution for 24 hrs at 37°C. Digestion was performed in duplicate. The digests were filtered through Whatman No.2 filter paper. The residue on the filter paper was washed with warm water. The nitrogen in the residue was estimated by micro-Kjeldahl method (3.2.2). The IVPD was obtained by calculating the difference between the amount of total nitrogen in the sample before and after the *in vitro* digestion with pepsin.

3.2.4 Effects on oil quality

The effects of heat treatments and storage on the changes in oil quality of groundnut were studied in relation to changes

in free fatty acids, iodine value and saponification value. The different oil constants were estimated by the method of A.O.A.C., (1980).

3.2.4.1 Saponification value

Reagents

1. Alcoholic KOH : Potassium hydroxide (40 g) was mixed with 45 g of granulated calcium oxide and powdered in morter. The mixture was dissolved in 1000 ml of alcohol.

2. Hydrochloric acid, 0.5 N
3. Phenolphthalein indicator

Procedure

One gram of oil was weighted accurately into 250 ml conical flask and 50 ml of alcoholic KOH was drained with definite time. The air condenser was attached to the flask and contents of the flask were refluxed on water bath until fat was completely saponified. The flask was then cooled to room temperature and few drops of phenolphthalein indicator were added. The contents were titrated with 0.5 N hydrochloric acid until colour changed from pink to colourless. The amount of hydrochloric acid required for titration was used for calculation of saponification value.

$$\text{Saponification value} = \frac{(\text{Vol. of HCl required for blank} - \text{Vol. of HCl required for sample})}{\text{Weight of sample (g)}} \times 28.05$$

3.2.4.2 Acid value

Reagents

1. Fat solvent (alcohol + petroleum ether, 50:50 v/v)
2. Potassium hydroxide, 0.01 N
3. Phenolphthalein indicator

Procedure

Oil sample (2 g) was accurately weighted and dissolved in 25 ml of fat solvent in a conical flask. Phenolphthalein indicator (3 to 4 drops) was added to flask and mixed thoroughly. The contents were titrated with 0.01 N potassium hydroxide until faint pink colour persisted for 20 to 30 seconds. The amount of alkali required for neutralization was used for calculation of the acid value.

$$\text{Acid value} = \frac{(\text{Vol. of KOH required for sample} - \text{Vol of KOH required for blank})}{\text{Weight of sample (g)}} \times 0.56$$

3.2.4.3 Iodine value

Reagents

1. Fat solvent ($CHCl_3$)
2. Hanus reagent : 13.2 g pure iodine or 1.3 g of sublimated iodine in acetic acid containing 3 ml of bromine solution was made to 1 liter with acetic acid.

3. Potassium iodide, 15%

4. Sodium thiosulphate, 0.1 N

5. Starch indicator, 1%

Procedure

Oil (0.5 g) was weighted accurately in 250 ml of iodine flask and dissolved in 10 ml of fat solvent. 25 ml of Hanus reagent was added to it and allowed to stand for 30 min in dark. The content of the flask was shaken occasionally. Subsequently, 10 ml of 15 percent potassium iodide solution was added and mixed thoroughly and titrated with 0.1 N sodium thiosulphate until yellow colour turns almost colourless. Then, few drops of starch indicator were added and the titration was continued until blue colour disappeared. The quantity of sodium thiosulphate required for titration was used for calculation of iodine value.

$$\text{Iodine value} = \frac{(\text{Vol. of } Na_2S_2O_3 \text{ required for blank} - \text{Vol. of } Na_2S_2O_3 \text{ required for sample})}{\text{Weight of sample (g)}} \times 12.69$$

3.2.5 Statistical analyses

The data obtained in the experiments were analyed for the statistical significance by the methods of Panse and Sukhatme (1957).

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Result and Discussion

4. RESULTS AND DISCUSSION

The groundnut kernels subjected to various heat treatments such as soaking, roasting and frying were analyzed for different parameters to assess the influence of processing on the quality of proteins and oil. The processed kernels were stored at ambient and cold temperature upto 150 days, and analyzed for various quality parameters to assess their shelf-life. The results are presented and briefly discussed in this section.

4.1 Moisture

The moisture content of unheated and heat treated groundnut kernels as well as the changes in moisture content during storage are presented in Table 1. The heat treatments significantly reduced the moisture content in kernels. The dry heating (roasting) reduced moisture content from 5.8 to 2.2 percent while the frying treatment reduced the moisture content of the kernels from 5.8 to 2.4 - 2.9 percent. The moisture content was found to reduce to a greater extent by dry heating as compared to the frying treatment. The temperature did not influence the moisture content markedly during storage. The moisture content of the kernel was found to reduce during storage at both the temperatures (Table 2). The interaction effects of different factors are presented in Table 3. All the treatments exhibited significant interaction effects. These observations indicate that the moisture

Table 1 : Effect of heat treatmens on the moisture content (%) in groundnut kernels during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	5.83	5.81	5.78	5.79	5.76	5.76	5.79
	27	5.83	5.80	5.81	5.78	5.75	5.73	5.78
Roasting	5	2.19	2.17	2.15	2.13	2.14	2.12	2.15
	27	2.19	2.15	2.13	2.10	2.10	2.08	2.12
Soaking + Roasting	5	2.20	2.17	2.15	2.13	2.12	2.12	2.15
	27	2.20	2.18	2.16	2.13	2.12	2.10	2.15
Frying	5	2.40	2.36	2.35	2.33	2.32	2.32	2.35
	27	2.40	2.36	2.33	2.30	2.27	2.26	2.32
Soaking + Frying	5	2.92	2.89	2.86	2.85	2.83	2.82	2.86
	27	2.92	2.87	2.84	2.82	2.80	2.78	2.84
Mean		3.11	3.08	3.06	3.04	3.02	3.01	3.05

Table 2 : Test of significance for change in moisture content in groundnut kernels due to heat treatments, temperatures and period of storage

Factors	Moisture %
Heat treatment	
Control	5.79
Roasting	2.14
Soaking + Roasting	2.15
Frying	2.33
Soaking + Frying	2.85
S.E. ±	0.002
C.D. at 5%	0.006
Storage temperature, ± 2°C	
5	3.06
27	3.04
S.E. ±	0.001
C.D. at 5%	0.004
Storage period, days	
0	3.11
30	3.08
60	3.06
90	3.04
120	3.02
150	3.01
S.E.±	0.003
C.D. at 5%	0.007

Table 3 : Interactions between various factors for moisture (%)

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature ± 2°C	
	5	27
Control	5.79	5.78
Roasting	2.15	2.12
Soaking + Roasting	2.15	2.15
Frying	2.35	2.32
Soaking + Frying	2.86	2.84
S.E.±	0.003	
C.D.at 5%	0.009	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	3.11	3.08	3.06	3.05	3.03	3.03
27	3.11	3.07	3.05	0.03	3.01	2.99
S.E. ±	0.004					
C.D.at 5%	0.010					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	5.83	5.81	5.79	5.79	5.76	5.75
Roasting	2.19	2.16	2.14	2.11	2.12	2.10
Soaking + Roasting	2.20	2.18	2.16	2.13	2.12	2.11
Frying	2.4	2.36	2.34	2.32	2.29	2.29
Soaking + Frying	2.92	2.88	2.85	2.83	2.82	2.80
S.E.±	0.006					
C.D.at 5%	0.016					

content of the raw and heated kernels significantly changed during storage at both ambient and refrigerated storage conditions. The moisture content of the kernels shows decreasing trend during storage which is desirable for increased shelf-life of the product.

