DEVELOPMENT AND QUALITY EVALUATION OF SOY- JAMBUL SEED POWDER FORTIFIED BISCUITS

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BY

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THESIS

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This is to certify that **Miss Meghatai Madukar Patil** has successfully completed the comprehensive examination held on 18th May, 2010 as required under the regulation of Master of Engineering.

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CERTIFICATE - II

This is to certify that the thesis entitled **"Development and Quality Evaluation of Soy Jambul Seed Powder Fortified Biscuits"** submitted for the degree of Master of Engineering in the subject of Agricultural Engineering (Processing and Food Engineering) embodies bonafide research work carried out by **Miss. Meghatai Madhukar Patil** under my guidance and supervision, and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation has been fully acknowledged. The draft of the thesis was also approved by the advisory committee on 29^{th} May 2010.

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This is to certify that the thesis entitled "**Development and Quality Evaluation of Soy Jambul Seed Powder Fortified Biscuits**." submitted by Miss. Meghatai Madhukar Patil to Maharana Pratap University of Agriculture & Technology, Udaipur in partial fulfillment of the requirements for the degree of Master of Engineering in the subject of Agricultural Engineering (Processing and Food Engineering) after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination was satisfactory. We, therefore, recommend that the thesis be approved.

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ABSTRACT

Protein fortification is an area of current interest because of nutritional awareness of consumers, government guidelines and changing demographics. Efforts were made to prepare biscuits having different combinations of jambul seed powder fortified with soy flour in order to enhance the nutritional value. Heat and mass transfer coefficients during baking process of biscuits were studied. Textural and nutritional qualities of biscuits were also analyzed. The statistical analysis of quality evaluation was made and storage stability of product was also observed.

Biscuits from blend of maida, soy flour and jambul seed powder were prepared by mixing them in different proportions viz., 60%+34%+6%, 60%+32%+8% and 60%+30%+10% . The biscuits were baked in a thermally controlled oven at temperature of 140 ^{o}C for 30 min. The convective heat transfer coefficients for all combinations were almost similar as 18.9 W m^{-2} $^{o}C^{-1}$ and mass transfer coefficients varied from 7.02 x 10^{-12} to 11.65 x 10^{-12} kg.mol/m^2sPa. The goodness of the model for biscuit A_2 described with coefficient of determination (R^2) 0.9753 and root mean square error (E_{rms}) 0.1914.

The prepared biscuits were subjected to textural analysis and compared with the control biscuit containing 60% maida and 40% soy flour obtained from local market. The hardness and fracturability of biscuits were greatly affected by the composition. i.e. soy flour and jambul seed powder. As the level of jambul seed powder increased from 6 to 10%, the hardness of the biscuit reduced and vice versa. The fracturability value of biscuit composition 60% maida + 32% soy flour +8% jambul seed powder was greater than the other combinations. Therefore, the combination 60% maida + 32% soy flour + 8% jambul seed powder were more crispy or crunchy than the other two combinations.

The amounts of protein, carbohydrates and total sugar were maximum for sample A_1, whereas, fat, reducing sugar, and ash were rich in sample A_3. The moisture content of biscuits was ranged from 0.032 to 0.038 g H_2O/g DM. Colour, texture, appearance, flavour and overall acceptability of biscuits were found better in treatment A_2, whereas, better taste was found in A_1 composition. Biscuit composition A_2 was found significantly superior to the composition A_1 and composition A_3. Supplemented biscuits can be stored safely in plastic pouch at room temperature for 30 days without any adverse changes.

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CHAPTER I

INTRODUCTION

Though India is considered as the third largest producer of Biscuits after USA and China the production of biscuits in the country, both in the organized (0.44mn tons) and unorganized sectors (0.66mn tons), is estimated to be around 1.1 million tonnes. The per capita consumption of biscuits in India is only 1.3 kg per annum as against about 15 kg per annum in developed countries (Baisya, 2008). The annual turnover of the organized sector of the biscuit manufacturers (as at 2001/2002) is 4.35 crores Indian Rupees. The biscuit market in the recent years has witnessed a little higher growth at around 8-10% pa.

Biscuits are amongst the lowest cost processed food in the country when compared to other Indian sweets and salted snacks. Biscuits are easy to use during travel or at home because of its availability in a variety of pack sizes. It is no longer viewed as a luxury tea time snack but essential daily food component for an average Indian household. Biscuits of different brands such as Glucose, Marie, Cream, Cracker etc are popular in all age groups as they are cheap as compared to many other ready-to-eat food items, enjoy longer shelf life and provide nutrients.

To solve the problems of malnutrition as a result of an unbalanced diet in a developing country, there is a need for a cheap and suitable protein source as food fortifier. As consumer demand grows for low-fat healthy foods, the use of soybean as key ingredients can be expected to expand. With addition of soy flour, the consumers can get additional nutrients as soy is high in protein but low in fat and carbohydrates. Also addition of soy flour improves the nutritional quality as it increases water absorption, helps in emulsification of fats and other ingredients (Messina, 2002). Many a times, biscuits are also fortified with thiamine, riboflavin, nicotinic acid, vitamin A, vitamin D and calcium to improve its nutritional quality. Protein rich biscuits have been found to be useful in diet therapy for treating of nutritional oedema syndrome in children as well as adults. Hence, high protein biscuits can be an excellent nutritional snack food vehicle with a high degree of acceptability, particularly children in both rural and urban areas.

The world soybean production is currently 219.8 million tonnes out of which India produced 9.3 million tonnes constituting about 4% of the total world production. Out of this production, less than 10% is directly used for human consumption (Gandhi, 2006). Soybean is an excellent source of soy protein (35-40%), hence the seed is the richest in food value of all plant foods consumed in the world (Kure *et al*. 1998). Nutritive value of soybean appears to have no equal in supplying protein, fat, mineral salts like calcium, magnesium phosphorus and to some extent vitamins A, D and B complex (SOPA, 2001). Techniques have been evolved even for making typical Indian products from soybean, such as soy-sattu, soy-suji, soy-sev, soy-idli, soy-dosa, soy-dhokla, soy-chakli, soy-shrikhand, soy-rasogulla, soy-gulabjamun, etc (Ali, 1991). Baked items like biscuits, buns, muffins, cakes and bread can also be fortified with soybean to enhance their protein content.

The hypocholesterolemic effects of soy protein have been demonstrated in clinical studies for more than 30 years although until recently, few health professionals were aware of this literature (Messina, 2002). Studies on the health benefits of soybean have indicated that it reduces the risk of heart diseases; is helpful in preventing cancer; and suits those suffering from diabetes and lactose intolerance. Another important aspect of soy protein is combating osteoporosis and relieving menopause symptoms. The protein content of soy biscuits is usually 11 to 12 per cent, against 7 to 8 per cent in normal biscuits available in the market. If these biscuits are enriched with protein from soybean or locally produced millets, can help the tribal or poor in maintaining their health. The need is to create awareness about soy products and their benefits and make available such products in the market through small scale decentralized soy food processing enterprises.

The jambul seeds contain Jamboline, Glucoside and Ellagic acid which is believed to have the power to check the pathological conversion of starch into sugar in cases of increased production of glucose (Shroti, 1962). It reduces the quantity of sugar in urine and allays the unquenchable thirst. Jambul seed is also used for the treatment of asthma. Use of Jambul seeds for Diabetes was also confirmed by "Shaligram Nighantu Pharmacopia" in ancient India. It has a high source in vitamin A and vitamin C. The fruit and seeds of jambul is used in the treatment of diabetes.Jambul is also a useful remedy for stomach cramps and flatulence. The seeds of jambul, powdered and consumed with half a cup of water, twice a day cures diarrhoea & dysentery. Jambul seed powder is an effective food remedy for bleeding piles. The leaves and bark are used for controlling blood pressure and gingivitis (Sukia *et al.*, 1987). Not only the fruit, but the seed, the leaves and bark of the jamun tree are believed to have medicinal properties. The bark of the tree has high astringent properties and is therefore used for gargles and as a mouthwash.

1.1 Scope and Justification of Study:

A new type of Jambul seed powder-containing biscuit has been developed and incorporated into the diabetic diet. It has been found to be effective in reducing the postprandial rise in the blood glucose level and in improving glycaemic control (Bhargava, 1991). These biscuits can be used for dealing with the symptoms of indigestion (Aiman and

Shorti, 1962). These biscuits can also stimulate the liver functions (Shorti, 1962). As these biscuits contain high fiber and low calories so it is an excellent nutritional snack food with a high degree of acceptability especially to diabetic patients. If these biscuits are enriched with protein of soybean and jambul seed powder can help not only children's health but also maintaining health of diabetic patients. There is an ever increasing demand for high protein biscuits for therapeutic value. Nutritionally, biscuits can be easily fortified with protein – rich flours to provide a convenient food to supplement the poor quality diets. Protein, low calories and high fiber fortified biscuits contain nutrients in concentrated forms and can be used for feeding programmes in institutes such as day – care centers and schools or as emergency rations (Singh *et al*. 2000).

Texture properties of most of bakery products are affected by their structure. The microstructure of these products consists of a continuous protein matrix and status of a loose and open structure with space occupied by the fat globules dispersed through the protein network. The structural arrangement of the network determines the textural characteristics and is affected by the factors such as the composition and manufacturing process. Process parameters such as coagulant type and its concentration, coagulation temperature, pressing variables such as pressure and time of pressing, rotational speed in case of centrifugal pressing are very important for obtaining desirable characteristics.

The knowledge of textural properties are important in many problems associated with the design of specific machine and analysis of behavior of products during handling and processing. Characterisation of food texture commonly falls into two main groups, based on sensory and instrumental methods of analysis. Sensory analysis includes use of the senses of smell, taste, and tongue, palate and teeth in the mouth. As would be expected, sensory methods of analysis are subject to wide variability, though this variability can be reduced by using trained assessors. It is sometimes preferable to use instrumental methods of assessing food texture rather than sensory analysis because they can be carried out under more strictly defined and controlled conditions. Furthermore, problems of experimental variability are more likely to be caused by sample heterogeneity than by instrumental imprecision. Another reason for instrumental analysis may be that often changes in ingredient levels cause several simultaneous changes in product characteristics. Finally, since the textural properties of soy-jambul seed powder biscuit play an important role in influencing quality and consumer acceptability and as such a very little research work has been reported on textural properties of food materials. Therefore, this project has been undertaken to prepare soy jambul seed powder biscuits, to study the nutritional analysis of developed biscuits using standard methods and to study storage stability of biscuits. Therefore, in the view of facts mentioned above, the present investigation was undertaken with following specific objectives:

1. To develop biscuits with fortification of soy flour and jambul seed powder.
2. To study physical and textural properties of developed product.
3. To evaluate quality of developed product.

CHAPTER II

REVIEW OF LITERATURE

A comprehensive review is mandatory in any research endeavor. This requires thorough efforts on the part of the investigator to select relevant subject matter, to organize and to report it systematically. This chapter deals with brief account of literature, which has direct and indirect bearing on the specific objectives of the investigation.

This chapter deals with the research findings reported by scientists, related to the development of food products specially biscuits, textural properties of the biscuits, quality analysis of the biscuits, heat and mass transfer coefficients and storage stability of finished product.

2.1 Soybean:

Soybean (*Glycine max*) is one of the nature's wonderful nutritional gifts. It is considered as "Gold" obtained from soil and is thus rightly called today the “Gold Nugget of Nutrition” owing to its nutritional composition (Singh et al., 2001). A cream-coloured oval bean about the size of a common pea, Soybeans belong to the legume family and are native to East Asia. Main varieties are panjab-1, Braig, Ankur, Gaurav, Jawahar (indiamart.com).

2.2 Area and Production of Soybean:

Soybeans are the most qualitatiively important grain legume in the world, with an average of 182 MT of seeds produced annually between 2000 and 2004, mainly in the USA (about 43%), and in Central and South America (42%). Five countries (USA, Brazil, Argentina, Paraguay and Uruguay) are responsible for 88% of soybean seed exports and 90% of soybean meal exports (www.grainlegume.com). In India Madhya Pradesh, Maharashtra, Rajasthan and Andhra Pradesh are the major producers of soybeans. Madhya Pradesh with 3.5-4.5 million tons of production followed by Maharashtra and Rajasthan are the major producers of soybean in India. In Uttar Pradesh the soybean cultivation has started gearing up in the recent years. The area, production and yield of soybean from 1970-71 to 2005-06 are presented in Table 2.1.

Table 2.1: Area, Production and Yield of Soybean.

Year	Area (Million Hects)	Production (Million Tonnes)	Yield (Kg/ha)
1970-71	0.03	0,01	426
1972-73	0.03	0.03	819
1973-74	0.05	0.04	829
1974-75	0.07	0.05	768
1975-76	0.09	0.09	975
1976-77	0.13	0.12	988
1977-78	0.2	0.18	940
1978-79	0.31	0.3	975
1979-80	0.5	0.28	568
1980-81	0.61	0.44	728
1981-82	0.48	0.35	741
1982-83	0.77	0.49	637
1983-84	0.84	0.61	735
1984-85	1.24	0.95	768
1985-86	1.34	1.02	764
1986-87	1.53	0.89	584
1987-88	1.54	0.9	582
1988-89	1.73	1.55	892
1989-90	2.25	1.81	801
1990-91	2.56	2.6	1015
1991-92	3.18	2.49	782
1992-93	3.79	3.39	894
1993-94	4.37	4.75	1086
1994-95	4.32	3.93	911
1995-96	5.04	5.1	1012
1996-97	5.45	5.38	987
1997-98	5.8	6.53	1126
1998-99	6.2	6.83	1245
1999-00	6.37	5.28	1024
2001-02	5.9	6.35	998
2002-03	6.54	5.24	1002
2003-04	6.32	5.89	989
2004-05	6.89	6.56	1020
2005-06	6.25	6.45	963

(Sourse: Baisya,2008)

2.3 Chemical Composition and Nutritive Value of Soybean:

The chemical composition of soybean varies with cultivars, stage of maturity and season. It is an excellent source of protein, dietary fibre, carbohydrates and minerals. Together, oil and protein content account for about 60% of dry soybeans by weight; protein at

40% and oil at 20% (Table 2.2). It is a rich source of certain minerals like calcium, phosphorus and iron which are necessary for human health.

Table 2.2: Proximate Composition of Soybean (per 100 g)

Constituent	Quantity (g)	Constituent	Quantity (g)
Energy	1,866 kJ (446 kcal)	Tryptophan	0.391 g
Protein	40.49 g	Methionine	0.547 g
Carbohydrates	20.16 g	Threonine	1.766 g
Dietary fiber	7.3 g	Leucine	1.309 g
Fat	19.94 g	Lysine	2.706 g
Arginine	1.153 g	Histidine	1.097 g
Alanine	1.715 g	Aspartic acid	0.112 g
Proline	1.379 g	Serine	0.357 g
Vitamin B6	0.377 mg (29%)	Vitamin C	6.0 mg (10%)

(Sourse:Baisya, 2008)

2.4 Jambul:

Jambul (*Syzygium cumini*) is an evergreen tropical tree in the flowering plant family Myrtaceae, native to Bangladesh, India, Pakistan and Indonesia. It has two varieties. One is oval and another is round in shape. Mainly for its fruit, jambul is a typical example of a plant used for food and for medicine. The jambul fruit, also known as rose apple or java plum, is a well known common fruit, grown all over India. The fruit has a combination of sweet, mildy sour and astringent flavour and tends to colour the tongue purple.

2.5 Chemical Composition and Nutritive Value of Jambul Seed:

70% of the jambul fruit is edible and glucose and furctose are the major sugars found in the ripe fruit. Sucrose is completely absent from the fruit. The fruit is laden with a large number of minerals, and provides fewer calories, as compared to other fruits. The seed of the fruit is also rich in protein and carbohydrates and traces of calcium have also been found.

Table 2.3: Proximate Composition of Jambul (per 100 g)

Food Value		Minerals and Vitamins	
Constituent	**Quantity (%)**	**Constituent**	**Quantity (mg)**
Moisture	83.7%	Calcium	15 mg
Protein	0.7%	Phosphorus	15 mg
Fat	0.3%	Iron	1.2 mg
Minerals	0.4%	Vitamin C	
Carbohydrates	14.0%	Small amount of Vitamin B Complex	
Fibre	0.9%		
*Value per 100 gm's edible portion		Calorific Value	62 kcal/kg

(Source: Bela *et al.* 2007)

2.6 Development of Fortified Biscuits:

Malnutrition is the deficiency of nutrients in human body which affects the body growth adversely. In rural areas, malnutrition problem is severe especially in women and children because of traditional foods having low nutritive value. Food products developed by modern technology (which have high nutritive value) are costly and are beyond the purchasing power of tribal hence it is required to improve the nutritional value of traditional food products. Soy flour as well as jambul seed powder is rich in nutrients which can be fortified for development of nutritious and value added food products.

Patel and Rao (1996) studied different properties of biscuits containing varying proportions (0, 5, 10, 15, 20 and 25%) of heat treated and germinated black gram flour (BGF) separately. The result showed that the diameter and thickness of biscuits gradually reduced with increasing quantity of BGFs. The hardness values significantly increased on incorporation of 25% of all the three differently processed BGF. The organoleptic studies inferred that 10% of untreated, 15% of heat treated and 10 % of germinated BGFs were optimum acceptable levels for fortification. Use of 35 % sugar, 22.5% fat, and 0.5% sodium stearoyl-2 lactylate improved significantly the biscuit baking quality. In general, biscuits made from composite flour-containing 15 % heat treated BGF, and optimized biscuit formulation were better than those made from 10 % of untreated or germinated BGF.

Singh *et al.* (1996) studied the biscuit prepared from the blends containing varying proportions (0, 10, 20, 30, 40, and 50%) of defatted soy flour (DSF).The traditional creamery method was used to determine diameter, thickness, spread ratio, spread factor, hardness and sensory characteristics. The thickness of soy-fortified biscuit increased, where as diameter, spread factor of biscuits decreased with the increasing level of DSFs. The results showed that a maximum of 20% DSF can be incorporated to prepare acceptable quality biscuits.

Singh *et al*. (1997) evaluated soy-fortified biscuits by comparing the effects of various levels of fat (20, 25, 30 and 35%) and sugar (28, 31, 34, 40 and 43%), using the traditional creaming method. With increasing levels of fat and sugar in the formulation, attributes such as weight, diameter, spread ratio and percent spread factor of biscuits increased, whereas thickness and hardness of the product decreased irrespective of soy flour incorporation. The results of sensory evaluation revealed that the scores for texture and overall acceptability in control as well as in soy biscuits improved upto 30% fat level and thereafter decreased. However, the effect of increasing levels of sugar on the texture and overall acceptability scores increased upto 37% in control biscuits and thereafter decreased.

Onweluzo and Iwezu (1998) evaluated biscuits prepared from different blends of wheat-soybean and cassava-soybean flours. Cassava-soybean flour biscuits (1:1) had higher protein and calorific values than wheat flour biscuits. Wheat-soybean flour (1:1) biscuits had twice the protein value of the wheat flour biscuits and higher calorific value. The control wheat flour biscuits showed a higher spread ratio of 1.8 and lower break strength of 1.8 kg. The cassava-fermented soybean (1:1) biscuits showed comparable crispness as break strength (1.7 kg) with the control, but had half the spread ratio of the control. The wheat-soybean biscuits (1:1) had low spread ratio (1.0) and high average break strength of 2.6 kg. Biscuits containing more than 50% fermented soybean flour showed low texture and flavor scores.

Singh *et al*. (1998) standardized soy biscuits with varying composition of baking powder (0.5, 0.8, 1.1 and 1.4%) and skim-milk powder (0.8, 1.6, 2.3 and 3.1 %), using the traditional creamery method. On the basis of good spread ratio and maximum overall acceptability score, baking powder at 0.8% level and skim milk powder (SMP) at 1.6 % level were incorporated in the formulation of soy biscuits. Then optimum levels of Sodium Stearoyl-2-Lactylate (SSL) (0.3 or 0.5 %) and Glyceryl Mono Stearate (GMS) (0.5, 0.75 or 1.0 %) were incorporated in the formulation with three different levels of fat (20, 25 and 30%). They reported that the spread ratio and overall acceptability increased, whereas hardness of the product decreased with increasing levels of SSL or GMS. Further, on the basis of maximum spread ratio and acceptability scores, SSL and GMS in soy biscuits were standardized at 0.5 and 1.0% levels, respectively. It was observed that both SSL and GMS could be used as shortening replacer in soy biscuits, since biscuits containing 25 % fat with standardized levels of GMS and SSL had almost the same quality characteristics as those of biscuits containing 30 % fat without emulsifiers.

Singh *et al.* (2000) evaluated the wheat flour and soy-fortified biscuits prepared with standardized levels of ingredients and emulsifiers (Stearoy-2-Lactylate and/or Glyceryl Mono Stearate for chemical composition, in vitro digestibility and protein efficiency ratio (PER). Addition of 20% defatted soy flour in the recipe increased the protein, ash, crude fibre, calcium, phosphorus, iron, sugar (reducing and non-reducing) and available lysine contents in biscuits. No trypsin inhibitor activity was found in soy biscuits but had marginally higher non-enzymatic browning than the control samples. The in vitro digestibility values of control and soy biscuits were found to be 68.46 and 83.82% respectively. The PER of soy biscuits (1.41) had improved to a great extent, which could be attributed to the higher levels of protein and available lysine content in defatted soy flour.

Gandhi *et al*. (2001) evaluated replacement of wheat flour up to 40% level with defatted soy flour in the standard sweet biscuits recipe which increased the protein content from 6.5 to 14.8%, bending hardness from 3.60 to 9.80N and cutting hardness from 6.02 to 23.04N of the biscuits. Sensory evaluation showed that all of the biscuits from various blends were acceptable with no significant differences among them.

Khedkar (2004) developed and evaluated the physical properties and sensory evaluation of soy fortified biscuits. The thickness increased by 44.96% after baking while the increase in diameter was only 2.08 %. The decrease in spread ratio was 42.02 %. The colour, texture and appearance were found to be best for composition 60% maida+10% sorghum flour+20% soybean flour and the flavour, taste and overall acceptability were best for composition 60% maida+30% sorghum flour+10% soybean flour. All the organoleptic qualities were significantly affected at 5% level. The composition (60% maida+10% sorghum flour+30% soybean flour) was best for nutritional evaluation of biscuits.

Meena and Meena (2004) developed different composition as a value added product by fortifying biscuits, laddu and sattu with soy flour, sorghum, refined wheat flour, bengal gram and ground nut. The result showed that the thickness and diameter of biscuits increased by 71 % and 5.55 % respectively. Biscuits having 5.8 % soybean, 46.6 % refined wheat flour, 5.8 % sorghum were liked more by consumer panel. Laddu and sattu prepared by using 13 %, soybean, 26 % bengal gram, 13 % sorghum were liked by consumer panel. The overall acceptability of sattu (7.32) was greater than laddu (6.82) while having the same composition.