Roasting of kernels is known to reduce the moisture content (Derise et al., 1974; Kabirullah et al., 1977). Khalil and Chughtai (1983) reported that roasting of kernels at 150°C for 30 min reduced the moisture content from 4.8 to 1.9 percent in 10 cultivars of groundnut. The results obtained in the present study are in agreement with literature values. The reduction in moisture content is known to prevent mold infestation, staling and rancidity (Woodroof, 1945). It, therefore, appears that a drastic reduction in moisture content due to heat treatments may be desirable in extending the shelf-life of heat processed groundnut.

4.2 Proteins

The changes in crude protein content due to heat treatments and storage of processed groundnut kernels are presented in Table 4, while, the test of significance and interaction effects of different factors are presented in Table 5 and Table 6, respectively. Unheated groundnut kernel contained 46.3 percent proteins. Roasting and frying

Table 4 : Effect of heat treatments on proteins (%) in groundnut kernels during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	46.30	46.79	47.34	47.39	47.56	47.61	47.16
	27	46.30	46.57	47.34	47.61	47.67	47.78	47.21
Roasting	5	51.05	50.78	51.32	51.43	51.49	51.49	51.26
	27	51.05	51.05	51.38	51.38	51.43	51.43	51.29
Soaking + Roasting	5	50.12	50.07	50.18	50.18	50.23	50.34	50.19
	27	50.12	50.29	50.18	50.45	50.51	50.56	50.35
Frying	5	51.38	51.87	52.03	52.09	52.14	52.14	51.94
	27	51.38	51.87	52.20	52.20	51.92	51.98	51.92
Soaking + Frying	5	49.69	50.23	50.40	50.45	50.40	50.40	50.26
	27	49.69	49.74	49.80	50.01	50.18	50.34	49.96
Mean		49.71	49.93	50.22	50.32	50.35	50.41	50.16

Table 5 : Test of significance for change in protein in groundnut kernels due to heat treatments, temperatures and period of storage

Factors	Protein, %
Heat treatment	
Control	47.19
Roasting	51.27
Soaking + Roasting	50.27
Frying	51.93
Soaking + Frying	50.11
S.E.±	0.010
C.D. at 5%	0.027
Storage temperature, ± 2°C	
5	50.15
27	50.16
S.E.±	0.006 NS
Storage period, days	
0	49.71
30	49.93
60	50.22
90	50.32
120	50.35
150	50.41
S.E.±	0.01
C.D. at 5%	0.03

Table 6 : Interactions between various factors for protein (%)

A. *Heat treatment x Storage temperature*

Heat treatment	Storage temperature, ± 2°C	
	5	27
Control	47.16	47.21
Roasting	51.26	51.29
Soaking + Roasting	50.19	50.35
Frying	51.94	51.92
Soaking + Frying	50.26	49.96
S.E. ±	0.014	
C.D. at 5%	0.038	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	49.71	49.95	50.25	50.31	50.36	50.40
27	49.71	49.90	50.18	50.33	50.34	50.41
SE ±	0.015					
C.D. at 5%	0.042					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	46.30	46.68	47.34	47.50	47.61	47.70
Roasting	51.05	50.92	51.35	51.41	51.46	51.46
Soaking + Roasting	50.12	50.18	50.18	50.32	50.37	50.45
Frying	51.38	51.87	52.12	52.14	52.03	52.06
Soaking + Frying	49.69	49.99	50.10	50.23	50.29	50.37
S.E. ±	0.024					
C.D. at 5%	0.067					

treatments caused a significant increase (about 4 to 5 %) in the protein content of the kernels. The protein content was found to be increased during storage. However, storage temperatures did not influence the protein content in stored nuts. Although, all interactions were found to be significant, the changes in the protein content due to storage of nuts were not of significant order.

An increase in the protein content of groundnut kernels due to heat treatment as well as during storage can be attributed to decrease in the moisture content. Since, the moisture content is drastically reduced due to heating of the nuts, an increase in content of proximate principles such as protein, fat, fibre, ash and carbohydrates are obvious. The relative increase in proximate principles would depend upon the extent of removal of the moisture. Such an increase in the nutrients can be regarded as apparent increase rather than true increase in the content of proteins. Similar results have been reported by Khalil and Chughtai (1983).

4.3 Soluble proteins

The change in soluble proteins due to heat treatments and storage are presented in Table 7. Test of significance for each treatment is shown in Table 8, while interaction effects are presented in Table 9. The soluble proteins increased rapidly in the untreated kernels during first 30 days

Table 7 : Effect of heat treatments on soluble protein (%) in groundnut kernels during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	18.9	22.8	23.4	26.2	25.6	25.1	23.67
	27	18.9	22.6	31.7	31.7	27.9	34.9	27.95
Roasting	5	27.6	29.2	26.2	28.4	31.0	35.4	29.63
	27	27.6	32.0	29.0	29.0	30.6	31.3	29.92
Soaking + Roasting	5	25.7	26.5	27.0	30.1	31.4	30.8	28.58
	27	25.7	26.5	29.0	26.2	31.4	31.3	28.35
Frying	5	23.4	21.8	20.4	24.6	23.7	29.1	23.82
	27	23.4	23.7	23.2	17.7	25.1	19.8	22.15
Soaking + Frying	5	19.0	19.6	19.3	18.2	20.7	18.2	19.17
	27	19.0	18.2	18.0	15.7	18.8	16.1	17.63
Mean		22.92	24.29	24.72	24.78	26.62	27.19	25.09

Table 8 : Test of significance for change in soluble protein in groundnut kernels due to heat treatments, temperatures and period storage

Factors	Soluble protein,%
Heat treatment	
Control	25.81
Roasting	29.78
Soaking + Roasting	28.47
Frying	22.98
Soaking + Frying	18.40
S.E.±	0.076
C.D. at 5%	0.210
Storage temperature, ± 2°C	
5	24.97
27	25.02
S.E.±	0.048
C.D. at 5%	0.130
Storage period, days	
0	22.92
30	24.29
60	24.72
90	24.78
120	26.62
150	27.19
S.E.±	0.083
C.D.at 5%	0.230

Table 9 : Interactions between various factors for soluble protein (%)

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature, ± 2°C	
	5	27
Control	23.67	27.95
Roasting	29.63	29.92
Soaking + Roasting	28.58	28.35
Frying	23.82	22.15
Soaking + Frying	19.17	17.63
S.E.±	0.11	
C.D.at 5%	0.30	

B. Storage temperature X Storage period

Storage temperature	Storage period, days					
	0	30	60	90	120	150
5	22.92	23.98	26.48	23.26	25.50	27.70
27	22.92	24.6	26.76	26.18	24.06	26.68
S.E.±	0.12					
C.D.at 5%	0.33					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	18.90	22.70	26.75	27.55	28.95	30.00
Roasting	27.60	30.60	30.80	27.60	28.70	33.35
Soaking + Roasting	25.70	26.50	31.40	28.00	28.15	31.05
Frying	23.40	22.75	24.40	21.80	21.15	24.40
Soaking + Frying	19.00	18.90	19.75	18.65	16.95	17.15
S.E.±	0.19					
C.D. at 5%	0.52					

of storage irrespective of storage temperatures. However, an increase in the soluble proteins during subsequent storage upto 150 days was not much pronounced. Roasting and frying of the kernels significantly increased the content of soluble proteins. During storage of heated kernels,there was slight increase in the soluble proteins. The results indicated that the content of soluble proteins increased significantly due to heat treatments and during storage of raw kernels.