Akubor and Ukwuru (2005) developed biscuits from soybean flour (SF) and cassava flour (CF) on a replacement basis (CF/SF, 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 0:100) and evaluated for their protein and fat contents, and physical and sensory properties. The protein and fat contents of the flour blend biscuits increased with increasing levels of SF. The width, thickness and spread ratio were not significantly ($p > 0.05$) different among the flour blend biscuits. Biscuits weights, however, decreased with increased SF substitution. Sensory evaluation indicated that there were no significant differences in color, texture, flavor, taste and overall acceptability of the flour blend biscuits. At 50% level of SF incorporation, biscuits had higher scores for all the sensory attributes evaluated.

Rababah *et al*. (2006) evaluated the effectiveness of substituting different concentrations of chickpea flour, bean flour, or isolated soy protein (ISP) on the physicochemical and sensory properties of biscuits. Fortification processes were conducted by substituting specified concentrations (3%, 6%, 9%, and 12%) of both broad bean and chickpea and (3%, 6%, and 9%) ISP from the total percent of wheat flour (100%). Proximate chemical analysis results of biscuits showed that fortification increased protein contents from 16.57% to 22.84%. Results indicated that fortification decreased spread factor compared with the control. Sensory and instrumental color results showed that fortified chickpea increased the lightness, while fortification with broad bean or ISP increased the darkness.

Vitali *et al*. (2006) studied the effect of modified wheat flour based tea–biscuit. In a biscuit phytate levels, iron content and in vitro availability was investigated. Standard recipe was enriched by addition of dietary fibers and integral raw materials. The average phytic acid content ranged from 0.138 to 1.084 g/100 g dry matter of biscuit. Iron content of investigated samples ranged from 0.655 to 4.222 mg/100 g biscuit and iron availability varied from 26% up to 56%. Data analysis showed that changes in sample composition resulted in significant changes in phytic acid, total and available iron content related to standard sample.

Anupama *et al*. (2007) developed nutritionally enrich the apple pomace biscuits, optimized apple pomace-black soybean flour-wheat flour mix was added. Levels of ingredients were optimized in apple pomace biscuits, black soybean flour biscuits and apple pomace: soy flour (50: 50) biscuits. Apple pomace : soy flour, baking powder, sodium bicarbonate and ammonium bicarbonate were the four optimized variables based on the result obtained from the four responses selected i.e. physical parameter % spread factor, rehological parameters hardness and fracturability and sensory parameter overall acceptability.

Frank *et al*. (2007) studied the effect of three different carbohydrate-based fat substitutes in a baking powder biscuit. The various fat replacers were substituted for fat in the biscuit formula at a rate of 33%, 66% and 100%. Comparable objective and sensory results indicated that crust colour was lightened significantly with increased use of the individual fat substitute. Tenderness decreased as substitute use increased when biscuits were rated by the sensory panel, but opposite results were obtained by the texture analyser. Objective analysis indicated that an increase in use of the fat substitute produced a moister biscuit, which was in agreement with the sensory panel.

2.7 Heat and Mass Transfer Coefficients:

Houova and Topinka (1985) determined the contact heat transfer coefficient between heating plate and product surface using four types of minced meat patties. The heat transfer coefficients measured in the range 200 to 1200 W m^{-2} K^{-1}, depending on product type, contact plate temperature, contact pressure and stage in the heat treatment.

Savoye *et al*. (1992) developed a heat and mass transfer model to describe a natural gas indirect fired baking tunnel-oven. A study of the state of the art of biscuit baking and modelling of baking ovens suggested the choice of structure of the dynamic model. The model includes heat transfer from gas combustion to the biscuits. In the baking chamber, conduction (for the band conveyor), convection and radiation fluxes are considered. Mass transfer coupled with heat transfer is described.

Kondjoyan and Daudin (1997) studied the effect of heat and mass transfer coefficients at the surface of a pork hindquarter for common air flow properties encountered in chillers and dryers. Air velocity and turbulence intensity ranged from 0.4 to 5.0 m s^{-1} and 1.3% to 30%, respectively. The local values of the transfer coefficients can be very different from one location to another at the body surface. An inversion of the air flow direction slightly affects the value of the mean transfer coefficients. An increase in turbulence intensity from 1.3% to 6% decreased the mean transfer coefficients values while a further increase in Tu increases those values.

Baik *et al*. (1999) evaluated surface heat flux and effective surface heat transfer coefficients during baking of two cakes in a tunnel-type multi-zone industrial oven. An average 75–80% of total heat flux was counted as radiation heat. Air-mass temperature outside the boundary layer was determined from the experimental temperature profiles over the h-monitor top plate. In the range of baking temperatures (186–225.8^{0}C), relative air velocities (0.02–0.437 m/s) and absolute humidities (0.0267–0.0428 kg H_2O/kg dry air) heat transfer coefficients were 20 to 48.0 W/m^{2}K.

Anwar and Tiwari (2001) studied the convective heat transfer coefficients of six crops, namely, green chillies, green peas, white gram, onion, potato and cauliflower under forced convection drying. Data obtained from experimentation under open and closed simulated conditions have been used to determine values of the coefficients C and n and, consequently, convective heat transfer coefficient. The data have also been analysed in terms of percent uncertainty.

Broyart and Trystram (2001) presented a steady-state mathematical model to calculate heat and mass transfers during the baking of thin cereal products (biscuit type) in a continuous, indirect, gas-fired oven. The temperature and composition of the baking atmosphere and biscuit on a transversal oven section are assumed to be uniform. The model takes account of heat transfer by radiation, convection and conduction as well as product–water phase change. For mass balances, the model takes account of the possible condensation of steam from baking atmosphere to product surface and product drying.

Tiwari *et al.* (2003) studied the effect of convective mass transfer coefficient during drying of jaggery in a controlled environment. The jaggery was dried in the roof type even span greenhouse with a floor area of 1.2×0.8 m^2 in natural and forced convection mode at atmospheric pressure till it attained almost no variation in mass. The experimental data of mass evaporated, temperatures of jaggery, air temperature and relative humidity were measured and the data used to evaluate the convective mass transfer coefficient by regression analysis. It was found that the convective mass transfer coefficient is a strong function of mass of jaggery, temperatures and relative humidity for a given size of greenhouse.

Jain and Tiwari (2004) studied the convective mass transfer coefficient and rate of moisture removal from cabbage and peas for open sun drying and inside greenhouse. The hourly data for the rate of moisture removal, crop temperature, relative humidity inside and outside the greenhouse and ambient air temperature for complete drying have been recorded. These data were used for determination of the coefficient of convective mass transfer and then for development of the empirical relation of convective mass transfer coefficient with drying time under natural and forced modes. The empirical relations with convective mass transfer for open and greenhouse drying have been compared. The convective mass transfer coefficient was lower for drying inside the greenhouse with natural mode as compared to open sun drying. Its value was doubled under the forced mode inside the greenhouse drying compared to natural convection in the initial stage of drying.

Jain (2006) studied the convective heat and mass transfer coefficients for solar drying (natural convection) of Indian minor fish species, such as prawn and carp. The hourly data for the rate of moisture evaporation, fish temperature and relative humidity of surrounding air have been recorded for complete drying of fish. These data were used for determination of the coefficients of convective heat and mass transfer. Convective heat and mass transfer coefficients are mainly dependent on the rate of moisture transfer under the drying process, which have been determined as the function of drying time and moisture content of fish. The convective mass transfer coefficient varied from 8.958 to 0.402 μms^{-1} for prawn and from 7.613 to 0.320 μms^{-1} for chelwa fish. The empirical rational models were developed to predict the convective heat and mass transfer coefficients with moisture contents. The goodness of fit of the model described higher coefficient of determination 0.9996 and low root mean square error 0.05079 for drying of chelwa fish.

Kumar *et al*. (2007) studied an open sun and greenhouse drying of onion flakes. The onion was continuously dried for 33 h both in open sun and in the roof type even span greenhouse with floor area of 1.2×0.78 m^2. The data used to determine values of the constant 'C' and exponent 'n' by regression analysis and, consequently, convective mass transfer coefficient. It is observed that there is a significant effect of mass on convective mass transfer coefficient for open as well as greenhouse drying.

Haque (2007) described analysis of heat and mass transfer coefficients for a single board of Pinus radiata (D. Don) timber over a range of high temperature and superheated steam drying conditions. The calculated heat transfer coefficients were in the range 20 to 60 W m^{-2} K^{-1}. The mass transfer coefficients were of the order of 2 x 10^{-8} to 3 x 10^{-7} kg m^{-2} s^{-1}, based on the vapor pressure difference, and of the order of 0.002 to 0.04 m s^{-1} (expressed in terms of mass transfer velocity) based on vapor concentration difference between the surface of the board and the bulk drying medium.

Gavrila *et al*. (2008) developed a dynamic mathematical model, based on physical and transport properties and mass and energy balances, for the simulation of unsteady convective drying of agricultural products (fruits and vegetables) in static bed conditions. The local material averaged drying rate and the heat flux depend on local air humidity and temperature, as well as local mass and heat transfer coefficients in interaction with the moisture and temperature distribution inside the material. The model utilized water sorption isotherm equations and the change in solid density due to the shrinkage phenomenon.

2.8 Textural and Engineering Properties of Biscuits:

Foods have several textural properties which contribute to the sensory experience. The texture refers to the structure and arrangement of particles in a substance. Among all the quality parameters, the texture of many foods is most sensitive and changeable especially during cold storage, freezing, thawing, cooking and other processes. It is an attribute that affects processing and handling, influences food habits and affects shelf-life and consumer acceptance of foods. Terms like hard, soft, pasty, crumbly, rubbery, chewy, fragile, weak, mealy, coarse have been used to describe texture of biscuit.

Szczesniak *et al.* (1963) performed texturometer evaluation of mechanical parameters of foods and found that it correlated well with scores obtained by the use of a trained texture profile panel. This correlation indicated that the General Foods texturometer had the capacity to measure certain characteristics with a type and intensity similar to those perceived by the human mouth.

Zoulikha *et al*. (1997) studied effect of three ingredients sugar, fat and water in soy biscuits on mixing, rheological behavior and size after cooking. Addition of sugar decreases dough viscosity and relaxation time. Addition of fat softens the dough and decreases the viscosity and relaxation time. Increase in water leads to a significant decrease in the dough viscosity and a slight reduction of the relaxation time. Finally, varying the protein content of the flour from 14 to 20% induces major changes at the mixing stage in the rheological properties of the dough and in the dimensions and texture of the biscuits.

Brown *et al*. (1998) reported nineteen ordinary consumers who assessed the hardness, crunchiness and crumbliness of a series of biscuits exhibiting texture differences. Chewing inverse correlation between hardness and crumbliness and weaker but significant correlations between hardness and crunchiness (positive) and between crunchiness and crumbliness patterns were obtained from all of the subjects eating the same samples by simultaneous recording of masticatory muscle activity and jaw movement. The hardness/crumbliness dimension was well represented by several instrumental measures of the mechanical properties of the samples and by several descriptors assessed by a trained sensory panel. Chewing data indicated an increase in masticatory muscle effort between the first 5 chews and the next 5 chews with a subsequent decline in effort to the end of the chewing sequence.

This was associated with a transfer of effort from a principally compressive force during the initial chews, to a mixture of compressive (fracture) force and grinding (shear) force during later chews. Mastication of the harder and crunchier samples required more total chewing effort. This study indicates the importance of the temporal changes occurring in the sample during mastication to perception of textural characteristics.

Senthil *et al*. (2002) blended wheat flour and defatted soy flour in the ratio of 65:20, 60:25, 55:30 and 45:40 for preparation of biscuits. Farinograph characteristics of flour blends showed that as the proportion of soy flour increased there was a slight increase in water absorption and decrease in dough stability. In fried savoury snacks the protein content increased gradually from 20.75 to 27.50%. When the proportion of soy flour was raised from 20 to 40% in the blend, the corresponding rise in protein content in fried sweet snack was from 15.75 to 21.75%. The products were subjected to sensory evaluation by adopting preference ranking test and analyzing the data using Friedman's test and Wilcoxon Mann–Whitney U Test. In sweet snack, irrespective of levels of soy flour significant difference was not found for all the attributes namely color, appearance, texture, aroma and taste. Hardness of fried snacks was measured as force required for 50% compression.

Zoulias *et al*. (2002) used carbohydrate or protein-based fat mimetic to replace up to 50% of fat in cookies. The effect of the type of fat mimetic and of the percentage of fat replacement on textural behaviour of the products was studied by compression tests. The stress–strain curves obtained were fitted by an exponential equation containing as parameters the maximum stress (σ_{max}), the maximum strain (ε_{max}) and a viscoelastic exponent (f). A simple mathematical model for σ_{max} and the ratio $\sigma_{max}/\ \varepsilon_{max}$, indicative of hardness and brittleness of the cookies, respectively, was developed. Hardness and brittleness of the cookies generally increased with fat replacement, but a moderate increase was obtained by some of the fat mimetics, resulting in products with better textural characteristics than their low-fat, no mimetic-added counterparts.

Conforti and Lupano (2004) analysed the effects of honey, lemon juice, and two different whey protein concentrates (WPC) on the structural and functional properties of biscuits. Firmness, elasticity, relaxation time, adhesiveness, consistency and cohesiveness of dough and colour, fracture stress and fracture strain of biscuits were also determined. The presence of WPC with high protein content produced a decrease in the firmness and consistency and an increase in the cohesiveness of dough. Honey increased the adhesiveness of dough, mainly in samples with the WPC of lower protein content and lemon juice, and tended to decrease dough relaxation time.

Brandt *et al.* (2006) designed a texture profile method. A texture profile is defined as the organoleptic analysis of the texture complex of a food in terms of its mechanical, geometrical, fat, and moisture characteristics, the degree of each present, and the order in which they appear from first bite through complete mastication. The texture profile analysis requires a panel of judges with prior knowledge of the texture classification system, use of standard rating scales, and proper panel procedures with regard to the mechanics of testing and sample control.

Tyagi *et al.* (2007) studied nutritional, sensory and textural characteristics of defatted mustard flour fortified biscuits to optimize the mustard flour supplement in the blend for making biscuits. The wheat flour was replaced by defatted mustard flour at 5, 10, 15 and 20% incorporation levels in biscuit preparation. The protein content of mustard flour biscuit increased nearly 2.5 times as a result of mustard flour incorporation, coupled with reduction in fat and an increase in fiber content. Sensory evaluation revealed that the sample containing 15% defatted mustard flour scored highest. Textural characteristics of all dough and biscuit upto 15% supplement of defatted mustard flour were similar. The study revealed that incorporation of 15% defatted mustard flour gave desirable results in terms of nutritional, sensory and textural attributes of mustard fortified biscuits.

Varsha *et al.* (2008) studied three popular baked products bread, biscuit and cake prepared by using 100% whole wheat flour (WWF) and 85% WWF + 15% soy flour (SF). As a result, bread, cake and biscuit were adjudged as satisfactory and liked very much, respectively by the judges. Incorporation of SF in the recipes significantly increased the protein, fat, crude fibre, ash, total dietary fibre, total sugar, calcium, phosphorus, iron and zinc contents of bread, biscuit and cake. All products were acceptable to the judges in terms of colour, appearance, texture and taste.

Darshan (2009) studied on textural properties of carrot fortified soy biscuits were prepared by mixing them in different proportions viz., 60% maida+ 30% soy flour+ 10% carrot powder (A1), 60% maida + 20% soy flour + 20 % carrot powder (A2), 60% maida + 10% soy flour + 30% carrot powder (A3).The result showed that the hardness and fracturability of biscuits were greatly affected by the composition i.e., soy flour and carrot powder. The biscuits having high percentage of soy flour had maximum hardness. As the level of carrot powder increased from 0 to 30%, the hardness of the biscuit reduced and vice versa. The more crispness or crunchiness obtained for the biscuits made by equal proportions of soy flour and carrot powder.

Kerstin Burse *et al.* (2009) studied anethole-flavored biscuits with different compositions (fat, flour, and sugar form) produced using an experimental design. Both fat content and sugar form had a significant effect on mechanical properties of the biscuits. Textural and sensory analyses of the biscuits confirmed that composition affected attributes such as aroma and sweetness and that interactions existed between some attributes.

2.9 Nutritional Analysis of Biscuits:

Nutrition plays a very important role in our lives, it could help to extend or decrease our life span as well as define our degree of livelihood as we progress into old age. With our potential to live longer than ever before comes the urgent need to monitor and adjust the amounts, the types of food and supplements that we ingest into our bodies. Proper nutrition in our early years will not only lead to a learned commitment but will also lead to a lifetime habit toward a healthy extended life.

Eneche (1999) developed biscuits with varying composition of millet flour (MF) and pigeon pea flour (PPF) (100:0, 75:25, 65:35, and 50:50). They all contained high proportions of protein (7.5–15.2%), fat (17.1–18.1%) and digestible carbohydrate (60.2–66.5%). The moisture content was in the range 5.0 to 6.6%, ash 1.5–2.3% and crude fiber 0–0.1%. The recipe with the 65% MF/35% PPF blend resulted in the highest scores for flavor, texture and general acceptability. There was no significant difference between all the biscuits and the familiar Nasco short cake biscuit (reference) in flavor, color, texture and general acceptability.

Dean (2003) analyzed several types of foods (meat pie, canned soup, baked beans, cereals and biscuit) for available carbohydrate, comprising free sugars, starch, dextrins and glycogen. Free sugars were extracted from the foods with 80% ethanol. Sugars are determined by reaction with orcinol in sulphuric acid at 95° by measurement of the absorbance at 420 nm of the resulting yellow solutions. Starch, dextrins and glycogen, if present, were determined in the insoluble residue remaining after extraction of the free sugars. The glucose was estimated with the specific enzyme glucose oxidize by colorimetry at 420 nm in the autoanalyser.

Shalini and Sudesh (2004) prepared biscuits from the blends containing different proportions (0%, 5%, 10%, 15% and 20%) of raw, soaked and germinated fenugreek seed flour and evaluated for width, thickness, spread ratio and sensory characteristics. The thickness of fenugreek supplemented biscuits increased, whereas width and spread ratio of biscuits decreased with the increasing level of fenugreek flour. The results showed that a maximum of 10% fenugreek flour can be incorporated to prepare acceptable quality biscuits. Addition of raw, soaked and germinated fenugreek flour to wheat flour increased the contents of protein (10.5%, 10.4% and 11.0%), lysine (2.15, 2.20 and 2.25 g/100 g protein), dietary fibre (12.7%, 11.3% and 10.9%), total Ca (58.3, 57.1, 57.7 mg/100 g) and total iron (7.40, 7.26 and 7.36 mg/100 g), respectively, at 10% level of substitution.

Valerie *et al*. (2004) experimented on moisture transfer at 20°C and evaluated water vapour sorption kinetics in two compartments 0.99 a_w agar gel/biscuit system. The model for moisture transfer in composite food was successfully validated with a lower agar gel a_w (0.90). Diffusivity estimated from moisture migration experiments in an agar gel/biscuit from sorption kinetic. This difference in diffusivity values could be partially explained by the significant influence of an external resistance to moisture transfer (evaluated to about 0.018 m/s) at the air/biscuit interface during sorption kinetics.

Nnam *et al*. (2003) developed biscuits from mixtures of unprocessed and processed hungry rice (acha), sesame and breadfruit flours with varying composition of 70:15:15, 60:25:15 and 60:15:25 (protein basis) and evaluated chemically and organoleptically. The biscuits contained appreciable quantities of phosphorus, calcium and ascorbate and fair levels of protein (9.02-14.30%). The biscuit from the processed 70:15:15 mixtures had the highest protein level. Biscuits from the processed 60:25:15 and 60:15:25 mixtures were preferred over others in terms of organoleptic attributes.

Kandhro *et al*. (2008) evaluated of 12 brands of biscuits for free fatty acids (FFA) and their fatty acid composition (FAC). The oil content and FFA varied from 13.7 to 27.6% and 0.2 to 1.0%, respectively. Total saturated, unsaturated, cis-monounsaturated and polyunsaturated fatty acids were determined in the range of 37.9–46.9, 53.0–62.0, 12.3–43.7 and 0.1–9.2%, respectively. The high amount of TFA was observed in all biscuit samples and varied from 9.3 to 34.9%. The quantity and quality of the lipid fraction of the biscuits indicated that the all analyzed biscuits are a rich source of fat, saturated fatty acids and trans fatty acids, consequently not suitable for the health of consumers.

Jisha and Padmaja (2009) developed muffins and biscuits from cassava flour, with various cereal and legume additives as well as rice bran. Pseudo-malted cassava flour-based muffins and biscuits had lower starch content (36–44% and 36.5–41.2%, respectively) than similar products from unmalted cassava flour (39–46% and 43.75%, respectively). The crude protein content of the muffins and biscuits from WPC fortified composite mixes ranged from 7.96% to 14.36% and 9.63% to 11.00%, respectively, which was significantly higher than the native cassava flour (1.30%). Besides, the total dietary fiber could be enhanced to the extent of 1.54–3.10% in muffins and 1.70–2.61% in biscuits.

Sampaio *et al*. (2009) studied moisture adsorption isotherms from a new biscuit considered as functional food which was determined using a gravimetric static method at 25 and 40 ºC and over a range of relative humidity from 0.112 to 0.903. The biscuit had 2.5, 3.3, 10.0 and 31.0% of ash, fiber, protein and fat, respectively, and 4.7% moisture content. The equilibrium moisture content of the biscuit (kg/kg) increased when the storage temperature at any given water activity (a_w) was reduced. The maximum isosteric heat of sorption 21.6 kJ/mol, which exponentially decreased when the moisture content was increased.

2.10 Storage Stability of Food Product:

Hozova *et al.* (1997) investigated amaranth-based snacks and crackers at one-month intervals during the four-month storage (20 ± 2 °C) changes in the organoleptic properties (scoring evaluation of shape, surface, colour, consistency, odour, taste and profiling of tastiness) and a_w values. The changes observed during storage in the surface, colour and consistency of snacks (score 0.1-0.3 out of 5) and in the odour of crackers (score 0.2-0.3 out of 4) were insignificant. The taste harmonized in both samples having as a result higher scores with regard to the starting values. Although the a_w values of products during storage varied to some extent (from 0.15 to 0.34), they did not influence the important sensory parameters (snacks crispness, crackers crunchiness).

Singh *et al.* (2000) stored biscuits under ambient conditions of average temperature, at 29.5°C and RH. 73.5% and packed into polypropylene and laminate of cellophane and butter paper. During storage, moisture content, peroxide value and free fatty acid contents of biscuits increased whereas hardness, crispness and overall sensory acceptability scores of biscuits decreased gradually. These changes were more pronounced in biscuits packed in laminated packaging than in polyprophylene film irrespective of levels of soy fortification. Thus, polypropylene proved to be a better packaging material for biscuits than the laminated one and biscuits packed in it could be stored for 45 days in laminated packaging, the shelf-life of biscuits was 30 days.

Akus *et al.* (2004) investigated the effect of different extraction methods on the quality of crude palm oil processed using traditional (local) and mechanical methods and their storage stability. Certain attributes determined prior to and after storage for three months such as free fatty acids (FFA), peroxide value (PV), saponification value (SV), moisture, impurities and volatile matter (MIV). The free fatty acids (FFA) ranged from 7 to 19 percent, peroxide value (PV) ranged from 3 mEq/kg to 6 mEq/kg and moisture, impurity and volatile matter (MIV) ranged from 0.21 to 0.64 percent for locally extracted crude palm oil samples and mechanically extracted crude palm oil samples. Among the three different storage containers used under different storage conditions, plastic containers (PC) resulted in a better storage stability of the crude palm oils in terms of FFA, SV, and MIV than transparent bottles stored on shelves (TBS) and amber-colored bottles stored on the bare floor (BPF).