The water soluble proteins measured in this study include albumins and some globulins. The proteins in the kernels are mostly present in protein bodies (Lott and Buttrose, 1978). An increase in the content of water soluble proteins during storage and due to heat treatments indicate structural changes in the protein bodies and the storage globulins. The roasting of kernels has been reported to cause aggregation of major globulins and degradation of certain proteins into the peptides and amino acids (Basha and Young, 1985). A large increase in the soluble protein content in unheated kernels during first 30 days of storage indicates a rapid metabolic activity of the freshly harvested resting seeds. This type of degradation of storage globulins during roasting and frying may be nutritionally desirable because such proteins may be easily digestible than the native storage proteins. The heating of groundnut kernels has been reported to increase the protein solubility (Noor, 1980). The dry heat treatment (120°C for

60 min) has been reported to increase the PER of groundnut protein. The increase in protein availability from heated kernels can be attributed to the partial degradation of complex storage globulins.

4.4 Methionine and tryptophan

The changes in methionine content during storage of unheated kernels as well as due to roasting and frying are presented in Table 10. The test of significance and interaction effects of different factors are shown in Table 11 and 12, respectively. The changes in methionine content in groundnut proteins due to heat treatments and storage are also calculated and the results are presented in Table 13,14 and 15. The methionine content in groundnut meal was found to decrease significantly due to heat treatments and during storage of raw and heated kernels. Among the heat treatments, frying was found to be more deterimental as compared to roasting. The storage temperatures significantly influenced the changes in methionine content in meal. Storage of kernels at ambient temperature resulted in more loss of methionine than the storage of kernels at 5°C. All the interactions were found to be significant (Table 12). When the results on methionine content are expressed on 16 g N basis, similar trend was observed (Table 13, 14 and 15). The results indicated that the methionine content continuously decreased during storage of raw kernels. Storage of heated kernels further

Table 10 : Effect of heat treatments on methionine (g/100 g meal) in groundnut kernels during storage

Heat treatment	Storage temperature ±2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	0.58	0.58	0.52	0.48	0.46	0.46	0.51
	27	0.58	0.56	0.44	0.42	0.40	0.42	0.47
Roasting	5	0.50	0.48	0.48	0.42	0.38	0.37	0.44
	27	0.50	0.49	0.42	0.38	0.35	0.32	0.41
Soaking + Roasting	5	0.50	0.48	0.46	0.42	0.40	0.38	0.44
	27	0.50	0.48	0.40	0.37	0.36	0.34	0.41
Frying	5	0.44	0.42	0.42	0.40	0.38	0.36	0.40
	27	0.44	0.42	0.38	0.36	0.33	0.30	0.37
Soaking + Frying	5	0.44	0.40	0.38	0.36	0.36	0.35	0.38
	27	0.44	0.38	0.37	0.35	0.34	0.32	0.37
Mean		0.49	0.47	0.43	0.40	0.38	0.36	0.42

Table 11 : Test of significance for change in methionine in groundnut kernels due to heat treatments, temperatures and period of storage

Factors	Methionine g/100 g meal
Heat treatment	
Control	0.49
Roasting	0.42
Soaking + Roasting	0.42
Frying	0.39
Soaking + Frying	0.37
S.E.±	0.002
C.D. at 5%	0.006
Storage temperature, + 2°C	
5	0.44
27	0.41
S.E.±	0.001
C.D. at 5%	0.004
Storage period, days	
0	0.49
30	0.47
60	0.43
90	0.40
120	0.38
150	0.36
S.E. ±	0.002
C.D. at 5%	0.007

Table 12 : Interactions between various factors for methionine (g/100 g meal)

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature ± 2°C	
	5	27
Control	0.51	0.47
Roasting	0.44	0.41
Soaking + Roasting	0.44	0.41
Frying	0.40	0.37
Soaking + Frying	0.38	0.37
S.E.±	0.003	
C.D.at 5%	0.009	

B. Storage temperature X Storage period

Storage temperature	Storage period, days					
	0	30	60	90	120	150
5	0.49	0.47	0.45	0.42	0.40	0.38
27	0.49	0.47	0.40	0.38	0.36	0.34
S.E.±	0.004					
C.D.at 5%	0.010					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	0.58	0.57	0.48	0.45	0.42	0.44
Roasting	0.50	0.49	0.45	0.40	0.37	0.34
Soaking + Roasting	0.50	0.48	0.43	0.39	0.38	0.36
Frying	0.44	0.42	0.40	0.38	0.35	0.33
Soaking + Frying	0.44	0.39	0.38	0.36	0.35	0.34
S.E.±	0.005					
C.D.at 5%	0.020					

Table 13 : Effect of heat treatments on methionine (g/16 g N) in groundnut kernels during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	1.07	1.08	0.96	0.88	0.85	0.84	0.95
	27	1.07	1.05	0.81	0.77	0.73	0.77	0.87
Roasting	5	0.86	0.83	0.82	0.71	0.64	0.63	0.75
	27	0.86	0.84	0.71	0.65	0.59	0.54	0.70
Soaking + Roasting	5	0.87	0.84	0.80	0.73	0.70	0.66	0.77
	27	0.87	0.83	0.70	0.64	0.62	0.59	0.71
Frying	5	0.75	0.71	0.71	0.67	0.64	0.60	0.68
	27	0.75	0.67	0.64	0.60	0.56	0.52	0.62
Soaking + Frying	5	0.77	0.70	0.66	0.62	0.62	0.61	0.66
	27	0.77	0.67	0.65	0.63	0.59	0.56	0.64
Mean		0.86	0.82	0.75	0.69	0.65	0.63	0.73

Table 14 : Test of significance for change in methionine in groundnut kernels due to heat treatments, temperatures and period of storage

Factors	Methionine g/16 g N
Heat treatment	
Control	0.91
Roasting	0.72
Soaking + Roasting	0.74
Frying	0.65
Soaking + Frying	0.65
S.E.±	0.004
C.D. at 5%	0.010
Storage temperature, ± 2°C	
5	0.76
27	0.71
S.E.±	0.002
C.D. at 5%	0.006
Storage period, days	
0	0.86
30	0.82
60	0.75
90	0.69
120	0.65
150	0.63
S.E. ±	0.004
C.D. at 5%	0.010

Table 15 : Interactions between various factors for methionine (g/16 g N)

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature, ± 2°C	
	5	27
Control	0.95	0.87
Roasting	0.75	0.70
Soaking + Roasting	0.77	0.71
Frying	0.68	0.62
Soaking + Frying	0.66	0.64
S.E. ±	0.005	
C.D. at 5%	0.014	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	0.86	0.83	0.79	0.72	0.69	0.67
27	0.86	0.81	0.70	0.66	0.62	0.60
S.E. ±	0.006					
C.D.at 5%	0.020					

C. Heat treatment x Storage period

6

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	1.07	1.07	0.88	0.83	0.79	0.81
Roasting	0.86	0.83	0.76	0.68	0.62	0.58
Soaking+Roasting	0.87	0.84	0.75	0.68	0.66	0.63
Frying	0.75	0.69	0.68	0.64	0.60	0.56
Soaking+Frying	0.77	0.68	0.66	0.62	0.61	0.59
S.E.±	0.009					
C.D.at 5%	0.025					

lowered the methionine content in the protein of the kernels.