Daglioglu *et al.* (2004) stored selected bakery products (biscuits, crackers, wafer and fruit cake) that contain high amount of fat (>10%). Free fatty acidity, peroxide value, and Rancimat induction times changed significantly ($p < 0.05$) in all samples. However, acidity and peroxide values remained under the maximum limits allowed by standards. Total fat contents ranged from 13.3% (petit beurre) to 27.1% (wafer), and the major fatty acids in the samples were palmitic, stearic, oleic, trans oleic, and linoleic acids. Changes in unsaturated fatty acids which majorly affects the lipid oxidation were insignificant ($p > 0.05$), and according to the obtained results all samples maintained their oxidative stability throughout shelf life.

Bolin *et al.* (2006) stored pouches of shredded lettuce at 2°C retained a marketable quality 2.5 times longer than those held at 10°C. In addition, a sharp blade exercising a slicing action was superior to either a sharp blade chopping or a dull blade slicing or chopping. Smaller shred size reduced storage life, as did the presence of any free moisture or cellular fluids on the lettuce surface. Higher the microbial load the shorter the storage life. The chemical dips tested did not increase storage life significantly.

Kanner *et al*. (2006) stored orange juice concentrates (11°, 34°, 44°, 58° Brix) between −18° and 36°C and tested periodically for non enzymatic browning, ascorbic acid destruction, furfural and sensory changes. Non enzymatic browning, the main deterioration phenomena in these products, was satisfactorily retarded at 12°C or lower. Ascorbic acid destruction rate constant was dependent on temperatures between 5 and 25°C, and was affected by degree of juice concentration. Furfural accumulation in juice was higher than that in 58° Brix concentrate. Orange juice concentrate of 58° Brix did not show flavor changes after storage at 5°C or 12°C for 17 or 10 months, respectively, when evaluated after reconstitution to 11° Brix.

Doncaster *et al*. (2007) stored biscuits under closed, open/light and open/dark conditions for appropriate periods of time. Moisture content, texture, colour and peroxide value were determined throughout the storage time. The results indicated that the moisture content of the samples increased under all storage conditions, with a softening of texture. Peroxide values increased with rapid acceleration towards the end of the storage period. Very little change was observed in the colour of the biscuits.

Horne *et al*. (2007) described the commercial production and packaging of two types of Army ration biscuits prepared from common ingredients with nine lots of vegetable oil. Results obtained from biscuits packaged in fiberboard cartons, punched cans, and sealed cans and stored for two years at 21°C. and 37°C. Considering only the development of “rancidity”, a 100-hour shortening appears to be adequate protection up to 12 months of storage at a maximum temperature of 37^{o}C. The poor storage life of Army ration biscuits, packaged in fiberboard containers, was shown to be due primarily to the nature of the packaging material.

Frining *et al*. (2008) stored mechanically deboned turkey meat incorporated into frankfurters at the 15% level and compared to red meat frankfurters. Mechanically deboned turkey meat exhibited higher emulsifying capacity than beef but lower than pork on a protein basis. Emulsion stability was not essentially affected by the addition of 15% mechanically deboned turkey meat in red meat frankfurters. Differences flavor tests, preference flavor tests, and TBA values indicated that frankfurters containing 15% mechanically deboned turkey meat were comparable to all red meat frankfurters in flavor stability if fresh deboned poultry meat is used. The use of mechanically deboned poultry meat, which had undergone 90 days of frozen storage, resulted in a significantly inferior product as indicated by flavor evaluation and TBA values. Color evaluation showed slight color fading of all frankfurter treatments during storage.

Capriles *et al*. (2009) studied the use of rapeseed oil (O) as a replacement for partially hydrogenated vegetable oil (F) in snack flavoring. Products with several different rapeseed oil contents were designed, packed, and then stored for twenty weeks at room temperature. Fatty acids compositions, TBA reactive substances (TBARS), shear strength and sensory acceptability were assessed throughout storage period. Total replacement reduced saturated fat by 72.5% in relation to market available snacks. TFA were initially absent in these products, but their production occurred spontaneously on the 8^{th} week with gradual increase during storage up to levels still lower than those observed in commercially available snacks. Low TBARS levels and stability of shear strength during the twenty-week of storage were also observed.

CHAPTER III
MATERIALS AND METHODS

This chapter deals with the materials used and procedure adopted to achieve the objectives of the present investigation. This includes the preparation of nutritious soy biscuits fortified with jambul seed powder, description of experimental set up used; evaluation of their textural properties, methodology adopted for estimation of heat and mass transfer coefficients during baking of biscuits and the biochemical analysis.

3.1 Preparation of Jambul Seed Powder Fortified Soy Biscuits

In the developing countries, malnutrition is one of the major problems in tribal, hilly and backward region, especially in women and children. Conventional protein source is insufficient in these countries to meet the situation. Soybean is rich in protein, and Jambul seed is believed to have medicinal properties and is used to treat diabetes. The nutritive value of traditional biscuits can be improved to a great extent by fortification of jambul seed powder with soy flour. Biscuits were prepared by using maida (refined wheat flour), soy flour and Jambul seed powder. Soybean flour and jambul seed powder were procured from food industries of Udaipur. All other ingredients were procured from the local market of Udaipur. The jambul seed powder fortified soy biscuits were prepared by using traditional creamy method (Meena & Meena, 2004) having different compositions as given in Table 3.1. The soy flour and jambul seed powder were mixed in various proportions (34% soy flour and 6% jambul seed powder; 32% soy flour and 8% jambul seed powder; 30% soy flour and 10% jambul seed powder) with 60% maida as a binding ingredient. The recipe such as ghee, sugar free, cardamom powder, baking powder, baking soda, salt and water were kept constant for all three combinations.

Measured quantities of maida, soy flour and jambul seed powder were mixed together and baking powder, baking soda & salt were added to the mix. Cream was prepared by adding the sugar free (used for diabetic patients) and cardamom powder (for flavour) to ghee and manually whipping it thoroughly for about ten minutes in a pan with the help of a spoon. The mix of flour was then added to the prepared cream and by adding 250 ml of milk, dough was made by hand. The prepared dough was flattened with the help of traditional wooden roller "belan", used in making chapattis, to a thickness of about 7.0 mm. Square pieces of size 45 mm x 45 mm were then taken out of the flattened dough with the help of a steel mould. These moulds of biscuits were then kept in a tray and placed in a thermally controlled oven. The baking of biscuits was done at a temperature of 140^{o}C for 30 minutes as shown in Plate 3.1. The biscuit samples of various combinations before and after baking are shown in Plate 4.1.

These baked biscuits were packed, sealed in polyethylene bags and evaluated for textural quality (Meena and Meena, 2004) and used for storage stability. The process flow chart for preparation of biscuits is given in Fig 3.1.

Table 3.1 Composition of the Jambul seed powder fortified soy biscuits

Ingredients	Biscuit samples		
	A_1	A_2	A_3
Maida, g	300	300	300
Soy flour, g	170	160	150
Jambul seed powder, g	30	40	50
Ghee, g	150	150	150
Sugar free, g	50	50	50
Baking powder, g	5	5	5
Baking soda, g	4	4	4
Salt, g	5	5	5
Cardamom powder, g	1	1	1

Plate 3.1 Experimental set up for Jambul seed fortified soy biscuits

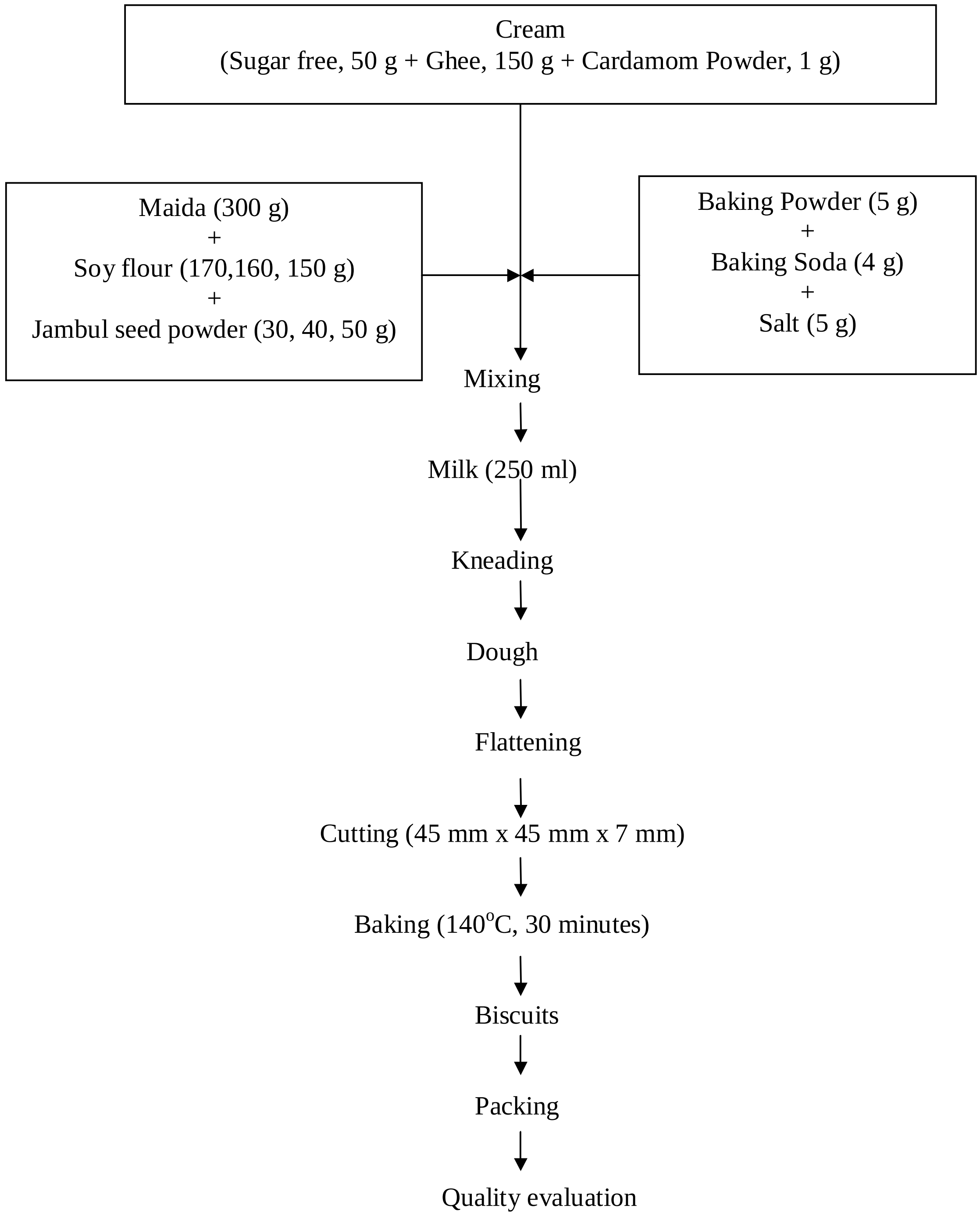


Fig. 3.1 Process flow chart for preparation of jambul seed fortified soy biscuits

3.2 Estimation of Heat and mass Transfer Coefficients of Biscuits:

3.2.1 Experimentation

A thermally controlled oven was used to bake the biscuit at 140°C for 30 minutes (Meena and Meena, 2004). The experimental set of oven with a hanging type digital balance (Sartorius GP-3202) of 3.2 kg capacity with least count of 0.01 g attached to circular steel wire mesh tray of diameter 21 cm as shown in Plate 3.1 was used to weigh the sample during baking. The weighing was done at interval of 3 minutes. The difference in weight gave the moisture evaporated from the biscuit during that observed time interval of 3 minutes. Initial moisture content of the biscuit was determined by oven drying method in which 1.4 g samples of biscuit dough was kept at 130°C for 5 h (Czuchajowska, 1989). The size, weight and volume of unbaked and baked biscuits were measured. The change in volume was assumed as linear which affected the density of the biscuits and this variation in density was considered in calculating the mass transfer coefficients. A non – contact infrared thermometer (Khera; resolution of 0.1°C and accuracy of ± 2%) was used for measuring the temperature at biscuit surface (T_s). A digital anemometer (Lutron AM-4201; resolution of 0.1 m s^{-1} and accuracy of ± 2%) was used to measure air velocity inside the oven.

3.2.2 Heat and Mass Transfer Coefficeints:

Convective heat and mass transfer coefficients are important to understand the rate of heat and moisture transfer during the baking process. To control and optimize baking process in order to maximize the quality, the precise values of heat and mass transfer parameters should be available. The heat and mass transfer coefficients are also necessary to evaluate the heating performance of a forced convection oven. An attempt was made to estimate the heat and mass transfer coefficients while baking biscuits under forced convection.

As baking was a forced convection process, the dimensionless Nusselt number (Nu) was used to estimate the convective heat-transfer coefficient h_c ($Wm^{-2}\,{}^{o}C^{-1}$) as (Geankoplis, 2003):

$$Nu = \frac{h_c L}{K_a} \quad \text{……..3.1}$$

Where,

h_c = convective heat-transfer coefficient, $Wm^{-2}\,{}^{o}C^{-1}$

L = characteristic dimension, m

K_a = thermal conductivity of fluid, $Wm^{-1}\,{}^{o}C^{-1}$

When the fluid was flowing parallel to flat surface under forced convection and heat transfer was occurring between the surface of length and the fluid, Nusselt number (Nu) can be estimated as for a Reynolds number (Re) < 3 X 10^5 and Prandtl number, Pr > 0.7 (Geankoplis, 2003):

$$Nu = 0.664\,(Re)^{1/2}(Pr)^{1/3} \qquad \text{……..3.2}$$

The convective heat transfer coefficient was determined by correlating Eqn (3.1) and (3.2)

$$h_c = \frac{K_a}{L}\,0.664\,(Re)^{1/2}(Pr)^{1/3} \qquad \text{……..3.3}$$

The convective mass transfer coefficient, k_g in m s^{-1}, can be estimated using Lewis relation (Saravacos, 1995) which is as follows,

$$k_g = \frac{h_c}{\rho_b C_b} \qquad \text{……..3.4}$$

Where,

h_c = convective heat-transfer coefficient, $Wm^{-2}\,^oC^{-1}$

ρ_b = density of biscuit, kg m^{-3}

C_b = specific heat of biscuit in, J $kg^{-1}\,^oC^{-1}$

Equation (3.4) can be re-written for convective mass transfer coefficient (k_G) in kg mol s^{-1} m^{-2} Pa^{-1} as

$$k_G = \frac{k_g}{R(T_s + 273.15)} \qquad \text{……..3.5}$$

Where,

k_g = convective mass transfer coefficient, m s^{-1}

R = universal gas constant, 8314.3 m^3 P a kg $mol^{-1}K^{-1}$

T_s = surface temperature of biscuit, ^oC

The following expressions were used for calculating values of the physical properties of air, such as specific heat (C_a) in J $kg^{-1}\,^oC^{-1}$, thermal conductivity (K) in W $m^{-1}\,^oC^{-1}$, density (ρ_a) in kg m^{-3} and dynamic viscosity (μ_a) in kg m^{-1} s^{-1} (Jain & Tiwari, 2003). The physical properties of air were estimated at a temperature (T_i) which was taken as average biscuit temperature T_s and oven temperature T_o (Jain, 2006).

$$C_a = 999.2 + 0.1434T_i + 1.101 \text{ X } 10^{-4}T_i^{\,2} – 6.7581 \text{ X} 10^{-8}T_i^3 \qquad \text{(Kyokai, 1978)} \qquad \text{……..3.6}$$

$$K_a = 0.0244 + 0.6773 \text{ X } 10^{-4}\,T_i \qquad \text{(Kyokai, 1978)} \qquad \text{……..3.7}$$

$$\rho_a = \frac{353.44}{(T_i + 273.15)} \qquad \text{(Toyama et al., 1987)} \qquad \text{……..3.8}$$

$$\mu_a = 1.718 \text{ X } 10^{-5} + 4.620 \text{ X } 10^{-8}\,T_i \qquad \text{(Kyokai, 1978)} \qquad \text{……..3.9}$$

The following model given by Siebel (1982) was used to estimate specific heat of biscuit based on its moisture content.

$$C_b = 837 + 334.9\, X_w \qquad \text{……..3.10}$$

Where,

C_b = specific heat of biscuit in, J $kg^{-1}\,{}^oC^{-1}$

X_w = moisture content of biscuit in wet basis, kg [H_2O]/kg [biscuit]

3.2.3 Computation Technique:

The temperature at surface of biscuit T_s was calculated after every 3 minute intervals and moisture evaporated was also determined by mass balance equation. The physical properties of air were evaluated for the mean temperatures of T_s and T_o using Eqns (3.6)-(3.9). These physical properties were utilized for estimating Reynolds (Re) and Prandtl numbers (Pr). The specific heat of biscuit at different moisture content was measured by using equations (3.10). By using Eqns (3.3)-(3.5), the values of h_c, k_g and k_G were computed at the various intervals of baking. By using the Matlab software 7.0 (Mathworks, Inc.), the empirical rational model was developed to predict the mass transfer coefficients and heat transfer coefficients with moisture contents.

The acceptability of the model has been determined by the coefficient of determination (R^2). In addition to the coefficient of determination, the goodness of fit was determined by various statistical parameters such as standard errors (SEE), reduced mean square of the deviation χ^2, mean bias error E_{MB} and root mean square error E_{RMS}. For quality fit, R^2 value should be higher close to one and SEE, χ^2, E_{MB} *and* E_{RMS} values should be lower (Pangavhane *et al.* 1999; Sarsavadia *et al.* 1999; Togrul and Pehlivan, 2002; Erenturk *et al.* 2004; Demir *et al.* 2004). The above parameters can be calculated for heat and mass transfer is as follows:

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(M_{R,\exp,i} - M_{R,pre,i}\right)^2}{N - z} \qquad \text{……..3.11}$$

$$E_{MB} = \frac{1}{N}\sum_{i=1}^{N}\left(M_{R,pre,i} - M_{R,\exp,i}\right) \qquad \text{……..3.12}$$

$$E_{RMS} = \left[\frac{1}{N}\sum_{i=1}^{N}\left(M_{R,pre,i} - M_{R,\exp,i}\right)^2\right]^{1/2} \qquad \text{……..3.13}$$

Where: $M_{R,exp,i}$ and $M_{R,pre,i}$ are the experimental and predicted heat transfer coefficients respectively; N is the number of observations; and z is the number of constants.

3.3 Studies on Textural Properties of Jambul Seed Powder Fortified Soy Biscuits:

The texture refers to the structure and arrangement of particles in a substance. It can be regarded as a manifestation of the rheological properties of a food. It encompasses all properties of foods which are perceived by kinesthetic and tactile senses of mouth. It is of topmost importance for palatability of food and an important attribute in that it affects processing and handling, influences food habits, and affects shelf-life and consumer acceptance of foods. The texture of food is one of the most challenging areas of food characteristics and main quality parameter affecting food preference. Therefore, the developed biscuits were allowed to texture profile analysis and their textural properties were compared with the control biscuit having 60% maida and 40% soy flour obtained from the local market.

3.3.1 Texture Profile Analysis (TPA):

TA.XT Plus/TA.HD Plus Textural Analyzer used for measuring textural properties of biscuit is shown in Plate 3.2 and its specifications are presented in Appendix C.1. The texture analyzer (TA) was a microprocessor controlled analysis system, which could be interfaced to a wide range of peripherals, including PC-type computers. The texture analyzer measured force, distance, and time in a most basic test, thus providing three dimensional product analyses. Forces could be measured against set distances and distances may be measured to achieve set forces. The probe carrier contained a very sensitive load cell. The TA.HD plus load cell had electronic overload protection. The TA-XT plus load cell had mechanical overload. The analyzer was linked to a computer that recorded the data via a software program Stable Micro System Exponents software (Stable Micro Systems).

Experiments were carried out by different tests that generated plot of force (kg) vs. distance (m), from which texture values for biscuits were obtained. Three replications of each combination were taken for analysis and samples were removed from their packets only a short time before testing. Different tests, probes, fixtures and measuring parameters used for analysis of texture are given in Table 3.3. During the testing, the samples were held manually against the base plate and the different tests were applied according to TA settings mentioned in Table 3.2. The textural properties such as hardness, fracturability and work of shear were measured by using different tests viz., penetration test, cutting test and bending test (Stable Micro Systems).

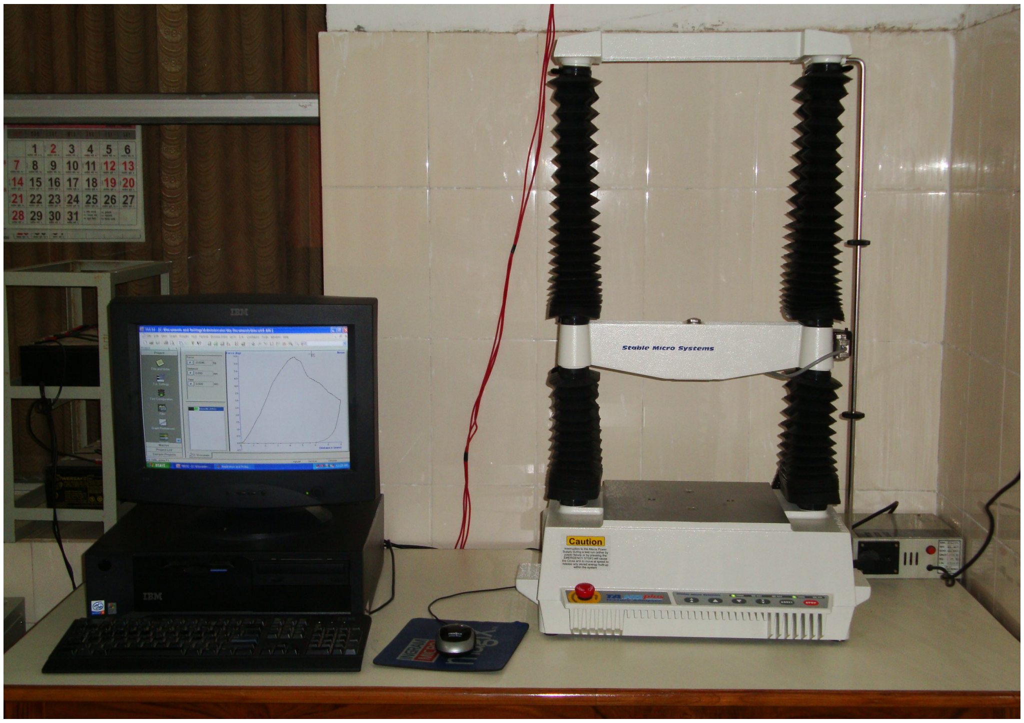


Plate 3.2 A view of Texture analyzer

Table 3.2 TA Settings used in Textural Analyzer for performing different tests

TA Settings	**Penetration Test**	**Cutting Test**	**Bending Test**
Modes	Measure Force in Compression	Measure Force in Compression	Measure Force in Compression
Option	Return To Start	Return To Start	Return To Start
Pre-Test Speed	1.0 mm s^{-1}	1.5 mm s^{-1}	1.0 mm s^{-1}
Test Speed	0.5 mm s^{-1}	2.0 mm s^{-1}	3.0 mm s^{-1}
Post-Test Speed	10 mm s^{-1}	10 mm s^{-1}	10 mm s^{-1}
Distance	8 mm	8 mm	8 mm
Trigger Force	Auto - 5g	Auto - 10g	Auto - 50g
Tare Mode	Auto	Auto	Auto
Data Acquisition Rate	400pps	400pps	500pps

Table 3.3 Different tests and probe/fixtures used in texture analysis of biscuits

Tests	Probe/Fixtures	Measuring Parameters
Penetration Test	5 mm cylinder probe	1. Hardness 2. Fracturability
Cutting Test	Blade set with knife	1. Hardness 2. Work of Shear
Bending Test	Three point bend rig	1. Hardness 2. Fracturability

3.3.2 Determination of Firmness of Biscuits:

Firmness, hardness or softness are textural properties that are generally on the same property spectrum. A soft product is one that displays a slight resistance to deformation, a firm product is moderately resistant to deformation and hardness describes a product which displays substantial resistance to deformation. However, it was also found that depending upon the product industry, one of these words may be more favourable or pertinent to a particular product. Firmness is the most commonly evaluated characteristic while determining biscuit texture. Depending upon the type of test conducted, firmness of biscuits can be obtained by measuring hardness, fracturability and work of shear (Stable Micro Systems).