The changes in tryptophan content in the meal and proteins of the unheated and heated groundnut kernels during storage were investigated. Both the storage and heat treatments significantly decreased the tryptophan content (Table 16 and 17). All the interactions were found to be significant (Table 18). When the results on the changes in tryptophan content are expressed on 16 g N basis, similar trend was noticed (Table 19, 20 and 21). The decrease in tryptophan content was more severe due to frying treatment than roasting. The decrease in both methionine and tryptophan was found to be gradual during storage.

The methionine and tryptophan are known to be deficient in groundnut proteins. Hence, the effect of storage and heat treatments are important. The decrease in amino acid content during storage can be attributed to complex chemical changes in storage proteins. Heat treatments such as roasting and frying to the kernels result in development of pleasant flavour (Buckholz and Daun, 1981). Walradt et al., (1971) reported that amino acids are released during heat treatments and participate in the development of flavour via Maillard reaction. A significant decrease in methionine due to frying treatment has been reported (Basha and Young, 1985). Khalil

Table 16 Effect of heat treatments on tryptophan (g/100 g meal) in groundnut kernels during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	0.34	0.34	0.33	0.32	0.32	0.32	0.33
	27	0.34	0.33	0.32	0.32	0.31	0.29	0.32
Roasting	5	0.27	0.26	0.25	0.24	0.24	0.23	0.25
	27	0.27	0.25	0.21	0.20	0.21	0.21	0.22
Soaking + Roasting	5	0.29	0.26	0.25	0.25	0.24	0.23	0.25
	27	0.29	0.25	0.24	0.23	0.22	0.21	0.24
Frying	5	0.28	0.27	0.26	0.24	0.23	0.22	0.25
	27	0.28	0.26	0.25	0.22	0.21	0.20	0.24
Soaking + Frying	5	0.27	0.25	0.24	0.24	0.23	0.21	0.24
	27	0.27	0.24	0.22	0.20	0.19	0.19	0.22
Mean		0.29	0.27	0.26	0.25	0.24	0.23	0.26

Table 17 : Test of significance for change in tryptophan in groundnut kernels due to heat treatments, temperatures and period of storage

Factors	Tryptophan, g/100 g meal
Heat treatment	
Control	0.32
Roasting	0.24
Soaking + Roasting	0.25
Frying	0.24
Soaking + Frying	0.23
S.E. ±	0.001
C.D. at 5%	0.004
Storage temperature, ± 2°C	
5	0.26
27	0.25
S.E.±	0.001
C.D. at 5%	0.003
Storage period, days	
0	0.29
30	0.27
60	0.26
90	0.25
120	0.24
150	0.23
S.E. ±	0.002
C.D. at 5%	0.005

Table 18 : Interactions between various factors for tryptophan (g/100 g meal)

A. Heat treatment x Storage temperature

Heat treatment	Storage temperature ± 2°C	
	5	27
Control	0.33	0.32
Roasting	0.25	0.22
Soaking + Roasting	0.25	0.24
Frying	0.25	0.24
Soaking + Frying	0.24	0.22
S.E.±	0.002	
C.D.at 5%	0.006	

B. Storage temperature x Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	0.29	0.28	0.27	0.26	0.25	0.24
27	0.29	0.27	0.25	0.23	0.23	0.22
S.E.±	0.002					
C.D.at 5%	0.006					

Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	0.34	0.34	0.33	0.32	0.32	0.30
Roasting	0.27	0.26	0.23	0.22	0.23	0.22
Soaking+Roasting	0.29	0.26	0.25	0.24	0.23	0.22
Frying	0.28	0.27	0.25	0.23	0.22	0.21
Soaking+Frying	0.27	0.25	0.23	0.22	0.21	0.20
S.E.±	0.004					
C.D.at 5%	0.010					

Table 19 : Effects of heat treatments on tryptophan (g/16 g N) in groundnut kernels during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	0.64	0.63	0.61	0.59	0.59	0.59	0.61
	27	0.64	0.62	0.59	0.59	0.57	0.53	0.59
Roasting	5	0.46	0.45	0.43	0.41	0.41	0.39	0.42
	27	0.46	0.43	0.36	0.34	0.36	0.36	0.38
Soaking + Roasting	5	0.51	0.44	0.44	0.44	0.42	0.40	0.44
	27	0.51	0.43	0.42	0.40	0.38	0.36	0.42
Frying	5	0.48	0.45	0.44	0.40	0.39	0.37	0.42
	27	0.48	0.44	0.42	0.37	0.35	0.34	0.40
Soaking + Frying	5	0.47	0.43	0.42	0.42	0.40	0.36	0.42
	27	0.47	0.42	0.39	0.35	0.33	0.33	0.38
Mean		0.51	0.47	0.45	0.43	0.42	0.40	0.45

Table 20 : Test of significance for change in tryptophan in groundnut kernels due to heat treatments, temperatures and period of storage

Factors	Tryptophan, g/16 g N
Heat treatment	
Control	0.60
Roasting	0.40
Soaking + Roasting	0.43
Frying	0.41
Soaking + Frying	0.40
S.E. ±	0.002
C.D. at 5%	0.006
Storage temperature, ± 2°C	
5	0.46
27	0.43
S.E.±	0.001
C.D. at 5%	0.004
Storage period, days	
0	0.51
30	0.47
60	0.45
90	0.43
120	0.42
150	0.40
S.E.±	0.002
C.D. at 5%	0.007

Table 21 : Interaction between various factors for tryptophan (g/16 g N)

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature, ± 2°C	
	5	27
Control	0.61	0.59
Roasting	0.42	0.38
Soaking + Roasting	0.44	0.42
Frying	0.42	0.40
Soaking + Frying	0.42	0.38
S.E.±	0.003	
C.D. at 5%	0.008	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	0.51	0.48	0.47	0.45	0.44	0.42
27	0.51	0.47	0.44	0.41	0.40	0.38
S.E.±	0.003					
C.D. at 5%	0.009					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	0.64	0.62	0.60	0.59	0.58	0.56
Roasting	0.46	0.44	0.40	0.37	0.39	0.37
Soaking + Roasting	0.51	0.44	0.43	0.42	0.40	0.38
Frying	0.48	0.45	0.43	0.38	0.37	0.35
Soaking + Frying	0.47	0.43	0.41	0.39	0.37	0.35
S.E.±	0.005					
C.D. at 5%	0.015					

and Chughtai (1983) reported that roasting of groundnut kernels for 150°C for 30 min decreased the lysine, threonine, methionine, cystine, arginine, tryptophan and tyrosin. This decrease in certain amino acids can be attributed to the heat distruction or the release of these amino acids from proteins and their subsequent participation in the production of flavour compounds or both. Khalil and Chughtai (1983) however, observed a significant increase in the content of aspartic acid, serine, glutamic acid, proline and phenylalanine in the roasted nuts. This indicates that all the amino acids are not destroyed due to heat processing of groundnut, but only certain amino acids are more sensitive to heat treatments. Basha and Young (1985) had reported that oil roasting of the groundnut kernels caused a decrease in methionine rich proteins and their polypeptides. The results therefore, indicate that heat processing of groundnut results in loss of essential amino acids which are already deficient in groundnut proteins. Hence, the optimum conditions for roasting and frying need to be standardized to minimize such losses.

4.5 *In vitro* Protein Digestibility

The changes in *in vitro* protein digestibility of raw and heated kernels during storage are presented in Table 22. The data were analyzed for test of significance for individual factor (Table 23) and their interactions (Table 24). The heating of kernels decreased the digestibility of residual proteins significantly. The frying treatment was found to be

Table 22 : Effect of heat treatments on IVPD (%) in groundnut kernels during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	76.65	77.71	78.78	79.72	80.60	81.42	79.15
	27	76.65	76.79	81.31	82.22	83.16	82.63	80.46
Roasting	5	70.91	74.73	77.23	82.80	82.08	82.08	78.31
	27	70.91	79.57	81.62	82.36	82.80	83.33	80.10
Soaking + Roasting	5	71.46	71.58	75.73	81.94	82.39	83.30	77.73
	27	71.46	77.31	81.50	83.33	81.73	75.38	78.45
Frying	5	69.08	72.00	72.93	74.95	77.28	74.97	73.54
	27	69.08	71.70	75.94	78.87	72.87	72.16	73.44
Soaking + Frying	5	63.19	64.46	65.01	67.42	71.61	71.61	67.22
	27	63.19	71.35	71.49	71.62	69.21	66.49	68.89
Mean		70.26	73.72	76.15	78.52	78.37	77.34	75.73

Table 23 : Test of significance for change in IVPD in groundnut kernels due to heat treatments, temperatures and periods of storage

Factors	IVPD, %
Heat treatment	
Control	79.80
Roasting	79.20
Soaking + Roasting	78.09
Frying	73.49
Soaking + Frying	68.05
S.E.±	0.17
C.D. at 5%	0.47
Storage temperature, ± 2°C	
5	75.19
27	76.27
S.E.±	0.11
C.D. at 5%	0.30
Storage period, days	
0	70.26
30	73.72
60	76.15
90	78.52
120	78.37
150	77.34
S.E.±	0.18
C.D. at 5%	0.52

Table 24 : Interactions between various factors for IVPD

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature, ± 2°C	
	5	27
Control	79.15	80.46
Roasting	78.31	80.10
Soaking + Roasting	77.73	78.45
Frying	73.54	73.44
Soaking + Frying	67.22	68.89
S.E.±	0.24	
C.D.at 5%	0.67	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	70.26	72.09	73.94	77.37	78.79	78.68
27	70.26	75.35	78.37	79.68	77.95	76.00
S.E.±	0.26					
C.D.at 5%	0.73					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	76.65	77.25	80.05	80.97	81.88	82.03
Roasting	70.91	77.15	79.43	82.58	82.44	82.71
Soaking + Roasting	71.46	74.43	78.62	82.64	82.06	79.34
Frying	69.08	71.85	74.44	76.91	75.08	73.57
Soaking + Frying	63.19	67.91	68.25	69.52	70.41	69.05
S.E.±	0.41					
C.D.at 5%	1.2					

more deterimental as compared to roasting. The protein digestibility was however, found to increase significantly during storage (Table 24). Storage temperatures significantly affected the protein digestibility. All the interactions were found to be significant.

The protein digestibility was estimated by pepsin hydrolysis of residual proteins in this investigation. The roasting of groundnut kernels at 120°C for 60 min has been reported to cause protein denaturation (Balogun and Koch, 1979). The decrease in protein digestibility observed in the present study due to heat treatments may be due to denaturation of proteins. However, this does not reflect on the over all protein digestibility because only one proteolytic enzyme has been used for protein hydrolysis and furtner that protein digestibilities related only to the residual proteins. Additional experiments need to be done with experimental animals to assess the influence of heat processing on the protein digestibility. The storage of groundnut kernels, either raw or heat processed, showed an increase in the protein digestibility. This can be attributed to the partial degredation of storage proteins during storage. However, the mechanism of such chemical changes in the proteins during storage needs continued investigations.

Heat treatments to groundnut has been reported to cause an increase in content of crude proteins, soluble proteins but significant decrease in methionine and tryptophan, and *in vitro* protein digestibility. These results indicate that the storage proteins undergo complex chemical changes due to heat treatments and storage of groundnut kernels. The heat treatment are generally considered as desirable because it induces desirable flavour. Although, considerable genetic variation in the protein content and changes in protein properties due to heat treatments have been reported in the literature (Basha and Young, 1985), the time and temperature of heating and type of heat treatment (dry roasting or frying in oil) seem to be important in both desirable and undesirable changes in groundnut proteins. Since, both roasted and fried kernels are consumed directly, their protein quality is important. However, information on availability of storage proteins from heated kernels is meagre. The results of the present study indicate that roasting of groundnut kernels at 160°C for 30 min or frying of kernels in groundnut oil for 2 min decreased methionine and tryptophan contents but increased soluble proteins significantly.

4.6 Oil

The changes in crude oil due to heat treatments and storage of groundnut kernels are presented in Table 25. The effects of heat treatments, storage periods and storage

Table 25 : Effect of heat treatments on oil content (%) in groundnut kernels during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	48.49	48.51	48.54	48.56	48.55	48.57	48.54
	27	48.49	48.56	48.61	48.65	48.66	48.69	48.61
Roasting	5	50.83	50.84	50.86	50.86	50.87	50.88	50.86
	27	50.83	50.84	50.89	50.92	50.95	51.27	50.95
Soaking + Roasting	5	50.13	50.16	50.19	50.21	50.22	50.23	50.19
	27	50.13	50.20	50.22	50.26	50.39	50.35	50.26
Frying	5	52.29	52.28	52.30	52.29	52.33	52.37	52.31
	27	52.29	52.36	52.39	52.41	52.45	52.48	52.40
Soaking + frying	5	51.58	51.57	51.59	51.62	51.66	51.67	51.62
	27	51.58	51.60	51.63	51.66	51.69	51.76	51.65
Mean		50.66	50.69	50.72	50.74	50.78	50.83	50.74

Table 26 : Test of significance for change in oil in groundnut kernels due to heat treatments, temperatures and period of storage