Hardness is defined as the maximum peak force during the first compression cycle (first bite) and has often been substituted by the term firmness. Units are kg, g or N. Depending on different tests; it can also be measured as area under the curve (kg m) or first peak force (kg). Fracturability is a parameter that was initially called brittleness The factor that helps determine fracturability is the suddenness (i.e. the distance at fracture) with which the food breaks. Sometimes it can also be given by linear distance. The linear distance function calculates the length of an imaginary line joining all points in the selected region. The greater the linear distance value the easier the sample is fractured.

3.3.2.1 Penetration Test By Using Cylindrical Probe:

The penetration test is defined as one in which the depth of penetration (or the time required to reach a certain depth) was measured under a constant load. In a penetration test, the cylinder probe was made to penetrate into the test sample and the force necessary to achieve a certain penetration depth or the depth of penetration in a specified time, under defined conditions, was measured and used as an index of firmness. In penetration test, firmness was represented by hardness and fracturability. The area under the curve was taken as an indication of the hardness (kg m) and the linear distance as an indication of fracturability of the product during textural analysis (Stable Micro Systems).

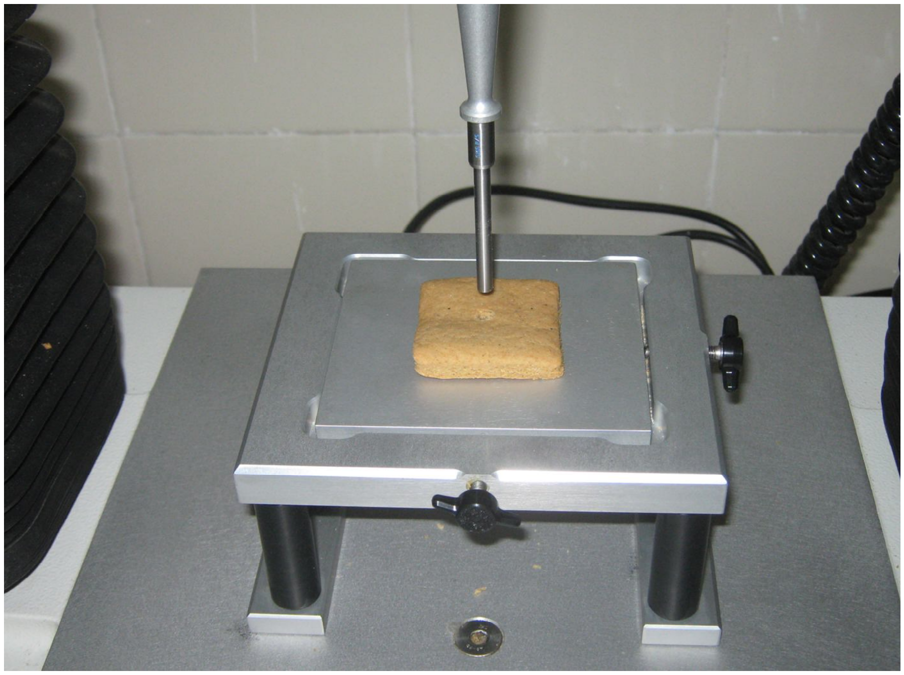


Plate 3.3   5 mm diameter stainless steel cylindrical probe

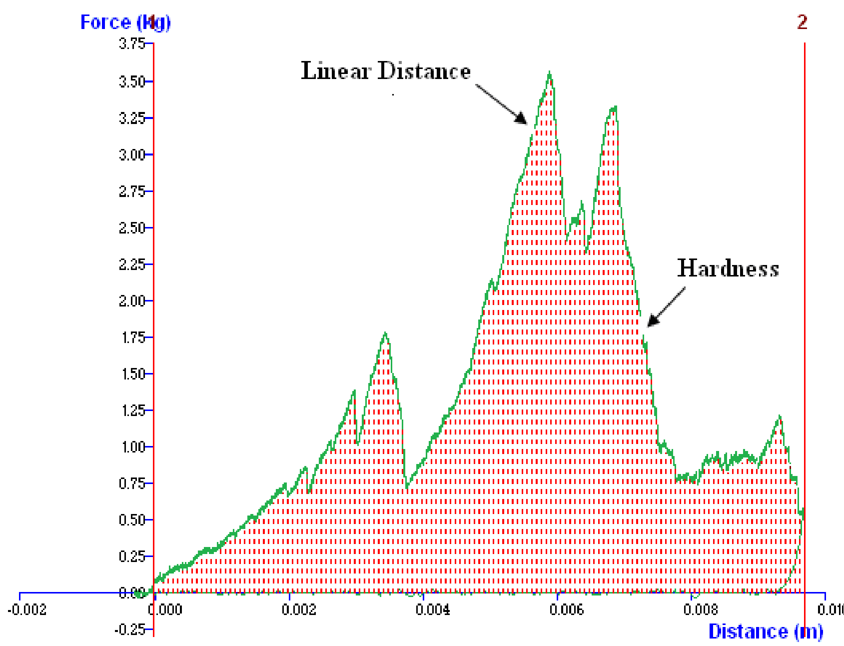


Fig 3.2 Typical texture profile curve for biscuit firmness by penetration test

Cylinder probe used for penetration test on biscuits to provide an index of firmness (hardness and fracturability) is shown in Plate 3.3. The probe was 5 mm in diameter and 45 mm in length. A typical textural profile curve (force – deformation curve) for biscuit by penetration test with one complete run is presented in Fig 3.2.

3.3.2.2 Cutting Test Using Blade Set:

In cutting test, firmness of biscuit was obtained by determining hardness and work of shear. Hardness (kg) was given by the first peak force and the area under the curve was taken as work of shear (kg m). This test applied a combination of compression, shearing and extrusion forces. A single blade having 70 mm width and 90 mm length was used to cut/shear through the sample of biscuit, under specified conditions. The slotted insert was secured on the heavy duty platform and the knife edge was attached to the load cell carrier and lowered into the slotted insert as shown in Plate 3.4. The heavy duty platform was repositioned so that there was no contact between the blade and slot surfaces and a ‘blank’ test run was performed as a check. The blade was then raised to place the sample. Samples were removed from their place of storage just prior to testing and allowed them to fit centrally on the platform under the knife edge. The blade was then allowed to shear through the sample. For comparison purposes, sample dimensions were kept constant. A typical textural profile curve for biscuit by cutting test with one complete run is presented in Fig 3.3.

3.3.2.3 Bending Test by Using Three Point Bend Rig:

In bending or snap test, firmness is represented by hardness and fracturability. The maximum peak force obtained in the curve and the distances at break indicate the hardness (kg) and fracturability (mm) of the product respectively. In this test, the two adjustable supports of the rig base plate were placed a suitable distance apart so as to support the sample. For comparison purposes this gap was kept constant. The base plate is then secured onto the heavy duty platform. The heavy duty platform was maneuvered and locked in a position that enables the upper blade to be equidistant from the two lower supports. The sample was placed centrally over the supports and 3 point bend rig which provides a variable support length up to 70 mm and width up to 80 mm was forced to bend the sample as shown in Plate 3.5. A typical textural profile curve for biscuit by bending test with one complete run is presented in Fig 3.4.

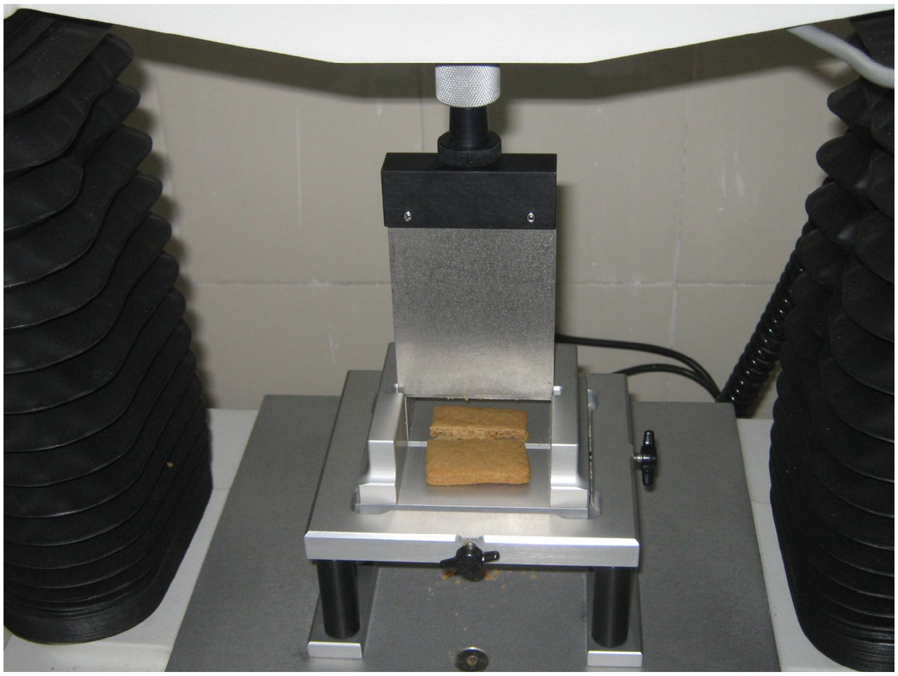


Plate 3.4 Blade set with knife

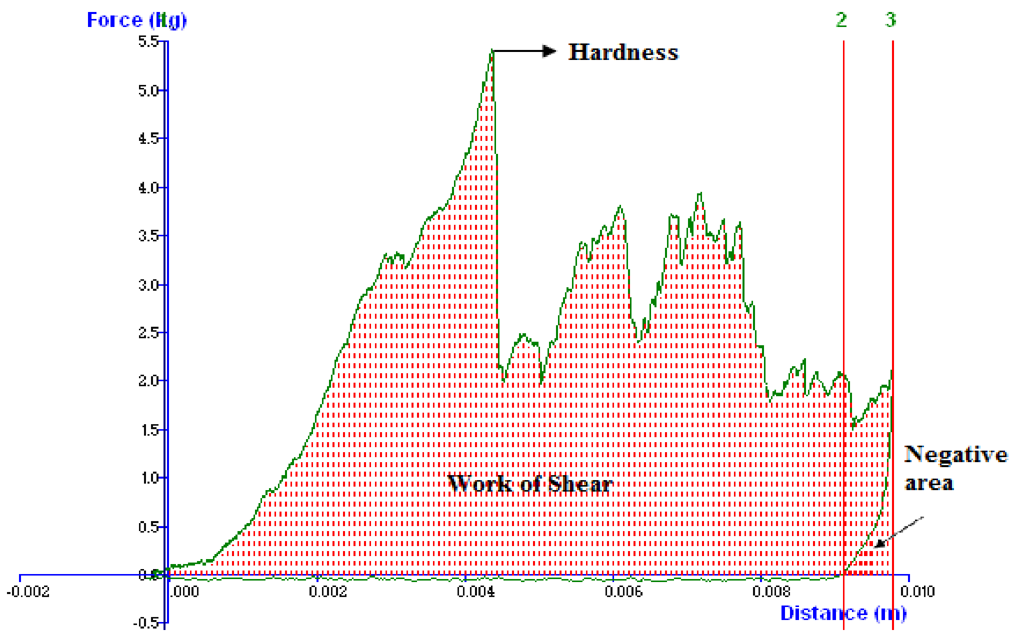


Fig 3.3 Typical texture profile curve for firmness of biscuits by cutting test

3.4 Analysis of Data:

Texture profile curves were obtained for different composition of biscuits. The textural properties such as hardness, fracturability and work of shear were determined. These data were graphically represented and the results were depicted from the trends obtained.

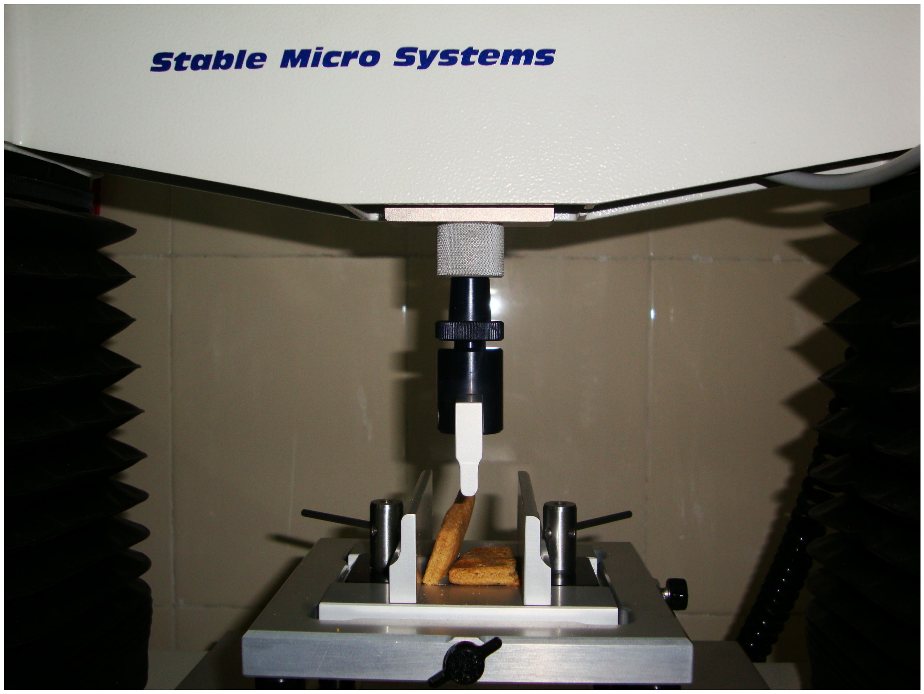


Plate 3.5 Three point bend rig

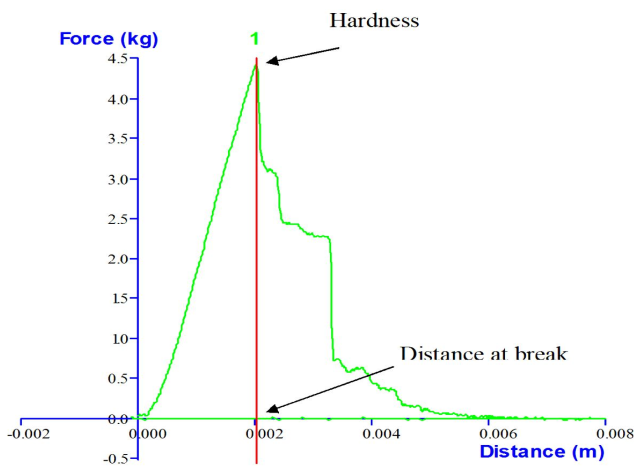


Fig 3.4 Typical texture profile curve for biscuit firmness by bending test

3.5 Parameters under Study:

Parameters selected for study may be subdivided into two major categories as independent and dependent parameters.

3.5.1 Independent Parameters:

A. Variation in soy flour : Jambul seed powder

1) 170 g : 30 g
2) 160 g : 40 g
3) 150 g : 50 g

3.5.2 Dependent Parameters:

A. Physical properties:

1. Length
2. Thickness
3. Spread ratio
4. Mass

B. Measurable parameters during baking in oven at regular intervals

1. Surface temperature of the biscuits, ^{o}C
2. Mass of the biscuits

C. Textural properties:

1. Firmness by Penetration Test (Hardness and Fracturability)
2. Firmness by Cutting Test (Hardness and Work of Shear)
3. Firmness by Bending Test (Hardness and Fracturability)

3.6 Physical Properties of Biscuits:

The thickness and diameter of biscuits will be measured by using vernier caliper, before and after baking of biscuits. The spread ratios of biscuits are the ratio of diameter and thickness. The mass of biscuits will be determined by electronic balance before and after baking.

3.7 Proximate Analysis of Soy-Jambul Seed Powder Biscuits:

The proximate analysis gives useful information about the material, particularly from nutritional and biochemical point of view. Following proximate constituents were analyzed in the developed and control biscuits.

3.7.1 Estimation of Moisture Content

Moisture is the major component of food. The moisture content of any food is determined not only to analyze the chemical composition of food material on moisture free basis but also to assess the shelf life of the product. Moisture content was determined as described by (Jain and Mogra, 2006) using oven drying method.

Ten gram of the sample was dried at 105^0C for 2h. After drying, the sample was cooled in desiccator and weighed. The data were recorded and the moisture content was calculated as,

$$\text{Moisture content } (\text{m.c}),\% \quad = \quad \frac{W_m}{W_m + W_d} \times 100 \qquad \text{……..3.14}$$

Where,

m.c = moisture content, percent wet basis

W_m = mass of water evaporated, g

W_d = mass of dry matter, g

3.7.2 Estimation of Total Ash:

The ash of the food stuff is the inorganic residue which remains after burning of organic matter. Muffle Furnace as shown in Plate 3.6, was used to determine total ash. Ten grams of sample was placed into a pre-weighed, dry porcelain crucible and was placed in muffle furnace for 6 hours at about 600°C. It was than cooled in a desiccator and weighed without delay. The ash content was determined as ,

$$\%\ \text{Ash} \quad = \quad \frac{W_a - W_c}{W_f} \times 100 \qquad \text{……..3.15}$$

Where,

Wa = Mass after ashing with crucible

Wc = Mass of empty crucible

W_f = Mass of fresh sample taken

3.7.3 Estimation of Total Protein:

Total protein was estimated by the method of micro-kjeldhal as shown in Plate 3.7, where hundred mg of the sample was transferred to 30 ml digestion flask to which 0.5 g of digestion mixture (98 parts K_2SO_4 + 2 parts ($CuSO_4$) and 2 ml of conc. H_2SO_4) was added and digested till it became colorless. Digested material was cooled and transferred to a distillation flask and diluted with distilled water. The mixture was cooled and transferred to micro-kjeldhal distillation unit with little quantity of distilled water. Ammonia was distilled by adding 10 ml of 40 % NaOH and the ammonia liberated was received in a 4 % boric acid containing methyl red and methylene blue indicators. Amount of liberated ammonia was determined by titrating with 0.02 N HCl. A blank run was also conducted simultaneously. Each ml of 0.02N HCl neutralizes 14.009 g of nitrogen. Percent nitrogen was determined as:

Plate 3.6 Muffle Furnace used for determination of total ash

Plate 3.7 Micro-kjeldhal distillation unit used for protein determination

$$\% \text{ Nitrogen} = \frac{\text{Amount of HCL used} \times \text{Normality of HCL} \times 14}{\text{Weight of sample (mg)}} \times 100 \quad \ldots..3.16$$

Here, Equivalent weight of nitrogen = 14

Crude protein content in sample was computed using a factor of 6.25(AOAC, 2000) as :

$$\text{Protein \%} = \text{Nitrogen \%} \times 6.2 \quad \ldots\ldots.3.17$$

3.7.4 Estimation of Soluble Protein:

Soluble protein was estimated using the method of BradFord (1976). Ten gram of each sample was ground with distilled water, filtered through Whatman No.4 filter paper and transferred in to a 250 ml volumetric flask. To 0.1 ml of extract added appropriate buffer to make volume one ml. Added 5 ml of Bradford reagent mix thoroughly and measured the absorbance at 595 nm after 2 min against a reagent blank. A standard curve was platted using bovine serum albumine as standard are presented in Appendix D.1.

3.7.5 Estimation of Carbohydrate:

The method given by Hedge and Hofreiter (1962) was used for this analysis. Weighed 100 mg of the sample into a boiling tube and hydrolyzed by keeping it in a boiling water bath for 3 h with 5 ml of 2.5 N HCl and cooled to room temperature. Neutralized the contents with solid sodium carbonate until the effervescence ceased and made up the volume to 100 ml and centrifuged. To 0.1 ml of it added, 0.9 ml of water and add 4ml of anthrone reagent. Mixed and boiled the contents for 8 min in a boiling water bath, cooled rapidly and read the green to dark green colour at 630 nm on Digital Spectrophotometer as shown in Plate 3.9. A standard curve was plotted using glucose as standard and an equation $y = 8.6545\,x$ (Appendix D.2) was deduced to calculate the amount of carbohydrates present in the samples.

$$\text{Carbohydrate in sample(\%)} = \frac{\text{Sugar value from graph (mg)}}{\text{Aliquot sample used (0.5 or 1ml)}} \times \frac{\text{Total vol. of extract (ml)}}{\text{Wt. of sample (mg)}} \times 100$$

3.7.6 Estimation of Crude Fat:

Fats and fatty acids are the esters of glycerol. Oil from food is solubilized in petroleum ether and then distilled off completely to estimate the crude fat in the sample. The method given by Sadasivam and Manickam (1992) was used for this analysis. Ten gram powder of soy-jambul biscuit was transferred to a thimble and plugged it with cotton. The plugged thimble was placed into the fat extraction tube of the soxhlet apparatus as shown in Plate 3.8. Approximately 75 ml anhydrous ether was poured through the sample into the soxhlet flask attached at a bottom of extraction tube. The condenser was attached at the top of the extraction tube. The sample was extracted for 16 hour. At the end of extraction period, thimble was removed and most of the ether was distilled off by allowing it to collect in the soxhlet tube. The remaining ether was evaporated at low temperature under a current of air. Then it was dried at 100 C for 1 hour, cooled and weighted. The percentage of crude fat in the sample was calculated as:

$$\% \text{ Crude Fat} = \frac{W_1}{W_2} \times 100 \qquad \text{........3.19}$$

Where,

W1 = Mass of ether soluble material, g

W2 = Mass of biscuit sample, g

3.7.7 Estimation of Free Fatty Acids or Acid Value of an Oil:

The free fatty acid in an oil is estimated by titrating it against KOH in the presence of phenolphthalein indicator. The acid number is defined as the KOH in mg required for neutralizing the free fatty acids present in 1g of sample. Dissolved ten gram ether extracted fat 10 ml of the neutral solvent in a 250 ml conical flask. Added a few drops of phenolphthalein, and titrated against 0.1 N potassium hydroxide until a pink colour was obtained which persisted for fifteen seconds. A blank run was also performed under similar condition. Acid value of an oil was calculated as follows:

$$\text{Acid value (mgKOH/g)} = \frac{\text{Titer value} \times \text{Normality of KOH} \times 56.1}{\text{Weight of sample (g)}} \qquad \text{.....3.20}$$

3.7.8 Estimation of Calorific Value:

The calorific value was calculated using physiological fuel of protein (4 kcal/g), fat (9 kcal/g) and carbohydrate (4 kcal/g) as:

$$\text{Energy (kcal/100 g)} = [(\% \text{ protein} \times 4) + (\% \text{ carbohydrate} \times 4) + (\% \text{ fat} \times 9)]$$

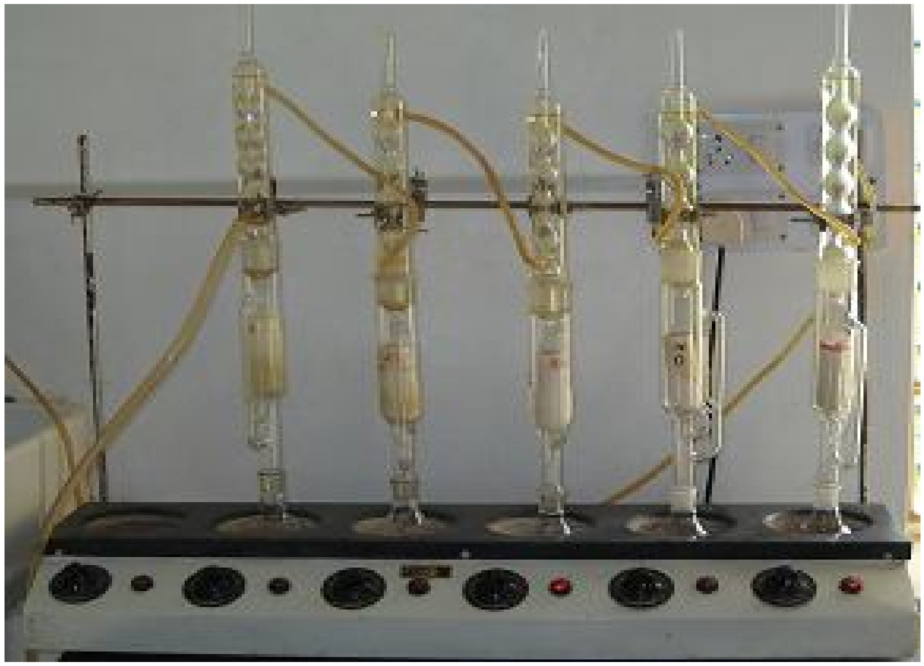


Plate 3.8 Soxhlet apparatus used for analysis of fat

Plate 3.9 Spectrophotometer used for carbohydrates and reducing sugar determination

3.7.9 Estimation of Reducing Sugar:

Reducing sugar of biscuits were determined using the method of Miller, (1972). Weighted 100 mg of the sample and extract the sugars with hot 80 % alcohol twice (5 ml each time).Collected the supernatant and evaporated it on water bath. To 0.5 ml of it added, 10 ml of water and 3 ml of DNS reagent. Mixed and boiled the contents of cooled rapidly and measure the absorbance at 510 nm on digital Spectrophotometer as shown in Plate 3.9 against a reagent blank. A standard curve was plotted using glucose as standard and an equation $y = 0.0025x$ (Appendix D.3) was deduced to calculate the amount of reducing sugar present in the samples.

$$\text{Reducingsugar in sample}(\%) = \frac{\text{Sugar value from graph}(\mu g)}{\text{Aliquot of alcohol} - \text{free extract used}(ml)} \times \frac{\text{Total vol. of alcohol} - \text{free extract}(10ml)}{\text{Wt. of sample}(100mg)} \times \frac{1}{100} \quad \text{……..3.22}$$

3.7.10 Estimation of Invert Sugar and Sucrose Content:

For invert sugar estimation, Lane and Eynon method (Ranganna, 1986) was used. To 50 ml of extracted sample added 50 ml of distill water. About 5 gm of citric acid was added to the solution and boiled for 10 min for the inversion of sugar. The prepared solution was then neutralized with 1 N NaOH solution using phenolphthalein as the indicator.

The solution was then titrated against Fehling solution and the amount of total invert sugar was estimated as per the procedure described by Ranganna (1986). Sucrose content of biscuit was estimated from the total invert sugar and the reducing sugars (Ranganna, 1986).

$$\text{Sucrose}(\%) = [\text{Total invert sugar}(\%) - \text{Reducing sugar}(\%)] \times 0.95 \quad \text{……..3.23}$$

3.7.11 Estimation of Total Sugar:

The amount of total sugar present in the biscuit was calculated from Equ. (3.23)

$$\text{Total sugar}(\%) = [\text{Reducing sugar}(\%) - \text{Sucrose}(\%)] \quad \text{……..3.24}$$

3.7.12 Estimation of pH:

The most convenient and reliable method for measuring pH is by the use of pH meter. The pH meter was first calibrated against standard buffer solution.

3.7.13 Estimation of Percent Titrable Acidity:

Acidity of soy-jambul seed powder biscuit paste was measured and expressed as amount of anhydrous citric acid present in 100 ml of biscuit paste. Ten ml of the sample was transferred to 250 ml conical flask for sample preparation. It was then diluted with distilled water and the volume was made up to 250 ml. Fifty millimeter of this solution was taken, few drops of phenolphthalein indicator were added to it and titrated against 0.1 N NaOH till the colour of solution turn into pale pink (Ranganna, 1986). The equation used for the calculation of titrable acidity is the following

$$\text{Titrable acidity, \%} = \frac{T \times N \times V \times E}{W_S \times V_S \times 100} \times 100 \qquad \text{........3.25}$$

Where,

T = titer value, ml

N = normality of alkali solution

V = volume made up, ml

E = equivalent weight of acid, g

W_s = weight of sample, g

V_s = volume of sample taken for titration, ml

3.7.14 Estimation of Ascorbic Acid:

Ascorbic acid content was estimated with slight modification of the method described which is based on the reaction 2, 6-dichlorophenol indophenol (2, 6-DCPIP).

For estimation of total ascorbate to 5.0 ml of TCA extract, added 200 µl of dithiothreitol (DTT) (to reduce oxidized ascorbic acid to reduced ascorbic acid) and incubated for 10 min. Five ml of this DTT treated extract was titrated against 0.025% DCPIP till end point of slightly pink colour persisted for 15s.For estimation of reduced ascorbic acid, 5.0 ml of TCA extract was titrated against 0.025% DCPIP until a pink colour appeared at the end point. The quantity of total and reduced ascorbate was calculated by comparing the amount of 2,6-DCPIP used for unknown sample with that used for a standard L-ascorbate (570 to 5700 µmols).A standard curve of ascorbate concentration verses volume of DCPIP used, yielded the equation $y = 0.0009x$, which was used to calculate as difference between total and reduced ascorbate.

3.7.15 Estimation of Water Activity (a_w):

The concept of water activity has a particular importance as an indicator of product quality, safety and storability. It can also indicate the stability of a food product with respect to microbial growth, chemical and biochemical reaction rates and physical properties (Barbosa-Canovas and Vega Mercado, 1996). A reduction of water activity below the optimum delays spores germination and decreases the growth rate. An automated instrument Rotronic Hygropalm as a shown in Plate 3.10 was used to determine the water activity of developed biscuit.

Water activity is measured by equilibrating the liquid phase water in the sample with the vapor phase water in the headspace and measuring the relative humidity of the headspace. The water activity meter is provided with a sample cup, which is sealed against sensor block. Inside the sensor block, there is a fan, a dew point sensor, temperature sensor block and an infrared thermometer. The dew point sensor measures the dew point temperature of the air and the infrared thermometer measures the sample temperature. From these measurements, the relative humidity of the headspace is computed as the ratio of saturation vapor pressure of air to the sample. The purpose of the fan is to speedup the equilibrium process and to control the boundary layer conductance of the dew point sensor.

Water activity was measured by placing in a container as shown in Plate 3.10 and placing the container on a sealed chamber and then the knob is closed to read the water activity of the sample.

3.7.16 Colour Measurement:

Colour is important to consumer as a mean of identification, as a method of judging quality and for its basic esthetic value and food is no exemption. The overall objective of colour to the food is to make it appealing and recognizable. The colorimeter used in the present investigation is presented in Plate 3.11. Colour of the prepared biscuit samples was measured using a Hunter Lab Colorimeter. A cylindrical glass sample cup (6.35 cm dia. x 4 cm deep) was placed at the light port (3.175 cm dia). Each sample was measured for colour values three times. The instrument was initially calibrated with a black as well as with standard white plate. The colour values are obtained on L*, a* and b* scale which is shown in Plate 3.12.

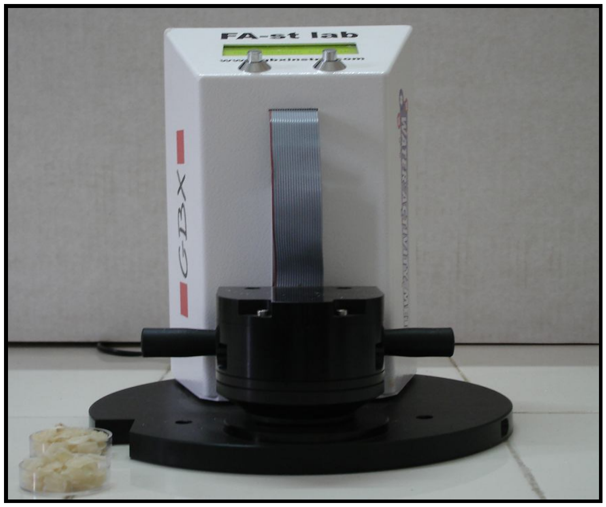


Plate 3.10 Water activity meter used for measuring liquid phase water

Plate 3.11 Hunter lab colorimeter used for measuring colour

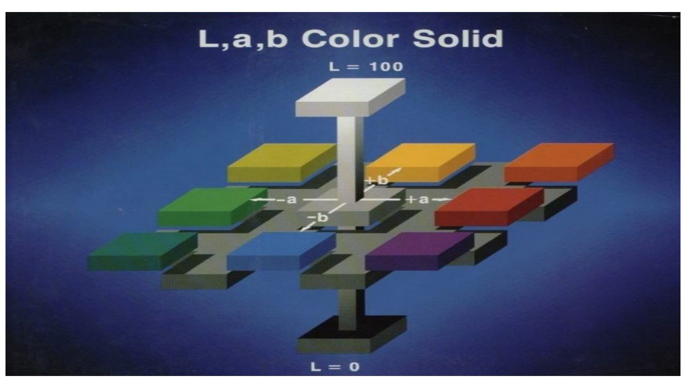


Plate 3.12 Colour Scale representing relationship of colour index (L*, a*, b*)

3.8 Sensory Evaluation of Biscuits:

Sensory evaluation is multi-disciplinarians that use human panelists with their senses of sight, taste, feeling to measure the sensory characteristics and acceptability of food products, as well as many other materials. There is no instrument that can replicate or replace the human response making the sensory evaluation.

Jambul seed powder-soy based biscuits were prepared in the study and conducted product oriented testing using a panel of 15 judges. They were all requested to identify differences among similar food products or to measure the colour, intensity of flavor (odor and taste) texture or appearance characteristics. Panelists were drawn from the institute where the research work was conducted. All the panelists were asked to complete the questionnaire giving their choice from like extremely to dislike extremely. The food products were rated on a nine-point hedonic scale. Nine points were awarded as like extremely-9, like very much-8, like moderately-7, like slightly-6, neither like nor dislike-5, dislike slightly-4, dislike moderately-3, dislike very much-2, dislike extremely-1 (Khedkar, 2004). The proforma, which was giving to each panelist, is given in Appendix E.1. The marking as per quality has also been given in Table E.2 of Appendix E.2. Fifteen members consumer test panel awarded grades for different quality aspects of jambul seed fortified soy biscuits like general appearance, color, flavor, texture, taste and overall acceptability.

3.9 Statistical Analysis:

The quality evaluation data were statistically analysed by using the analysis of variance. In analysis of variance, the sum-of-square, degree of freedom, mean-square and F-ratio were calculated.

3.10 Storage Stability:

In modern age, food packaging has become very important because of protection of the product from contamination by macro & micro-organisms and their filth, prevention from loss or gain of moisture, shielding the product from oxygen and to facilitate handling (Ball, 1960). Good packaging actually serves two purposes, which are essentially technical and presentational. Technical aspects in packaging aim to extend the shelf life of the food by better protection from all the hazards during storage. Presentational aspects are not concerned with shelf life but such packaging increases sales by creating a brand image that the buyer instantly recognizes (Peter and Axtell, 1993). The sample was stored in three different air tight packing materials such as Plastic pouch, Plastic container and Steel box showed in Plate 3.13 through Plate 3.15. The biscuits were withdrawn at an interval of 15 days over a period of 60 days and analyzed for colour, water activity, fat and extractable fat acidity.

Plate 3.13 Biscuits stored in plastic pouch

Plate 3.14 Biscuits stored in plastic container

Plate 3.15 biscuits stored in steel box

CHAPTER IV

RESULTS AND DISCUSSION

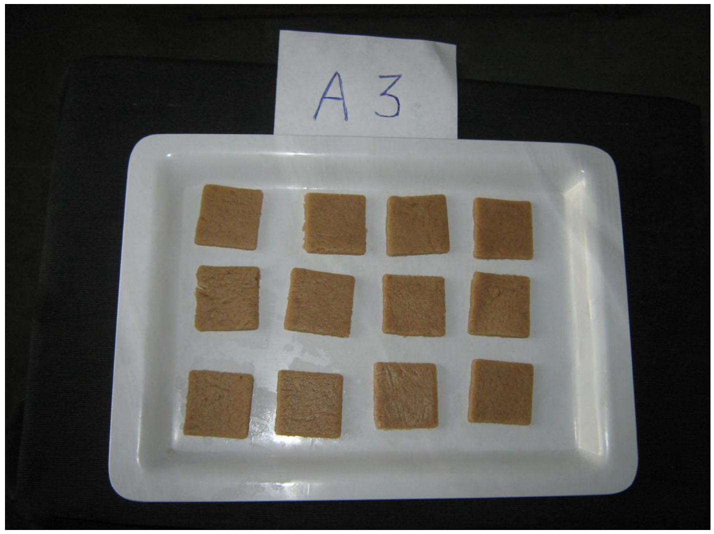
This chapter describes the results obtained for physical properties of biscuits made by blending of jambul seed powder and soy flour in various proportions of (60% maida + 34% soy flour + 6% jambul seed powder), (60% maida + 32% maida + 8% jambul seed powder), (60% maida + 30 % soy flour + 10 % jambul seed powder). The textural properties of prepared biscuits were compared with the control biscuits (60% maida + 40% soy flour) obtained from the local market. Experimental data during baking were used to estimate heat and mass transfer coefficients. The qualities of the product were determined with the help of biochemical and sensory evaluation. The statistical analysis of quality evaluation was presented and discussed in this chapter. Storage stability of product was also observed for 2 months and results are also presented in this chapter.

4.1 Product formulation:

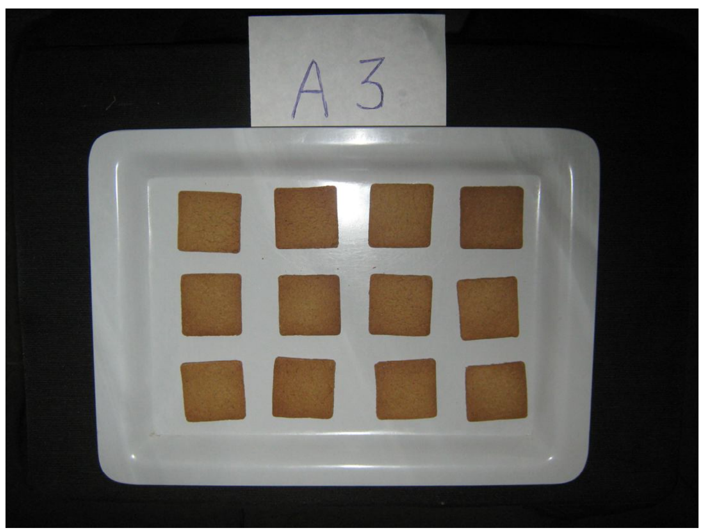
The biscuits were prepared by making different proportional of soy flour and jambul seed powder. The standard procedure was used for proportional of biscuits as described in chapter III. The maida, soy flour and jambul seed powder were taken 60%, 34% and 6% in one sample and it was denoted as A_1, similarly 60% maida, 32% soy flour and 8% jambul seed powder was used in sample A_2 and A_3 was prepared by taking 60% maida, 30% soy flour and 10 % jambul seed powder. The thickness, length, mass and other physical properties of biscuits before and after baking were measured in triplicate and mentioned in Appendix A.

The average value of the length, width, thickness, mass, volume and spread ratio before and after baking are presented in Table 4.1. The average length and thickness of unbaked biscuits was maintained as 4.5 and 0.7 cm respectively. The length of biscuits after baking was increased to 4.6 cm for all compositions showing 2.22 % change. The thickness of biscuits were also increased after baking and were found in the range of 0.81 to 0.83 cm showing 15.7 to 18.6 per cent increment. Similar results have been reported for physical and sensoric attributes of flaxseed flour supplemented cookies by shahzad *et al.*, (2006). The width of unbaked biscuits were same 4.5 cm but after baking it was increased to 4.58 to 4.66 cm showing 1.77 to 3.55 per cent increment for various composition (Table 4.1).

The mass of individual biscuits before baking was measured and found to be 12.13, 12.59 and 12.78 g for A1, A2 and A3 composition respectively which was reduced to 9.28, 10.17 and 10.30 g respectively showing reduction in mass in the range of 19.22 to 23.66 per cent. The volume of individual biscuits before baking was 14.20 cm^3 which increased to 16.97 to 17.93 cm^3 sharing 19.50 to 26.27 per cent increment.



Biscuits before baking



Biscuits after baking

Plate 4.1 Jambul seed powder fortified soy biscuits before and after baking

Table 4.1 Physical properties of biscuits before and after baking

Biscuit samples	A_1 (60% Maida + 34% Soy flour + 6% jambul seed powder)			A_2 (60% Maida + 32% Soy flour + 8% jambul seed powder)			A_3 (60% Maida + 30% Soy flour + 10% jambul seed powder)		
	Before baking	After baking	(%) Change	Before baking	After baking	(%) Change	Before baking	After baking	(%) Change
Length (cm)	4.50	4.60	(+)2.22	4.50	4.60	(+)2.22	4.50	4.60	(+)2.22
Width (cm)	4.50	4.66	(+)3.55	4.50	4.63	(+)2.89	4.50	4.58	(+)1.77
Thickness (cm)	0.70	0.82	(+)16.70	0.70	0.83	(+)18.60	0.70	0.81	(+)15.71
Mass(g)	12.13	9.26	(-)23.66	12.59	10.17	(-)19.22	12.78	10.30	(-)19.40
Volume (cm^3)	14.20	17.82	(+)25.49	14.20	17.93	(+)26.27	14.20	16.97	(+)19.50
Spread ratio, L/T	6.42	5.63	(-)12.30	6.42	5.52	(-)14.01	6.40	5.71	(-)10.92

The spread ratio of biscuits before and after baking were also determined and before baking it was found to be in the range of 6.40 to 6.42 which reduced to 5.52 to 5.70 for various proportion of soy flour and jambul seed powder are presented in Table 4.1.

It can be seen from Table 4.1 that as the soy flour percent in composition decreased from 34 to 32 percent and jambul seed powder increased from 6 to 8 percent in the biscuits, the spread ratio decreased from (-) 12.30 to (-) 14.01percent, however further increase in the jambul seed powder to 10 percent, the spread ratio increased to (-) 10.92 percent. The results found in the study are also in confirmation with the studies conducted by Singh *et al.*, (1996)

4.2 Estimation of heat and mass transfer coefficients of biscuit

The heat and mass transfer coefficients of biscuits of various compositions named as A_1 (60% maida + 34% soy flour + 6 % jambul seed powder), A_2 (60% maida + 32% soy flour + 8 % jambul seed powder) and A_3 (60% maida + 30% soy flour + 10 % jambul seed powder) were estimated during the baking process, under forced convection. The oven temperature (T_o) and air velocity (v) of fan were kept constant as 140°C and 1.1 m s^{-1} respectively. The size of the biscuits was 4.5 cm x 4.5 cm x 0.7 cm. Length of the biscuit (4.5 cm), parallel to air flow was taken as characteristic dimension L (m). The change in physical properties such as weight, length, width, thickness and volume of biscuits before and after baking were observed in the study and are presented in Table 4.1. Expansion of biscuit volume during baking for all combinations was assumed as linear. The initial volume of the unbaked biscuit was 14.2 X 10^{-6} m^3 for all three combinations. The final volume of biscuit for combinations A_1, A_2 and A_3 were 17.82 X 10^{-6} m^{-3}, 17.93 X 10^{-6} m^{-3} and 16.97 X 10^{-6} m^{-3} respectively. The variation in volume affected the density of the biscuits and the change in density with moisture content of biscuits during baking process are given in Table B.1 to Table B.6 of Appendix B. About 19.5 % to 26.27 % expansion was found in the volume of biscuits during baking process which is presented in Table 4.1.

One biscuit of desired composition was placed in pan of oven and its mass was measured after every 3 minutes along with its temperature. The oven temperature was kept constant at 140^0C. It was found that initially the reduction in mass due to evaporation was small (in first 3 minutes). Similarly the temperature of biscuits were also near to room temperature (23 to 23.9 ^{0}C) in initial stage of baking, but after initial settling of temperature (3 min) the temperature of biscuits increased from 120 to 139.1, 122.2 to 139.2 and 125.4 to 139.4 ^{0}C for A_1, A_2, and A_3 composition respectively which has been presented in Table 4.2 to 4.4.

The initial moisture content of dough used for preparation o biscuits was about 0.333 g of water / g dry matter for all three compositions. The computed values of convective heat and mass transfer coefficients during baking of biscuits at temperature of 140^oC and air velocity of 1.1 m/s are summarized in Table 4.2 to Table 4.4. During baking the moisture content of biscuit A_1 was reduced from 0.3124 to 0.0715 kg[H_2O]/kg[DM]. Similarly, the moisture content of biscuits A_2 was reduced from 0.3112 to 0.0662 kg[H_2O]/kg[DM]. About 0.250 kg[H_2O]/kg[DM] of moisture was removed from biscuit A_3 in 30 minutes of baking. The moisture evaporation was lower at the first interval of 3 minutes and it was suddenly increased to 0.35 g and 0.36g for biscuits A_1, A_2 and 0.35g in A_3 in the next interval. As baking continued the rate of moisture evaporation gradually decreased.