Factors	Oil, %
Heat treatment	
Control	48.57
Roasting	50.90
Soaking + Roasting	50.22
Frying	52.35
Soaking + Frying	51.63
S.E. ±	0.01
C.D. at 5%	0.03
Storage temperature, ± 2°C	
5	50.70
27	50.77
S.E. ±	0.007
C.D. at 5%	0.020
Storage period, days	
0	50.66
30	50.69
60	50.72
90	50.74
120	50.78
150	50.83
S.E. ±	0.011
C.D. at 5%	0.032

Table 27 : Interactions between various factors for oil (%)

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature, ± 2°C	
	5	27
Control	48.54	48.61
Roasting	50.86	50.95
Soaking + Roasting	50.19	50.26
Frying	52.31	52.40
Soaking + Frying	51.62	51.65
S.E.±	0.015	
C.D.at 5%	0.041	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	50.66	50.67	50.70	50.71	50.73	50.74
27	50.66	50.71	50.75	50.78	50.83	50.91
S.E.±	0.02					
C.D.at 5%	0.05					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	48.49	48.54	48.57	48.61	48.61	48.63
Roasting	50.83	50.84	50.88	50.89	50.91	51.08
Soaking + Roasting	50.13	50.18	50.21	50.24	50.31	50.29
Frying	52.29	52.32	52.35	52.35	52.39	52.42
Soaking + Frying	51.88	51.59	51.61	51.64	51.68	51.72
S.E.±	0.026					
C.D.at 5%	0.071					

temperatures are given in Table 26, while the interaction effects are shown in Table 27. Although, storage period and temperature influenced the crude oil content of raw and heated kernels, the differences are not of significant order. Both roasting and frying of the kernels caused an increase in the crude oil content by about 2 percent.

An increase in the oil content due to heat treatments can be attributed to the loss of moisture in the kernel. The kernels fried in oil exhibited higher oil content as compared to roasted kernels. This can be attributed to absorption of oil by the kernels during frying process. Khalil and Chughtai (1983) reported that mean oil content in the kernels of groundnut cultivars increased from 47 to 48.5 percent during roasting at 150°C for 30 min. The results therefore, indicate that both heating and storage treatments do not significantly affect the crude oil content of groundnut kernels. Thus, results obtained in present investigation are in agreement with literature.

4.7 Saponification value

The changes in saponification value of oil in groundnut kernels due to heat treatment and during storage are presented in Table 28. The effects of factors such as heat treatment, storage temperature and storage period are summarised in Table 29 and their interaction effects are shown in Table 30.

Table 28 : Effect of heat treatment on saponification value of groundnut kernel oil during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	193.0	192.5	193.9	195.4	196.9	196.9	194.8
	27	193.0	192.5	195.4	196.9	198.4	199.9	196.0
Roasting	5	187.5	192.5	195.4	195.4	196.9	198.4	194.4
	27	187.5	194.0	195.4	199.9	201.5	203.0	196.9
Soaking + Roasting	5	185.7	191.1	196.9	198.4	199.6	199.9	195.3
	27	185.7	192.5	199.9	203.0	204.5	206.0	198.6
Frying	5	185.7	189.6	196.9	198.4	201.5	203.0	195.8
	27	185.7	195.5	201.5	206.0	209.0	212.1	201.6
Soaking + frying	5	181.3	191.1	198.4	199.9	201.5	204.5	196.1
	27	181.3	195.5	203.0	207.5	212.1	218.1	202.9
Mean		186.6	192.7	197.7	200.1	202.2	204.2	197.2

Table 29 : Test of significance for change in saponification value of groundnut kernel oil due to heat treatments, temperatures and period of storage

Factors	Saponification value
Heat treatment	
Control	195.40
Roasting	195.61
Soaking + Roasting	196.93
Frying	198.73
Soaking + Frying	199.50
S.E.±	0.34
C.D.at 5%	0.95
Storage temperature, ± 2°C	
5	195.27
27	199.20
S.E.±	0.215
C.D. at 5%	0.601
Storage period, days	
0	186.64
30	192.67
60	197.67
90	200.08
120	202.18
150	204.17
S.E.±	0.37
C.D.at 5%	1.04

Table 30 : Interactions between various factors for saponification value

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature ± 2°C	
	5	27
Control	194.8	196.0
Roasting	194.4	196.9
Soaking + Roasting	195.3	198.6
Frying	195.8	201.6
Soaking + Frying	196.1	202.9
S.E.±	0.5	
C.D.at 5%	1.3	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	186.6	191.3	196.3	197.5	199.3	200.5
27	186.6	194.0	199.0	202.7	205.1	207.8
S.E.±	0.5					
C.D.at 5%	1.5					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	193.0	192.5	194.7	196.2	197.7	198.4
Roasting	187.5	193.3	195.4	197.7	199.2	200.7
Soaking + Roasting	185.7	191.8	198.4	200.7	202.1	203.0
Frying	185.6	192.5	199.2	202.2	205.2	207.5
Soaking + Frying	181.3	193.3	200.7	203.7	206.8	211.3
S.E.±	0.8					
C.D.at 5%	2.3					

The saponification value was found to increase significantly during storage in raw and heated groundnut (Table 28). The saponification value was found to decrease in freshly roasted or fried kernels. However, it was subsequently increased during storage. Both storage period and storage temperature significantly increased the saponification value of oil in the kernel. An increase in saponification value due to storage period was more pronounced than the heat treatments and storage temperatures. The kernels stored at ambient temperature exhibited higher saponification value than those stored at 5°C (Table 29). All the interaction were found to be significant.

The saponification value of any oil is related to molecular weight of constituent fatty acids. An increase in the saponification value indicates the formation of low molecular weight fragments. The decrease in saponification value in the present study can be attributed to the loss of low molecular weight volatile fatty acids during heating. However, during storage, the kernel oil undergo hydrolytic and oxidative changes resulting in complex breakdown of fatty acids which may be responsible for an increase in saponification value of oil of the stored kernels. However, the quantitative increase in saponification value due to heating, storage temperature or storage period is not of significant order.

The results obtained on saponification value of different samples are in agreement with the literature values (Nagaraj, 1984; Narashimha Char et al., 1985). However, information on changes in saponification value due to heat processing in groundnut is grossly lacking.

4.8 Acid value

The changes in free fatty acid content due to heat treatments and storage of the kernels were investigated. The results are expressed in terms of acid value (Table 31). The influence of individual factor was analyzed (Table 32) and their interaction effects were studied (Table 33). Although, the crude oil content did not change due to heating and storage treatments, considerable qualitative changes seem to occur in the kernel oil, Both roasting and frying treatments markedly increased the acid value of the oil in the kernel. Similarly, when the unheated and heated kernels were stored upto 150 days, significant increase in acid value was observed. The acid value was found to increase from 0.25 to 0.73 and 1.18 in the unheated kernels during the storage at 5°C and 27°C, respectively. Similar trend was observed in the acid value during storage of heated kernels. An increase in acid value was more pronounced in fried kernels as compared to roasted kernels, and in the kernels stored at ambient temperature as compared to kernels stored at cold temperature. An increase in acid value was gradual up to 120 days of storage

Table 31 : Effects of heat treatments on acid value of groundnut kernels oil during storage

Heat treatment	Storage temperature ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	0.25	0.26	0.31	0.39	0.47	0.73	0.40
	27	0.25	0.26	0.43	0.53	0.62	1.18	0.54
Roasting	5	0.31	0.33	0.35	0.44	0.59	0.95	0.49
	27	0.31	0.50	0.53	0.56	0.65	1.60	0.69
Soaking + Roasting	5	0.39	0.35	0.40	0.44	0.58	1.29	0.57
	27	0.39	0.48	0.51	0.56	0.63	1.91	0.75
Frying	5	0.38	0.41	0.45	0.47	0.65	1.41	0.63
	27	0.38	0.52	0.55	0.58	0.68	2.21	0.82
Soaking + frying	5	0.35	0.42	0.47	0.51	0.66	1.27	0.61
	27	0.35	0.54	0.57	0.58	0.69	2.17	0.82
Mean		0.34	0.41	0.46	0.51	0.62	1.47	0.63

Table 32 : Test of significance for change in acid value of groundnut kernel oil due to heat treatment and period of storage

Factors	Acid value
Heat treatment	
Control	0.47
Roasting	0.59
Soaking + Roasting	0.66
Frying	0.72
Soaking + Frying	0.71
S.E.±	0.004
C.D. at 5%	0.010
Storage temperature, ± 2°C	
5	0.54
27	0.72
S.E.±	0.002
C.D. at 5%	0.007
Storage period, days	
0	0.34
30	0.41
60	0.46
90	0.51
120	0.62
150	1.47
S.E.±	0.004
C.D. at 5%	0.012

Table 33 : Interaction between various factors for acid value

A. Heat treatment X Storage temperature

Heat treatment	Storage temperatue, ± 2°C	
	5	27
Control	0.40	0.54
Roasting	0.49	0.69
Soaking + Roasting	0.57	0.75
Frying	0.63	0.82
Soaking + Frying	0.61	0.82
S.E. ±	0.005	
C.D. at 5%	0.014	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	0.34	0.35	0.40	0.45	0.59	1.13
27	0.34	0.46	0.52	0.56	0.65	1.81
S.E.±	0.006					
C.D. at 5%	0.020					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	0.25	0.26	0.37	0.46	0.55	0.96
Roasting	0.31	0.42	0.44	0.50	0.62	1.27
Soaking + Roasting	0.39	0.41	0.45	0.50	0.61	1.60
Frying	0.38	0.47	0.50	0.52	0.67	1.81
Soaking + Frying	0.35	0.48	0.52	0.54	0.68	1.72
S.E.±	0.009					
C.D. at 5%	0.024					

which was found to increase rapidly during subsequent storage upto 150 days. All the treatments such as heating, storage temperature and period significantly affected the acid value of oil (Table 32). All the interations were found to be significant.

Several investigators have studied the changes in oil of groundnut kernels during storage of raw and heated kernels (Sabale et al., 1975; St.Angleo and Ory, 1975; Uematsu and Ishii, 1981; How and Young, 1986). It has been reported that both free fatty acids and peroxide number increase considerably due to frying of oil (Murthi et al., 1979). The oil in stored nuts is known to undergo oxidative and lipolytic changes. The oxidative changes are catalysed by lipoxygenase, while the lipolytic changes are catalysed by the enzyme lipage. Raw groundnut stored for 5 months at $4^{o}C$ have showed appreciable peroxidation (St. Angelo and Ory, 1975). An increase in the acid value during storage of raw groundnut kernels observed in the present study can be attributed to the activities of these oxidative and hydrolytic enzymes. The high acid value in the kernels stored at ambient temperature as compared to the kernels stored at cold conditions can be due to more activity of these enzymes at ambient temperature.

The lipoxygenase responsible for lipid oxidation and lipid hydrolysis in raw groundnut are usually destroyed in

roasting and frying processes. Hence, heat processed groundnut should exhibit minimum lipid oxidation during storage. However, results indicated that the lipid oxidation or hydrolysis continued at similar rates during storage of heat processed groundnut. This indicates that the lipid oxidation seem to be catalysed by non-enzymatic processes during storage. The constituents such as metals, metalloprotein and salts have been implicated as catalysts of lipid peroxidation in roasted nuts during storage (St.Angelo et al, 1979). In roasted groundnut,the peroxide value was found to increase at faster rate than raw groundnut (St.Angelo and Ory, 1975). The roasted groundnut was found to get oxidised relatively rapidly during storage. Further, surface oil from dry roasted groundnut was found to get oxidised more rapidly than oil roasted kernels. These reports indicate that the heat processed groundnuts are equally susceptible to deteriorative chemical changes in oil as the raw groundnut kernels or perhaps even more succeptible than the raw kernels. It is thus clear that although, roasting and frying reduces the moisture content and induces desirable nutty flavour in the kernels, decreases their shelf-life by inducing oxidative changes in kernel lipids. Hence, the storage conditions for heat processed groundnut and its products need to be standardized to increase their shelf-life.

4.9 Iodine value

The changes in iodine value of the kernel oil due to heat treatments and storage are presented in Table 34. The

Table 34: Effect of heat treatments on the iodine value of oil in groundnut kernels during storage

Heat treatments	Storage temperatures ± 2°C	Storage period, days						
		0	30	60	90	120	150	Mean
Control	5	95.40	95.17	94.97	94.40	94.20	93.90	94.67
	27	95.40	94.90	94.67	93.90	93.67	93.10	94.27
Roasting	5	93.50	93.40	93.27	92.77	91.87	91.37	92.69
	27	93.50	93.27	92.40	91.37	90.10	89.30	91.66
Soaking + Roasting	5	92.87	92.60	92.40	91.60	90.87	90.50	91.81
	27	92.87	92.27	91.50	89.97	89.20	87.80	90.60
Frying	5	96.57	95.40	95.07	94.67	93.90	93.40	94.83
	27	96.57	95.20	94.80	93.40	92.40	91.50	93.98
Soaking + Frying	5	94.9	94.17	93.40	93.27	92.77	92.00	93.42
	27	94.9	93.90	92.90	91.77	90.70	89.97	92.36
Mean		94.65	94.03	93.54	92.71	91.97	91.28	93.03

Table 35 : Test of significance for change in iodine value of groundnut kernel oil due to heat treatments, temperatures and period of storage

Factors	Iodine value
Heat treatment	
Control	94.47
Roasting	92.18
Soaking + Roasting	91.20
Frying	94.41
Soaking + Frying	92.89
S.E. ±	0.027
C.D. at 5%	0.075
Storage temperature, ± 2°C	
5	93.48
27	92.57
S.E.±	0.017
C.D. at 5%	0.048
Storage period, days	
0	94.65
30	94.03
60	93.54
90	92.71
120	91.97
150	91.28
S.E.±	0.029
C.D.at 5%	0.083

Table 36 : Interactions between various factors for iodine value

A. Heat treatment X Storage temperature

Heat treatment	Storage temperature, ± 2°C	
	5	27
Control	94.67	94.27
Roasting	92.69	91.66
Soaking + Roasting	91.81	90.60
Frying	94.83	93.98
Soaking + Frying	93.42	92.36
S.E.±	0.038	
C.D.at 5%	0.110	