The average temperature (T_i) of oven and biscuits at regular time interval were given in Table B.4 through Table B.6 of Appendix B. The reduction in mass of biscuits due to evaporation of moisture during baking was also determined and by mass balance equation, the moisture content of biscuits after every three minutes were also determined. The physical properties of air entering to the oven were measured and Reynolds number (Re) and Prandtl number (Pr) were calculated. The values of Reynolds number (Re) and Prandtl number (Pr) along with heat and mass transfer coefficient values at various time intervals were also mentioned in Table 4.2 to 4.4 respectively for A_1, A_2 and A_3 composition respectively.

Table 4.2 Heat and mass transfer coefficients during baking of biscuit A_1

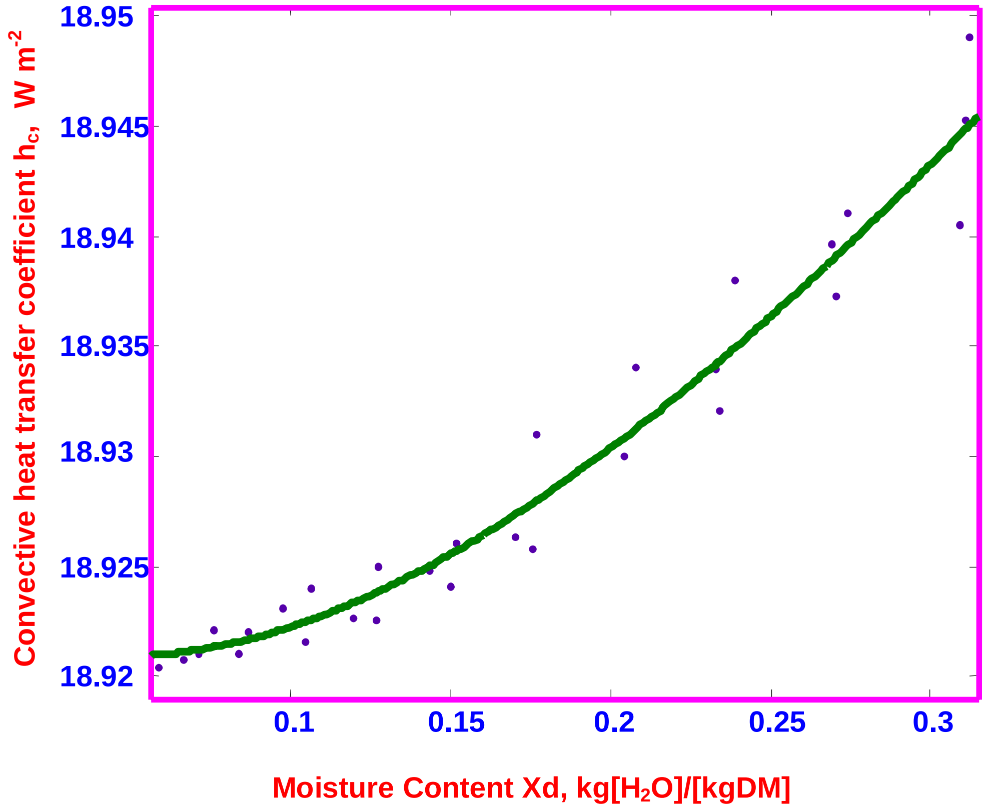
t (Min)	W (kg)	T_s (^oC)	T_o (^oC)	M_e (kg)	M (kg)	Xd kg[H_2O]/ kg[dry matter]	Re	Pr	h_c W m^{-2} $^oC^{-1}$	K_g x 10^5 ms^{-1}	k_G x 10^{12} kg.mol/m^2sPa
0	0.01213	23	140	-	0.00303	0.3333	2355.236	0.708	19.119	2.425	8.22
3	0.01194	120	140	0.00019	0.00284	0.312431	1871.66	0.712	18.949	2.620	7.81
6	0.01159	125	140	0.00035	0.00249	0.273927	1850.91	0.712	18.941	2.765	8.19
9	0.01127	127	140	0.00032	0.00217	0.238724	1842.70	0.712	18.938	2.920	8.63
12	0.01099	130	140	0.00028	0.00189	0.207921	1830.50	0.712	18.934	3.065	9.03
15	0.01071	132	140	0.00028	0.00161	0.177118	1822.43	0.712	18.931	3.240	9.52
18	0.01048	135.2	140	0.00023	0.00138	0.151815	1809.63	0.713	18.926	3.392	9.93
21	0.01026	136.5	140	0.00022	0.00116	0.127613	1804.46	0.713	18.925	3.553	10.38
24	0.01007	137.2	140	0.00019	0.00097	0.106711	1801.69	0.713	18.924	3.701	10.81
27	0.00989	138.5	140	0.00018	0.00079	0.086909	1796.57	0.713	18.922	3.860	11.25
30	0.00975	139.1	140	0.00014	0.00065	0.071507	1794.21	0.713	18.921	3.999	11.65

Table 4.3 Heat and mass transfer coefficients during baking of biscuit A_2

T (Min)	W (kg)	T_s (^oC)	T_o (^oC)	M_e (kg)	M (kg)	Xd kg[H_2O]/ kg[dry matter]	Re	Pr	h_c W m^{-2} $^oC^{-1}$	$K_g \times 10^5$ ms^{-1}	$k_G \times 10^{12}$ kg.mol/m^2sPa
0	0.01259	23.5	140	-	0.00302	0.33333	2352.279	0.708	19.1184	2.337	7.920
3	0.01239	122.2	140	0.0002	0.00282	0.311258	1862.491	0.712	18.945	2.412	7.17
6	0.01203	127.1	140	0.00036	0.00246	0.271523	1842.297	0.712	18.938	2.545	7.52
9	0.01169	131.2	140	0.00034	0.00212	0.233996	1825.652	0.712	18.932	2.678	7.88
12	0.01142	132.6	140	0.00027	0.00185	0.204194	1819.940	0.712	18.930	2.804	8.23
15	0.01116	135.6	140	0.00026	0.00159	0.175497	1808.040	0.712	18.925	2.938	8.60
18	0.01093	136.8	140	0.00023	0.00136	0.15011	1803.282	0.712	18.924	3.079	9.00
21	0.01072	137.9	140	0.00021	0.00115	0.126932	1798.936	0.712	18.922	3.210	9.36
24	0.01052	138.6	140	0.0002	0.00095	0.104857	1796.179	0.712	18.921	3.352	9.77
27	0.01033	139	140	0.00019	0.00076	0.083885	1794.606	0.712	18.920	3.490	10.17
30	0.01017	139.2	140	0.00016	0.0006	0.066225	1793.820	0.712	18.920	3.630	10.57

Table 4.4 Heat and mass transfer coefficients during baking of biscuit A3

t (Min)	W (kg)	T_s (^oC)	T_o (^oC)	M_e (kg)	M (kg)	Xd kg[H_2O]/ kg[dry matter]	Re	Pr	h_c W m^{-2} $^oC^{-1}$	K_g x 10^5 ms^{-1}	k_G x 10^{12} kg.mol/m^2sPa
0	0.01278	23.9	140	-	0.00301	0.333333	2349.918	0.708	19.1176	2.3025	7.7988
3	0.01257	125.4	140	0.00021	0.0028	0.309392	1849.266	0.7121	18.940	2.370	7.02
6	0.01222	127.6	140	0.00035	0.00245	0.270718	1840.255	0.7122	18.937	2.495	7.37
9	0.01188	129.9	140	0.00034	0.00211	0.233149	1830.905	0.7123	18.933	2.621	7.72
12	0.01159	132.3	140	0.00029	0.00182	0.201105	1821.225	0.7124	18.930	2.750	8.08
15	0.01131	135.2	140	0.00028	0.00154	0.170166	1809.631	0.7125	18.926	2.901	8.49
18	0.01107	136.3	140	0.00024	0.0013	0.143646	1805.262	0.7126	18.924	3.048	8.91
21	0.01085	137.8	140	0.00022	0.00108	0.119337	1799.33	0.7126	18.922	3.183	9.29
24	0.01065	137.5	140	0.0002	0.00088	0.097238	1800.514	0.7126	18.923	3.357	9.80
27	0.01046	138.2	140	0.00019	0.00069	0.076243	1797.753	0.7127	18.922	3.505	10.22
30	0.0103	139.4	140	0.00016	0.00053	0.058564	1793.035	0.7127	18.920	3.643	10.61



. 4.1 Variation in ‘h_c’ with moisture content of biscuits during baking

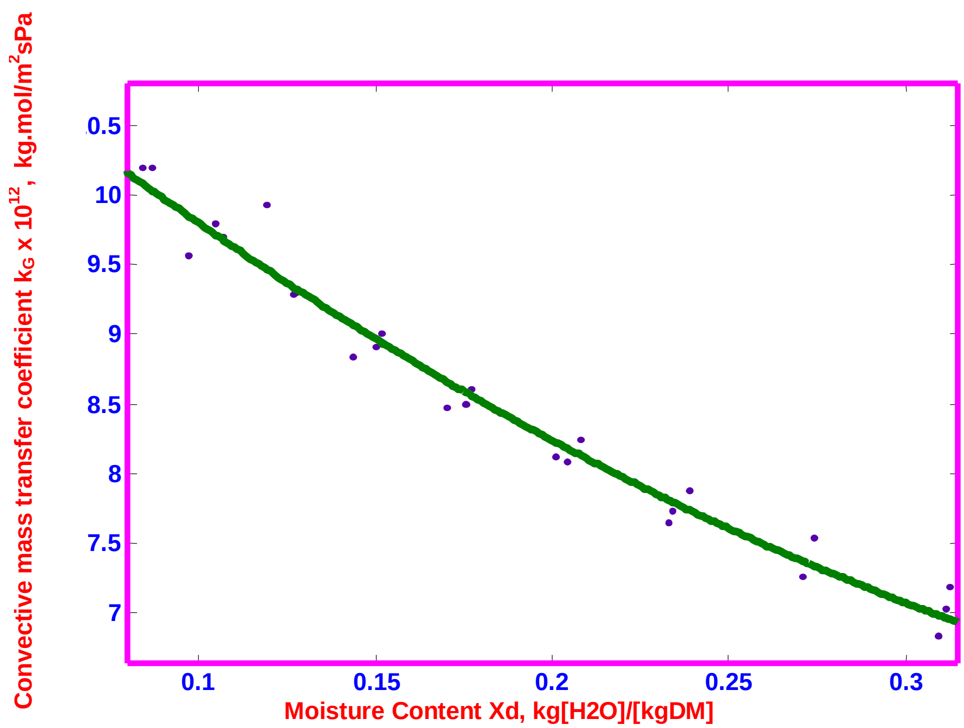


Fig. 4.2 Variation in ‘K_G’ with moisture content of biscuits during baking

Reynolds number (Re) ranged between 1871.91 and 1793.035 and Prandtl number (Pr) vary between 0.712 to 0.713 throughout the baking process as given in Table 4.2 to Table 4.4. The Reynolds number ($Re<3 \times 10^5$) indicated that the entire baking fell within the laminar flow regime (Geankoplis, 2003).

The variation in convective heat transfer coefficient with moisture content of biscuits is presented in Fig. 4.1. The convective heat transfer coefficients h_c during baking of biscuit A_1, A_2 and A_3 were observed to be 18.9 W m^{-2} $^oC^{-1}$ throughout the baking process. The convective mass transfer coefficient k_g for biscuit A_1 varied from 2.370 x 10^{-5} to 3.999 x 10^{-5} ms^{-1} and increased with decreasing in moisture content of biscuits. This range was observed almost same for composition A_2 and A_3. The convective mass transfer coefficient k_G also followed the increasing trend with moisture content and varied from 7.02 x 10^{-12} to 11.65 x 10^{-12} kg.mol/m^2sPa. Similar results were obtained for other two treatments such as A_2 and A3. The variation in convective mass transfer coefficient k_G with the moisture content of all three biscuits is also presented in Fig 4.2. The heat transfer coefficients at various time interval during baking were statistically analyzed and regression equation of following form were predicted in which the heat transfer coefficient was predicted as a function of moisture content of biscuits during baking.

In general equations for heat transfer coefficients and mass transfer coefficients in following form were predicted.

$$h_c = \frac{a\,X_d^{\,2} + b\ X_d + c}{X_d + q} \qquad \text{.....4.1}$$

$$\mathbf{k_G} = \frac{a\,X_d^{\,2} + b\ X_d + c}{X_d + q} \qquad \text{.....4.2}$$

Where,

a, b, c and q = regression coefficients

hc = convective heat transfer coefficient, W m^{-2} $^oC^{-1}$

k_G = convective mass transfer coefficient, kg mol s^{-1} m^{-2} Pa^{-1}

X_d = moisture content of biscuit, kg[H2O]/kgDM]

The linear models existed between the convective heat transfer coefficient hc (W m^{-2} $^oC^{-1}$) and the convective mass transfer coefficient k_G (kg.mol/m^2sPa) as a function of moisture content (X_d), kg[H_2O]/kg[DM].

$$h_c = \frac{0.2621\,X_d^{\,2} + 18.90\ X_d + 8.774}{X_d + 0.4637} \qquad \text{.....4.3}$$

$$k_G = \frac{2.993 \times 10^4 X_d^2 - 3.354 \times 10^4 X_d + 1.851 \times 10^4}{X_d + 1577} \quad \ldots..4.4$$

The goodness of fit of the model for heat transfer coefficient was found to be optimum as described by coefficient of determination 0.9537 and root mean square error 0.001833 as presented in Fig 4.1 and the goodness of fit the model for mass transfer coefficient described with coefficient of determination 0.9753 and root mean square error 0.1914 presented in Fig 4.2 for baking of biscuit.

The convective heat transfer coefficients and mass transfer coefficients of biscuits can be quantified using Eqn (4.3) and Eqn (4.4), by knowing moisture content. Furthermore, the convective mass transfer coefficient can also be evaluated with knowledge of density and specific heat of biscuits, which is again the function of the moisture content of biscuit . The statistical analysis of data revealed that linear rational model equations provided best fit to the observed values of heat and mass Transfer coefficients. The predicted equations with their coefficient of correlation values of heat and mass transfer coefficient are presented in the Table 4.5 and Table 4.6 respectively.

Table 4.5 Predicted equation and coefficient of correlation values for heat transfer coefficient

Biscuit Composition	Equation predicted	R^2
A_1 (60% maida + 34% soy flour+6 % jambul seed powder)	$h_c = \frac{0.2978 X_d^2 + 18.92 X_d + 12.29}{X_d + 0.6494}$	0.9919
A_2 (60% maida + 32% soy flour+8 % jambul seed powder)	$h_c = \frac{0.8451 X_d^2 + 18.81 X_d + 34.}{X_d + 1.804}$	0.9973
A_3 (60% maida + 30% soy flour+10 % jambul seed powder)	$h_c = \frac{0.1282 X_d^2 + 18.91 X_d + 2.125}{X_d + 0.1123}$	0.9895

It was observed that the values of coefficient of correlation for heat transfer coefficient were more than 0.9895 for all the experiment condition which revealed the good correlation between the predicted and observed data

Table 4.6 Predicted equation and coefficient of correlation values for mass transfer coefficient

Biscuit Composition	Equation predicted	R^2

A_1 (34% soy flour+6 % jambul seed powder)	$k_G = \frac{3.653 \times 10^4 X_d^2 - 3.541 \times 10^4 X_d + 1.906 \times 1}{X_d + 1453}$	0.9837
A_2 (32% soy flour+ 8% jambul seed powder)	$k_G = \frac{3.412 \times 10^4 X_d^2 - 3.105 \times 10^4 X_d + 1.741 \times 1}{X_d + 1491}$	0.9515
A_3 (30% soy flour+ 10% jambul seed powder)	$k_G = \frac{3.371 \times 10^4 X_d^2 - 3.161 \times 10^4 X_d + 1.761 \times 1}{X_d + 1526}$	0.9467

It was observed that the values of coefficient of correlation for mass transfer coefficient were more than 0.9467 for all the experiment condition which revealed the good correlation between the predicted and observed data.

4.3 Textural properties of biscuits

4.3.1 Firmness

Firmness/hardness/softness are textural characteristics that are generally on the same property spectrum. A soft product is one that displays a slight resistance to break, a firm product describes one that is moderately resistant to rupture and hardness describes a product which displays substantial resistance to rupture. Firmness is the most commonly evaluated characteristic while determining biscuit texture. Depending upon the type of test conducted, firmness of biscuits can be obtained by measuring hardness, fracturability and work of shear (Stable Micro Systems).

4.3.2 Firmness by penetration test

In penetration test, firmness is represented by hardness and fracturability. The area under the curve is taken as an indication of the hardness (kg m) and the linear distance as an indication of fracturability of the product during textural analysis. The linear distance function calculates the length of an imaginary line joining all points in the selected region. The greater the linear distance value the easier the sample is fractured. It is calculated using kg and m (regardless of the units on display). Fig 4.3 through 4.6 shows the textural profile curves (force-deformation curves) obtained from the textural analyzer for the samples made from different blend levels such as Control, A_1, A_2 and A_3 respectively. In the test, the probe was allowed to penetrate in the specimen at a constant rate. Table 4.7 shows the mean values of hardness and fracturability of biscuit samples having different proportions of soy flour and jambul seed powder as calculated in various experiments. The values of hardness and fracturability for different replications are given in Table C.1 of Appendix C.

It was seen from Table 4.7 that as the blend percent of the jambul seed powder increased in the sample, the hardness went on decreasing. The hardness values obtained for the biscuits of various blends were in the range of 0.0066 to 0.0083 kg m. Control biscuit made by 60% maida and 40% soy flour had maximum hardness of about 0.0083 kg m. When 6% of the soy flour was replaced by jambul seed powder, there was about 8.43% decreases in its hardness. As amount of increased jambul seed powder was increased from 6 to 8 % in the sample, hardness values further decreased to 0.0075 kg m showing 9.33 % decrement from the control sample. With further increase in jambul seed powder from 8 to 10 %, the hardness values further reduced to 0.0066 kg m showing 20.48% decrement. Comparisons of the texture of three different biscuit samples A_1, A_2 and A_3 among themselves were found hard, firm and soft respectively. Higher fiber content in soy flour than maida may be attributed to the increased toughness of the biscuits in proportion to the soy flour level.

Table 4.7 Hardness and fracturability of biscuit samples for penetration test

Biscuit	**Firmness**	
	Hardness (kg m) 'Mean Area'	**Fracturability (mm) 'Mean Linear distance'**
Control (60% maida + 40% soy flour)	0.0083	32.79
A_1 (60% maida + 34% soy flour+6 % jambul seed powder)	0.0076	32.75
A_2 (60% maida + 32% soy flour+8 % jambul seed powder)	0.0075	32.95
A_3 (60% maida + 30% soy flour+10 % jambul seed powder)	0.0066	32.67