B. Storage temperature X Storage period

Storage temperature ± 2°C	Storage period, days					
	0	30	60	90	120	150
5	94.65	94.15	93.82	93.34	92.72	92.23
27	94.65	93.91	93.25	92.08	91.21	90.33
S.E.±	0.042					
C.D.at 5%	0.120					

C. Heat treatment X Storage period

Heat treatment	Storage period, days					
	0	30	60	90	120	150
Control	95.40	95.03	94.82	94.15	93.93	93.50
Roasting	93.50	93.33	92.83	92.07	90.98	90.33
Soaking + Roasting	92.87	92.43	91.95	90.78	90.03	89.15
Frying	96.57	95.30	94.93	94.03	93.15	92.45
Soaking + Frying	94.90	94.03	93.15	92.52	91.73	90.98
S.E.±	0.066					
C.D.at 5%	0.180					

influence of factors like heat treatment, storage period and storage temperature is calculated (Table 35) and their interaction effects are presented (Table 36). Storage of raw groundnut for 150 days both at ambient temperature and 5°C did not affect the iodine value of oil significantly. Similar results were indicated by Pattee et al.(1982). However, their was significant decrease in iodine value of the kernel oil due to heat treatments as well as during storage of heated kernels. The mean iodine value was found to decrease from 94.65 to 91.28 during 150 days of storage. All the interactions were found to be significant. The results indicated that, in general, iodine value is not markedly influenced during storage of raw groundnut and due to heat treatments. However, storage of heated kernels markedly reduced the iodine value of oil in the kernels.

The iodine value of any oil reflects on the degree of unsaturation in the constituent fatty acids. Groundnut oil consists of 80 percent unsaturated fatty acids. Hence, it is more susceptible to oxidative spoilage. The raw groundnut stored for a period of 150 days did not show a marked change in iodine value. This may be due to the fact that the oil present in the kernels is protected from oxidative agents by mechanism like compartmentation and presence of natural antioxidants in the kernel. When the nuts are roasted or fried, such compartmentation might have broken and the oil is exposed

to oxidative agents which has caused a decrease in iodine value during storage of heated kernels. However, this needs further investigations. The results obtained on iodine value of different samples are in agreement with the reported values(Pattee et al., 1982).

Heating of groundnut oil has been reported to cause significant losses in polyunsaturated fatty acids and iodine value (Rai and Narayanan 1984). Frying of the oil has also been reported to cause losses in natural antioxidant such as tocopherol (Duplesis et al., 1981). Storage of roasted kernels for 8 months under different atmospheric conditions have been reported to cause significant losses in polyunsaturated fatty acids such as oleic and linoleic acids, (How and Young, 1986). This may be responsible for decrease in iodine value in the heated kernels during storage.

Roasting and frying treatments to groundnut kernels induced considerable changes in proteins and oil. These changes continued during storage of heated kernels. The results indicated that both time and temperature of dry roasting and frying need to be standardized to minimize the loss in important amino acids. The heated kernels exhibit shorter shelf-life as compared to untreated nuts. This has been mainly due to oxidative changes in groundnut lipids which

induce undesirable flavour. The deteriorative changes in lipids become more pronounced when the storage exceeded 120 days. Further investigations are therefore essential to develop simple treatments to the heated kernels or standardize the storage conditions to minimize the loss in nutritional quality and eliminate the development of undesirable flavour during storage.

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Summary and Conclusions

5. SUMMARY AND CONCLUSIONS

Groundnut is the most important crop of India. India alone contributes over 26 percent of the world's production of groundnut. Although, a major proportion of produce of the country is crushed or solvent extracted to obtain edible oil, a significant amount of produce is also used for direct consumption. The groundnut kernels are commonly subjected to dry roasting and frying treatments. The roasted and fried kernels exhibit a pleasant flavour which make them acceptable snack by every one. Besides, the heated nuts are often used to prepare several traditional products such as chikki and variety of bakery items. It is therefore essential to know the effects of heat treatments on the quality of proteins and oil and, the shelf-life of such nuts. Investigations were therefore carried out to study the effects of the dry roasting and frying by commonly used procedures, on the chemical changes in proteins and oil of the groundnut kernels. The results obtained are briefly summarized in this section.

1. Both roasting and frying treatments reduced the moisture content in the kernels from 5.8 to about 2.2 to 2.9 percent.

2. The heat treatments to the kernels increased the contents of crude protein by about 4 percent. However, the storage of raw and heated kernels had no influence on the

content of crude protein. Both storage and heat treatments to the raw kernels markedly increased the soluble proteins. The soluble protein content was found to increase from 18.9 percent to about 25 percent during 150 days storage. Similarly heating of the kernels was also found to increase the content of soluble proteins to the same extent. Storage of heated kernels however, did not show a marked change in soluble protein.

3. Storage of the raw groundnuts upto 150 days resulted in significant loss in tryptophan and methionine contents. The heat treatments to the kernels also caused a significant decrease in content of these amino acids. Storage of the heated kernels further decreased the content of these amino acids. The losses were more pronounced during storage at ambient temperature than cold storage. The heat treatments to the kernels although improved the content of soluble proteins, the *in vitro* pepsin hydrolysis of the residual storage proteins was found to decrease in such nuts. The storage of both raw and heated kernels however, exhibited a significant increase in protein digestibility.

4. The heat treatments to groundnut kernels increased the crude oil content by about 2 percent. However, storage of raw and heated kernels had no significant effect on the content of oil.

5. The heating the kernels significantly decreased the saponification value of the kernel oil. However, the saponification value of the oil was found to increase significantly during storage of raw and heated kernels. The differences in saponification value were however not of significant order. The heat treatments and storage of raw and heated kernels decreased the iodine value of the oil. However, the differences were not pronounced. The changes in acid value of the oil were found to be much pronounced. The heat treatments to kernels significantly increased the acid value of the kernel oil. Similarly, there was a gradual increase in acid value during storage of raw and heated kernels upto 120 days. Acid value was found to increase rapidly when the storage period extended beyond 120 days indicating a faster deteriorative changes in the oil. In general, the heated kernels exhibited higher saponification value, lower iodine value and higher acid value.

6. Soaking of kernels in 20 percent salt solution before dry roasting and frying had no significant effect on the changes in storage proteins and oil of the kernels. Storage temperature exhibited a significant effect on the changes in proteins and oil in the groundnut kernels. The losses in methionine and tryptophan as well as an increase in acid value were found to be of lower magnitude in the nuts stored at 5°C as compared to those stored at ambient temperature.

The results indicated that although the roasting and frying induce the desirable texture and flavour to the groundnut kernels, these treatments caused significant loss in the protein and oil quality. The heated kernels exhibited shorter shelf-life as compared to raw kernels. Hence, both time and temperature of roasting and frying as well as storage conditions for heated kernels need to be carefully standardized. Further investigations on the changes in functional, and nutritional properties of the proteins and oil of heated groundnut kernels are essential.

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6. LITERATURE CITED

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Chapter Opener Page

Vita

7. VITA

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