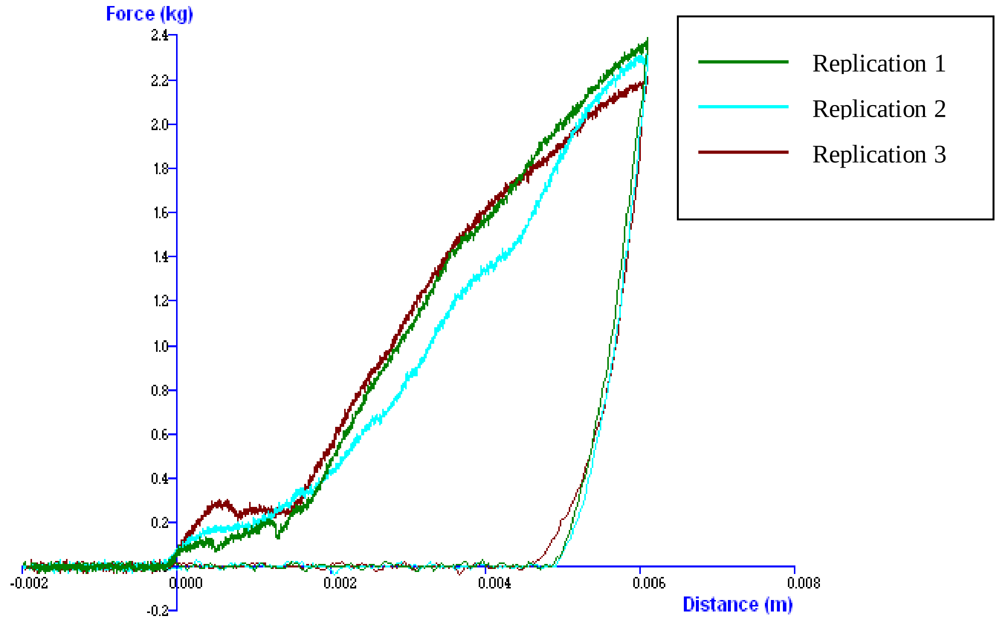


Fig 4.3 Texture profile curve of control biscuits in penetration test

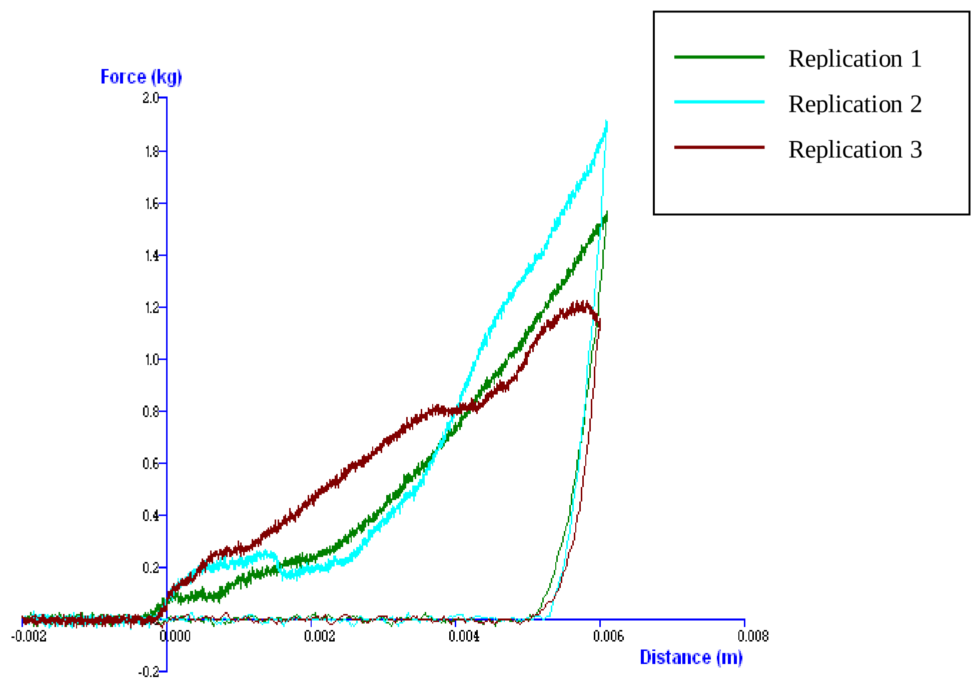


Fig 4.4 Texture profile curve of biscuits A1 in penetration test

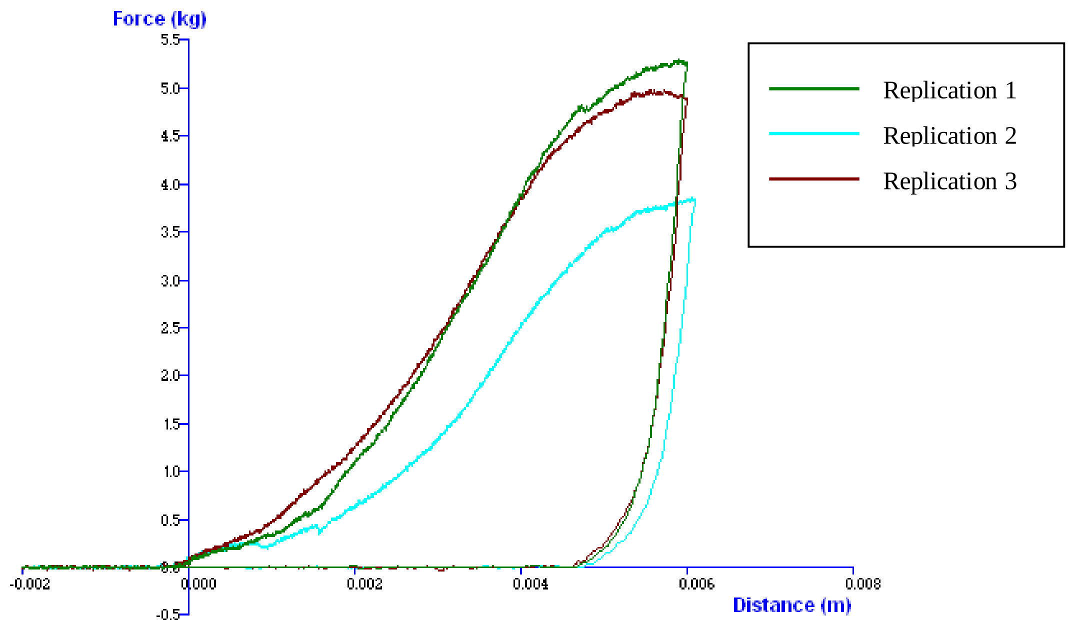


Fig 4.5 Texture profile curve of biscuits A2 in penetration test

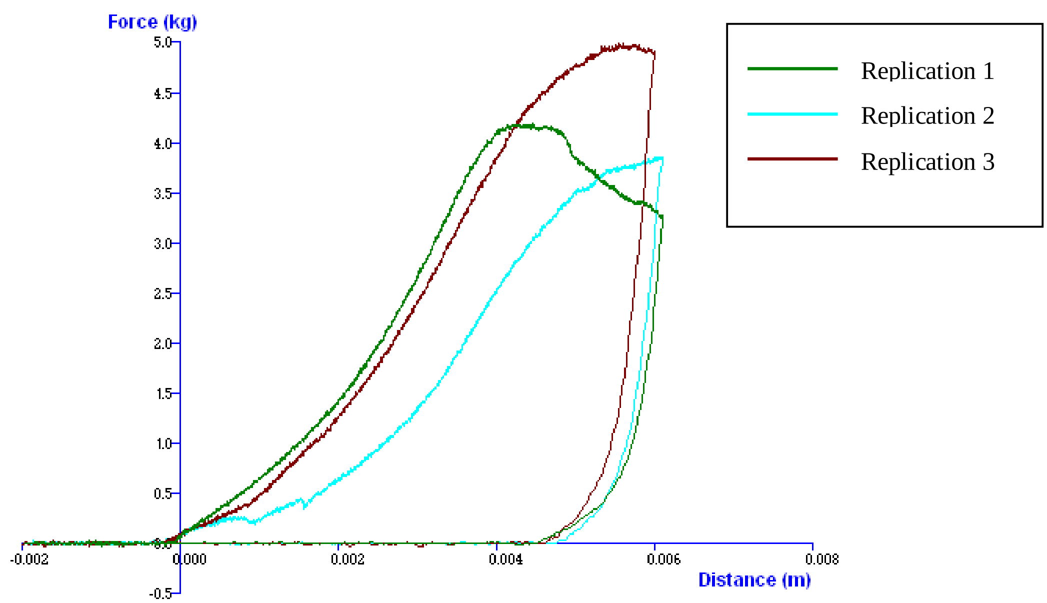


Fig 4.6 Texture profile curve of biscuits A3 in penetration test

The decrement in the hardness values with decrease in soy flour % was also reported by Gandhi et al, 2001. Results of the present study are also in agreement with the findings of Awasthi *et al.*, (1999) and Singh et al. (1996) on biscuits containing varied levels of soy flour. They reported that the force required to compress the product increased in direct proportion to the soy flour in the dough. The linear distance which indicate fracturability was obtained almost same for all biscuits. However, the greater the linear distance value, the easier to fracture the sample. The fracturability value of biscuit A_2 was found to be 32.95 and greater than A_1 and A_3. Therefore, the combination A_2 having proportion of 32% soy flour and 8% jambul seed powder were more crispy or crunchy than others.

4.3.3 Firmness by cutting test

In cutting test, firmness was obtained by determining hardness and work of shear. Hardness (kg) was given by the first peak force and the area under the curve was taken as work of shear (kg m) in the textural analyzer test. Fig.4.7 to Fig 4.10 shows the curves obtained from the texture analyzer, for the samples made from different blend levels such as Control, A_1, A_2 and A_3 respectively. As the blade started shearing in the sample, different peaks were observed at certain depths. Table 4.8 shows the mean values of hardness and work of shear of biscuit samples having different proportions of soy flour and jambul seed powder.

Table 4.8 Hardness and work of shear of biscuit samples for cutting test

Biscuit	Firmness	
	Hardness (kg) 'Mean First Peak Force'	**Work of shear (kg m) 'Mean Total Area'**
Control (60% maida + 40% soy flour)	6.13	0.028
A_1 (60%maida + 34% soy flour+6 % jambul seed powder)	5.56	0.024
A_2 (60%maida + 32% soy flour+8 % jambul seed powder)	4.80	0.021
A_3 (60% maida + 30% soy flour+10 % jambul seed powder)	3.56	0.021

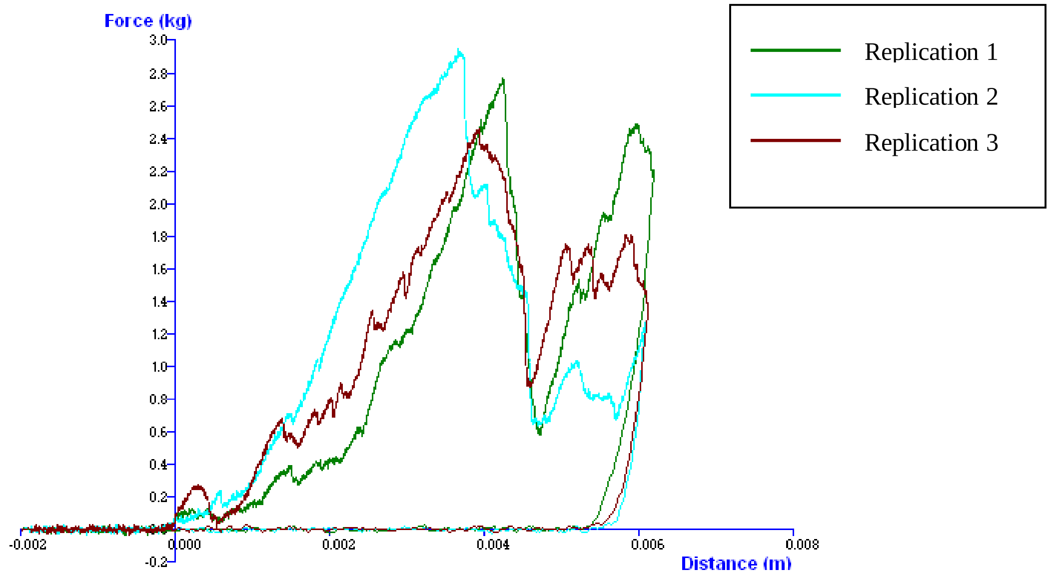


Fig 4.7 Texture profile curve of control biscuits in cutting test

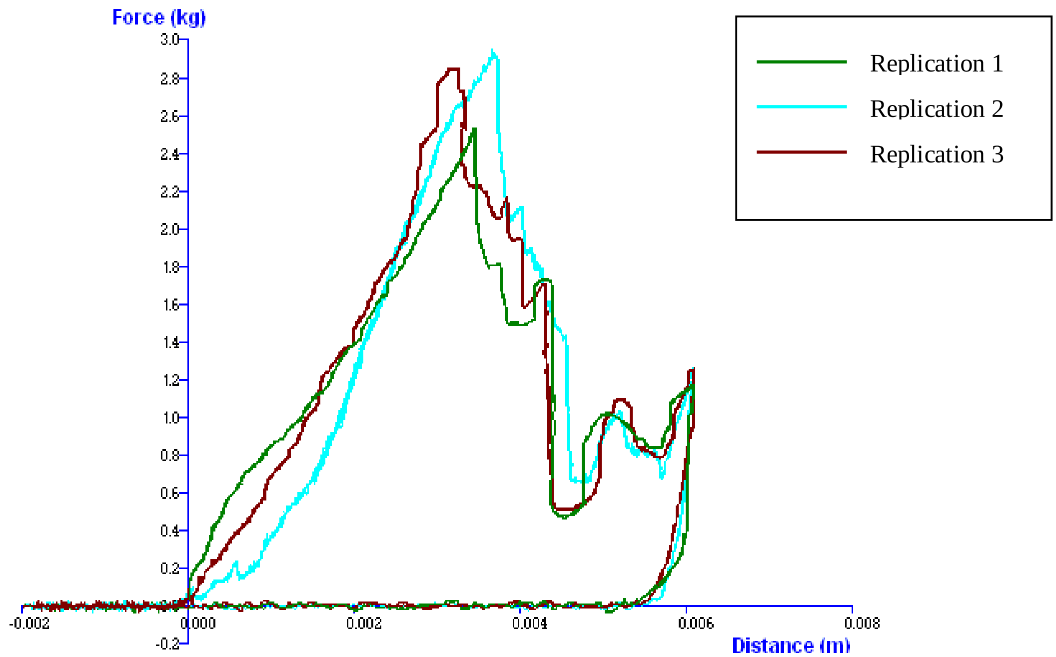


Fig 4.8 Texture profile curve of biscuits A1 in cutting test

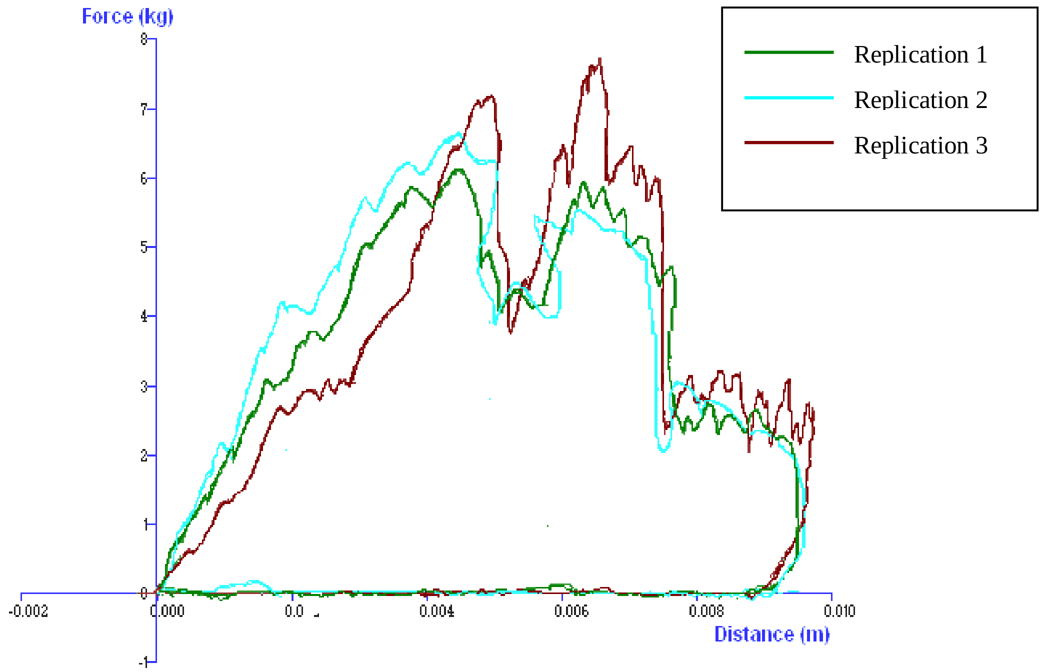


Fig 4.9 Texture profile curve of biscuits A2 in cutting test

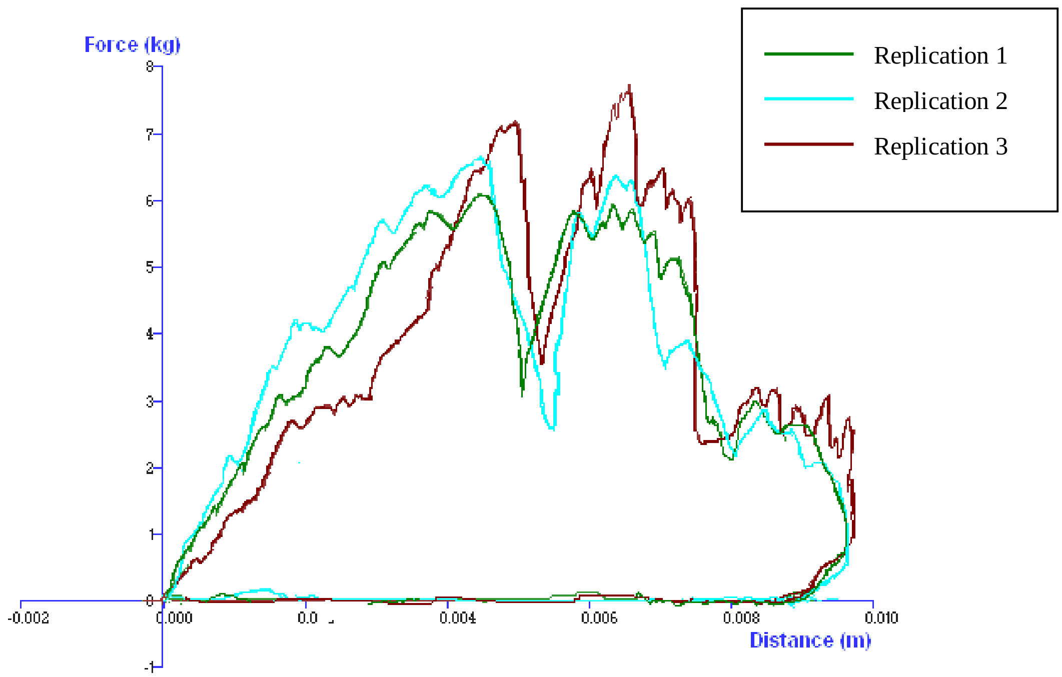


Fig 4.10 Texture profile curve of biscuits A3 in cutting test

The values of hardness and work of shear for various replications are given in Table C.1 of Appendix C. From the Table 4.8 it can be seen that the hardness of biscuits keep on decreasing as the blend percent of the jambul seed powder increased. The hardness values obtained for the biscuits of various blends at first peak were in the range of 3.56 to 6.13 kg. The shear force and work of shear to cut the sample was found highest for control biscuit (60% maida and 40% soy flour). As per cent jambul seed powder increased in biscuits from 0 to 6 %, 6 to 8 % and 8 to 10 % in the biscuit samples, both the values of hardness and work of shear were decreased (Table 4.8).

Replacement of soy flour upto 10% level with jambul seed powder in the biscuits recipe resulted in 41.92 % decrement in its hardness and 25 % of work required to shear the biscuit was also reduced. Biscuit A_1 had a maximum hardness (cutting or shearing force) followed by A_2 and A_3. Therefore, it can be reported that the texture of biscuits A_1 was hard, A_2 was firm and A_3 was soft comparatively. From Table 4.8 it is cleared that less force and less work was required to shear the biscuit samples containing higher percent of jambul seed powder. However, A_2 biscuits having 8 % jambul seed powder and 32 % soy flour had better firmness comparable to other combinations.

4.3.4 Firmness by bending test

In bending or snap test, firmness was represented by hardness and fracturability. The maximum peak force obtained in the curve and the distances at break indicated the hardness (kg) and fracturability (mm) of the product respectively. Fig.4.11 to 4.14 shows the bending curves obtained from the textural analyzer for the samples made from different blend levels. Once the trigger force was attained, the force increased until such time as the biscuit fractured and fell into two pieces. This was observed as the maximum force and referred as the 'hardness' of the sample in biscuit.

The distance at the point of break was the resistance of the sample to bend and related to the 'fracturability' of the sample. Table 4.9 shows the average of three replications of hardness and fracturability of biscuit samples having different proportions of soy flour and jambul seed powder. The values of hardness and fracturability for replications of biscuit A_3 are given in Table C.1 of Appendix C.

It can be seen from the Table 4.9 that the biscuit samples having high per cent of soy flour exhibited greater hardness.In bending test, the hardness values obtained for the biscuits of various blends were in the range of 1.52 to 3.04 kg. Similar values for hardness of biscuits have been reported by Onweluzo and Iwezu, 1998. When 6% of the soy flour was replaced by jambul seed powder, hardness values decreased about 0.64 kg. As increased in jambul seed powder from 6 to 8 % in the biscuit samples, hardness values decreased about 0.58 kg.

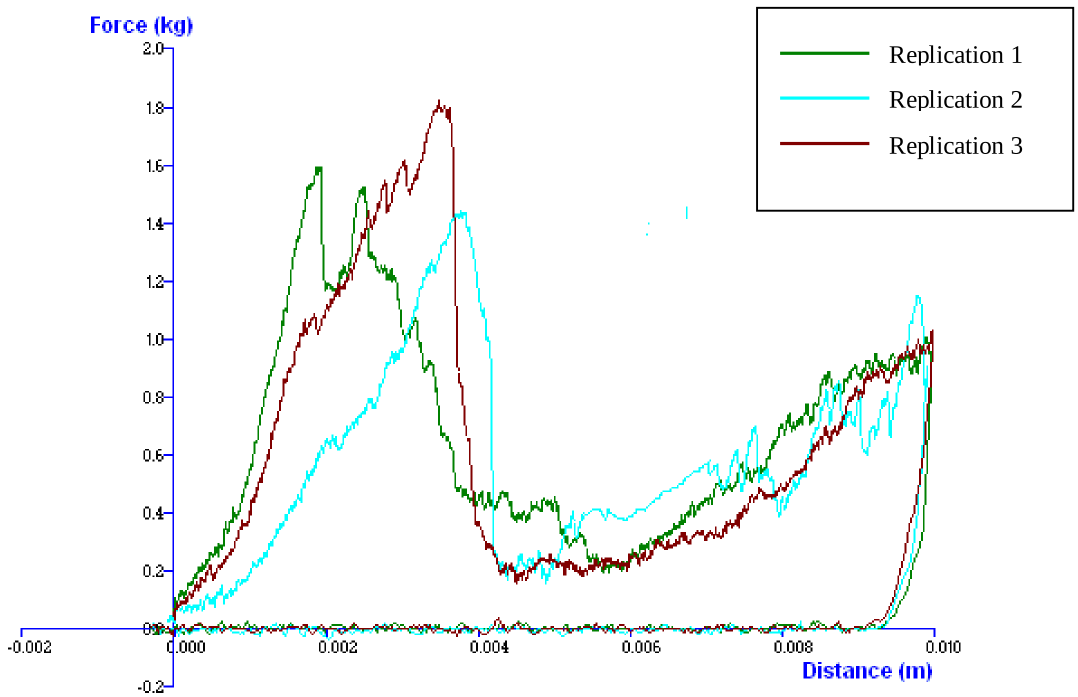


Fig 4.11 Texture profile curve of control biscuits in bending test

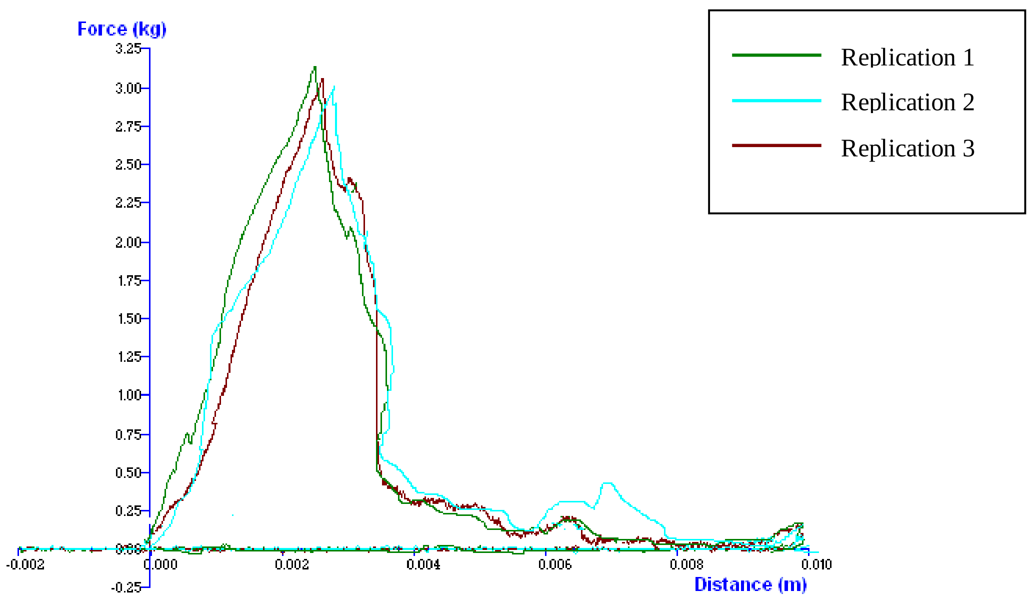


Fig 4.12 Texture profile curve of biscuits A1 in bending test

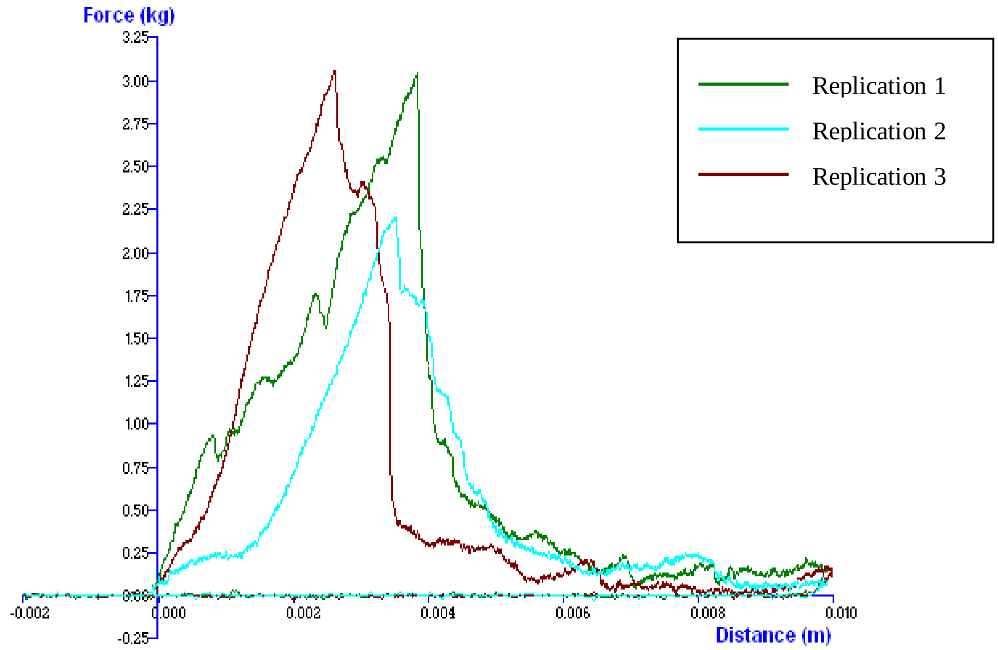


Fig 4.13 Texture profile curve of biscuits A2 in bending test

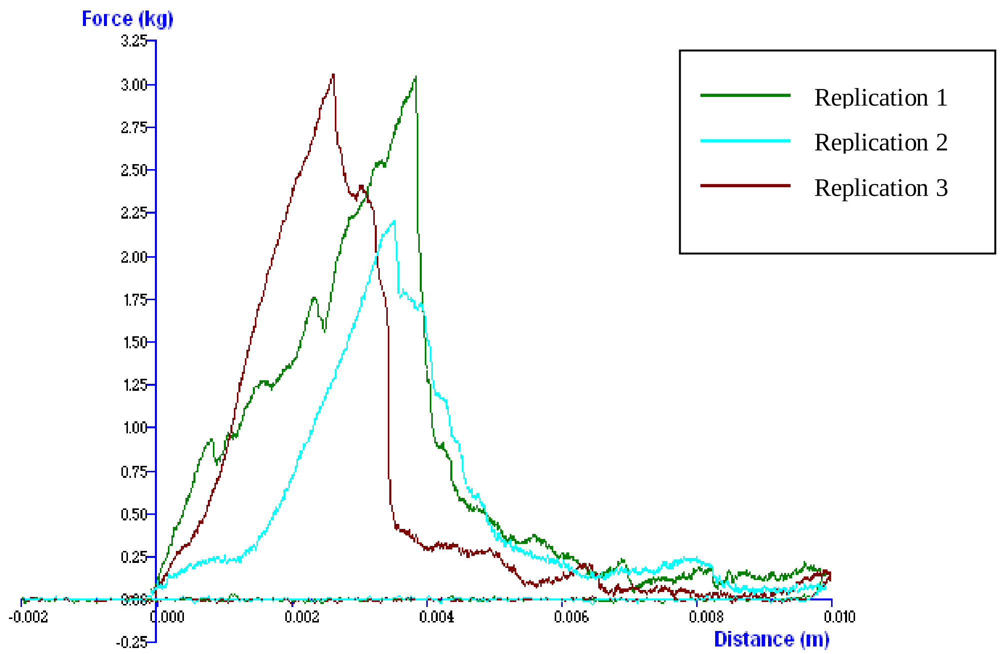


Fig 4.14 Texture profile curve of biscuits A3 in bending test

Table 4.9 Hardness and fracturability of biscuit samples for bending test

Biscuit	Firmness	
	Hardness (kg) 'Mean Maximum Force'	**Fracturability (mm) 'Mean Distance at Break'**
Control (60% maida+40 % soy flour)	3.04	3.65
A_1 (60 % maida +34% soy flour+6 % jambul seed powder)	2.40	2.81
A_2 (60% maida + 32% soy flour+8 % jambul seed powder)	1.82	2.42
A_3 (60% maida + 30% soy flour+10 % jambul seed powder)	1.52	4.19

With further increased of the jambul seed powder from 8 to 10 %, the hardness values further reduced from 1.82 kg to 1.52g. It was observed that the hardness of biscuit reduced by increasing the percentage of jambul seed powder in soy biscuits and as jambul seed powder increased from 6% to 10% level, there was almost 1.5 kg reduction in hardness of soy biscuits (control). Sample A_2 was broken at a very short distance (2.42 mm) and had a high fracturability compared to other combinations. The biscuit sample A_3 having high jambul seed powder was fractured at maximum distance 4.19 mm indicating less crispiness. Therefore, more per cent of jambul seed powder than soy flour also affected the texture of biscuits by making them soft and less crispy. However, the more crispness was obtained for the biscuit sample having soy flour and jambul seed powder in 32% and 8% respectively.

4.4 Nutritional analysis of biscuits:

The standard procedures were used for biochemical analysis of biscuits as described in Chapter III. The data for chemical analysis of the biscuits made from different blends from soy flour are shown in Table 4.10. The moisture content of control biscuits and biscuits prepared from different blends was found to be 3.13, 3.38, 3.31 and 3.20 per cent for control, A1, A2 and A3 samples respectively. It can be seen that as the jambul seed powder content increased in the samples the moisture content values decreased. The control sample has least value of moisture content. Similar type of results have also been found and reported by Brewer *et al*; (1992). It may be due to higher water holding capacity of the soy flour due to which samples containing larger percentage of soy flour, i.e A_1 has the maximum moisture content after taking.

The total ash in control biscuits as well as biscuits prepared from different blends are presented in Table 4.10. The total ashes of composition A_3 biscuits (34% soy flour + 6% jambul seed powder) were higher than those of composition A_1 and A_2 biscuits. Ash content of control (40% soy flour + 60% maida) was found to be 1.90.Correspondingly higher level of minerals in soy beans and jambul seed powder may be responsible for these increased values. Similar results have been reported by Singh *et al*; 2000

Comparisons with composition A_1, A_2, A_3 and control biscuits showed that there was a slight increase of protein content for composition A_1, A_2 and A_3 than the control biscuit. Biscuit composition A_2 (34% soy flour + 6% jambul seed powder) were found to have a higher protein value because of the high initial protein of the soy flour and jambul seed powder. The protein content was observed highest with progressive highest proportion of soybean flour in the biscuits, indicating that supplementation of jambul seed powder with soy flour would greatly improve the protein nutritional quality of biscuit. This could obviously be due to the significant quantity of protein in soybean seeds. Similar results have been reported for the enrichment of protein may be achieved through incorporation of protein-rich soy flours by Gandhi *et al*., 2001; Patel & Rao, 1996; Sharma & Chauhan, 2002; Singh, Singh, & Chauhan, 1996.

The carbohydrates of control biscuits and biscuits prepared from different blends were found to be 68, 67.2, 66.9 and 66.4 percent for control, A_1, A_2 and A_3 samples respectively (Table 4.10). The biscuits made from 60% maida + 40 % soy flour (control biscuit) had highest value of carbohydrates because of high per cent of carbohydrates in the soy flour. There was not much difference in carbohydrates among all the biscuits prepared from different blends but decreasing with decrease in soy flour in the composition.

The fat content of the control biscuits was 35.20 per cent while relatively lower and comparable values were observed for composition A_1, (24.28%), A_2 (26.22%), and for composition A_3 (26.76%).Regarding fat content of biscuits, the use of good amount of ghee as shortening might have contributed to the much higher values of fat which in turn resulted in relatively higher energy value. Similarly, another groups of authors (Singh et al; 2000) attempted nutritional improvement of conventional biscuits by incorporating soy flour which was reflected in significantly higher amounts of protein. ash, carbohydrates etc.

Acidity of extracted fat was about 0.4% for all samples, indicating no danger of rancidity in the biscuits. There was not difference in free fatty acids values among the all the compositions. Similar type of results have also been found and reported by Manly,(1996).The pH values of all the biscuit samples above 7 and only jambul seed powder showed pH value as 4.7.

The calorific value of control biscuit and biscuits prepared from different blends was found to be 660.8, 554.02, 569.3, and 515.64Kcal/100gm. The calorific value of control biscuit (60% maida + 40% soy flour) was higher than other biscuits because of the higher amount of fat in control biscuit. However, the calorific value of all the three compositions of biscuits was slightly different from each other depending on the amount of fat per cent in the composition.

The sugar free reduced the total sugar level with a simultaneous increase of reducing sugar level. Reducing sugar and total sugar, contents of control (60 % soy flour + 40 % Maida) biscuits were 13.3% and 5.07% respectively, (Table 4.10). The biscuits supplemented with 6%, 8% and 10 % of jambul seed powder showed a non-significant decrease in total and reducing sugar contents as compared to control biscuits. Among the supplemented biscuits, biscuits with jambul seed powder exhibited minimum values of total and reducing sugars namely vary between 12.8-12.34% and 3.52 – 3.96% for all the three combinations respectively. Biscuits made from blends of 30 % Maida + 10% jambul seed powder exhibited maximum contents of total and reducing sugars. Ascorbic acid was not found in all the combinations of biscuits.

Water is necessary for the growth of microbes but they can not grow in pure water. Most spoilage bacteria require a minimum of a_w of 0.90. An aw of 0.85 or less suppresses the growth of organism of public health significance (Dwivedi *et al.*,2007) .In Table 4.10 shows the average water activity values of all the products which ranged from 0.319 to 0.398. These values below 0.4 indicated that the products were below the levels at which microbial growth could takes place. At 0.3 – 0.4, a relatively smaller enzyme activity can be noticed and the lipid oxidation rate also reached to its minimum water activity in this range of water activity.

Since, the present study aimed at developing the biscuits rich in above mentioned nutrients. Apart from these, the biscuits were also found to be rich in almost all the assessed nutrients. Hence, in view of their nutritional significance as well as convenience, the biscuits can be suitable for feeding trials in supplementary feeding programmes and also have commercial viability.

Table 4.10 Nutritional analysis of different biscuit compositions

	Biscuit Composition				Jambul seed powder
	A_1 (60%maida + 34% soy flour+6 % jambul seed powder)	A_2 (60%maida + 32% soy flour+8 % jambul seed powder)	A_3 (60%maida + 30% soy flour+610% jambul seed powder)	Control (60%maida + 40% soy flour)	
Moisture (%)	3.38	3.31	3.20	3.13	3.08
Total Ash (%)	1.13	1.30	1.57	1.90	0.97
Soluble Protein (%)	0.5	0.7	0.8	0.6	0.03
Crude protein (%)	16.67	16.43	16.10	18	3.67
Carbohydrates (%)	67.2	66.9	66.4	68.0	10.23
Crude fat (%)	24.28	26.22	26.76	35.20	3.74
Free fatty acids (%)	0.4	0.4	0.4	0.4	0.1
Calorific Value (Kcal/100gm)	554.02	569.30	570.84	660.80	89.26
Reducing Sugar (%)	3.1	3.5	3.6	5.07	0.57
Total sugar (%)	12.8	12.52	12.34	13.3	2.3
pH (%)	7.37	7.41	7.57	7.8	4.7
Percent titrable acidity (%)	ND	ND	ND	ND	6.8
Ascorbic acid (%)	ND	ND	ND	ND	0.1
Water activity (%)	0.319	0.325	0.357	0.384	0.398

ND: Not Detected

4.5 Color measurement

Color is one of the most important factors in the quality of baked products. Results obtained from color evaluation are shown that in Table 4.11. There was a slight variation in the lightness values among the biscuit samples A_1, A_2, A_3 as shown by L* values of 9.74–17.69. Narrow range of a* values (12.74–13.97), indicate that the samples developed fairly uniform tinge of red color during baking. Sample were less yellowish in color as shown by comparatively less b* values (7.63–10.17). Jambul powder showed L* value 30.16, a* value 9.09 and b* value 7.43 respectively and control biscuit (40% soy flour and 60% maida) showed L* value 30.57, a* value 10.94 and b* value 10.27 respectively .Color evaluation of soy-jambul fortified biscuits showed a decrease in brightness with increased levels of jambul seed powder. Soy flour and jambul seed powder containing biscuits were significantly ($P \leq 0.05$) darker (L), redder (a) and more yellow (b) than those of control biscuits. It can be seen from the results given that development of color during baking was not markedly affected by the incorporation of soy flour at different levels.

Table 4.11 Colour values of biscuit samples

Samples	L*	a*	b*
Composition A_1 (60% maida + 34% soy flour+6 % jambul seed powder)	17.69	12.74	10.17
Composition A_2 (60% maida + 32% soy flour+ 8% jambul seed powder)	11.89	12.80	7.97
Composition A_3 (60% maida + 30% soy flour+ 10%jambul seed powder)	9.74	13.97	7.63
Control (6o% maida + 40% soy flour)	30.57	10.94	10.27
Jambul seed powder	30.16	9.09	7.43

L*=index of lightness/brightness; a*= index of redness/greenness; b*= index of yellowness/blueness.

4.6 Sensory evaluation

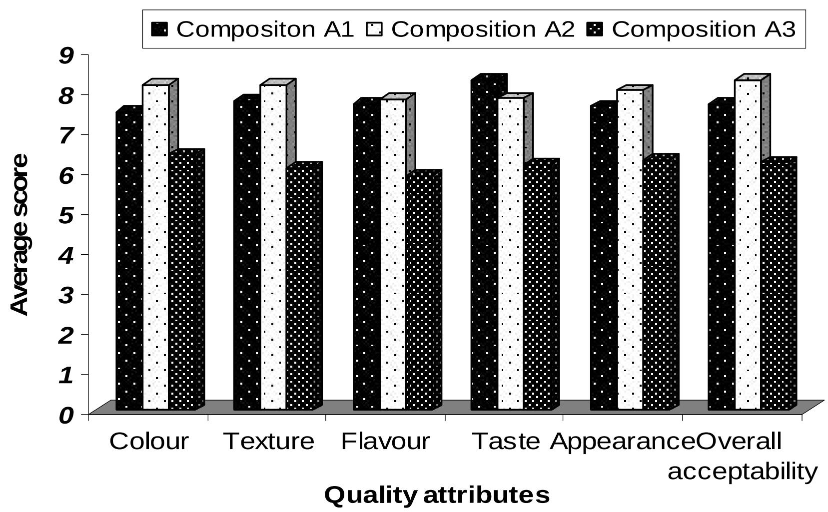
The sensory evaluation was done on the basis of colour, texture, flavour, taste, appearance and overall acceptability. There were three samples of biscuits of different compositions. The quality was judged by a fifteen member's consumer panel. The food products were rated on a nine-point hedonic scale as described in chapter III. The average scores of soy jambul seed powder biscuits given by the consumer panel for each characteristic are represented in Fig 4.15. It was observed that the maximum scores of colour (8.13), texture (8.13), flavour (7.78), taste (8.26) appearance (8.00), and overall acceptability (8.26) were obtained for the composition of A_2. It was observed from Fig 4.15 that the combination A_2 containing 32% soy flour and 8% jambul seed powder was most accepted by the judges of consumer panel.

Plate 3.16 Sensory Evaluation of Biscuits

Table 4.12. Average score of biscuits by consumer panel

Sample No.	Colour	Texture	Flavour	Taste	Appearance	Overall acceptability
Composition A_1 (60% maida + 34% soy flour+6 % jambul seed powder)	7.46	7.73	7.66	8.26	7.60	7.66
Composition A_2 (60% maida + 32% soy flour+8 % jambul seed powder)	8.13	8.13	7.78	7.80	8.00	8.26
Composition A_3	6.40	6.06	5.86	6.13	6.26	6.20

(60% maida + 30% soy flour+10 % jambul seed powder)						



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ig.4.15 Average score of various attributes of sensory evaluation

From Fig 4.15 it can be found that the scores for colour, texture, flavour, taste, appearance and overall acceptability (OA) of biscuits A_1 were 7.46, 7.73, 7.66, 7.8, 7.6 and 7.66 respectively. Similarly, the scores for colour, texture, flavour, taste, appearance and overall acceptability (OA) of biscuits A_3 were observed as 6.4, 6.06, 5.86, 6.13, 6.26 and 6.2 respectively. The scores for flavour were almost same for A_1 and A_2 composition.

The scores for colour, texture, flavour, taste, appearance and overall acceptability (OA) of biscuits were found to decrease with increasing per cent of jambul seed powder and decreasing per cent of soy flour. It can be clearly seen from Table 4.12

It is evident from the results that highest score was obtained by biscuits prepared from 32% soy flour + 8 % jambul seed powder while lowest by biscuits prepared from 30 % soy flour + 10% jambul seed powder. Judges have disliked the biscuits prepared from 34% soy flour + 6 % jambul seed powder and 30 % soy flour + 10% jambul seed powder with respect to colour when subjected under sensory evaluation. More darkness in the colour of the biscuits was observed as the level of the supplementation of the jambul seed powder was increased in the soy flour that may be subjected to the dark brown colour of the biscuits.

Texture of the biscuits containing soy flour in their formulation was significantly affected with the increase in the level of the jambul seed powder. Biscuits prepared from 32 % soy flour + 8 % jambul seed powder got highest (8.13) score while lowest score was obtained in the biscuits prepared from 30 % soy flour + 10% jambul seed powder. With respect to the texture, judges have accepted biscuits prepared from all the treatments of the composite flours.

The results indicated that the biscuits prepared from 32% soy flour + 8 % jambul seed powder significantly got highest score (8.20) for flavour. The data for quality score of taste revealed that judges placed sample 34 % soy flour +6 % jambul seed powder at top position (8.26) and rejected 30 % soy flour + 10% jambul seed powder (6.13). Judges have disliked the biscuits prepared from 32% soy flour + 8 % jambul seed powder and 30 % soy flour + 10% jambul seed powder with respect to taste when subjected under sensory evaluation. The samples 32% soy flour + 8 % jambul seed powder and 30 % soy flour + 10% jambul seed powder scored very low as the judges complained of excessive jambul seed powder-like flavour in them, which might be due to the bitter taste of jambul seed powder.

The highest (8.00) significant value for the quality score of the biscuits was found for 32 % soy flour + 8 % jambul seed powder and lowest (4.41) for the biscuits prepared from 30 % soy flour + 10% jambul seed powder. Judges have disliked the biscuits prepared from 30 % soy flour + 10% jambul seed powder when subjected under sensory evaluation for their appearance.

Maximum score (8.26) was obtained by biscuits prepared from 32 % soy flour + 8 % jambul seed powder while minimum scores (7.66) and (6.2) were scored by the biscuits prepared from 34 % soy flour+ 6% jambul seed powder and 30 % soy flour + 10% jambul seed powder. Biscuits prepared from 34 % soy flour+ 6% jambul seed powder and 30 % soy flour + 10% jambul seed powder have been rejected by judges with respect to overall acceptability.

4.7 Statistical Analysis of sensory evaluation obtained by various judges:

The statistical analysis was performed on the basis of grade score. The data collected during the sensory analysis are presented in Appendix E.2. The statistical analysis was carried out in MS excel programme and ANOVA (Analysis of variance) Tables were prepared.

In analysis of variance for each organoleptic quality factor are presented in Table 4.13 to 4.18. It is evident from the tables that all the organoleptic qualities were significantly affected at 5 % level of significance.

4.7.1 Colour:

Colour is very important parameter in judging whether biscuits were baked properly and uniformly or not and also reflects the suitability of raw material used for the preparation and provides information about the formulation and quality of the product (Figure 4.15). Mean quality score of the colour of the biscuits have been given in the Table 4.12 and ANOVA Table presented in 4.13

Table 4.13 Analysis of Variance for colour

Source of variation	Sum of square	Degree of freedom	Mean sum square	F-ratio
Treatments	22.933	2	11.4665	6.55*
Judges	27.66	14	1.97	1.125
Error	49.067	28	1.75	-

*Significant at 5%

	SEm	CD
Treatments (3)	0.34	0.98
Judges (15)	0.34	0.98

Sum mean table

Treatments mean	A_2	A_1	A_3
Biscuit taste	8.13	7.46	6.40

It can be concluded that biscuits composition A_2 (32% soy flour+ 8% jambul seed powder) gave the highest biscuit colour (8.13) and was found significantly superior to that composition A_1 (34% soy flour+6 % jambul seed powder) and A_3 (30% soy flour+ 10%jambul seed powder) whereas its superiorly over that composition A_1 (34% soy flour+6 % jambul seed powder) only was not significant.

4.7.2 Texture:

The texture of food is one of the most challenging areas of food characteristics and main quality parameter affecting food preference. The Analysis of variance (ANOVA) table was prepared for texture and shown in Table 4.14.

Table 4.14 Analysis of Variance for Texture

Source of variation	Sum of square	Degree of freedom	Mean sum square	F-ratio
Treatments	36.05	2	18.025	12.17*
Judges	22.31	14	1.593	1.07
Error	41.6	28	1.48	-

*Significant at 5%

SEm	CD		
Treatments (3)	0.31		0.90
Judges (15)	0.31		0.90

Sum mean table

Treatments mean	A_2	A_1	A_3
Biscuit texture	8.13	7.73	6.06

It can be concluded that biscuits composition A_2 (32% soy flour+ 8% jambul seed powder) gave the highest biscuit texture (8.13) and was found significantly superior to that composition A_1 (34% soy flour+6 % jambul seed powder) and A_3 (30% soy flour+ 10%jambul seed powder) whereas its superiorly over that composition A_1 (34% soy flour+6 % jambul seed powder) only was not significant.

4.7.3 Flavour:

Flavour is the main criterion that makes the product to be liked or disliked. Quality score for the flavour of the biscuits revealed that the flavour of the biscuits varied significantly among different treatments.

Table 4.15 Analysis of Variance for Flavour:

Source of variation	Sum of square	Degree of freedom	Mean sum square	F-ratio
Treatments	34.98	2	17.49	9.5*
Judges	29.78	14	2.127	1.155
Error	51.52	28	1.84	-

*Significant at 5%

SEm	CD		
Treatments (3)	0.35		0.97
Judges (15)	0.35		0.97

Sum mean table

Treatments mean	A_2	A_1	A_3
Biscuit flavour	7.78	7.66	5.86

It can be concluded that biscuits composition A_2 (32% soy flour+ 8% jambul seed powder) gave the highest biscuit flavour (7.78) and was found significantly superior to that composition A_1 (34% soy flour+6 % jambul seed powder) and A_3 (30% soy flour+ 10%jambul seed powder) whereas its superiorly over that composition A_1 (34% soy flour+6 % jambul seed powder) only was not significant.

4.7.4 Taste:

The statistical analysis regarding the taste of biscuits prepared from composite flours has been depicted in Table 4.16. It is obvious from the results that supplementation significantly effected the overall acceptability of the biscuits.

Table 4.16 Analysis of Variance for Taste

Source of variation	Sum-of-square	Degree of freedom	Mean-square	f-ratio
Treatments	37.73	2	18.86	11.22*
Judges	32.8	14	2.34	1.39
Error	47.07	28	1.68	-

*Significant at 5%

SEm	CD		
Treatments (3)	0.35		0.97
Judges (15)	0.35		0.9

Sum mean table

Treatments mean	A_1	A_2	A_3
Biscuit taste	8.26	7.8	6.13

It can be concluded that biscuits composition A_1 (34% soy flour+ 6% jambul seed powder) gave the highest biscuit taste (8.26) and was found significantly superior to that composition A_2 (32% soy flour + 8% jambul seed powder) and A_3 (30% soy flour+ 10%jambul seed powder) whereas its superiorly over that composition A_2 (32% soy flour+8 % jambul seed powder) only was not significant

4.7.5 Appearance:

Table 4.12 shows the quality scores for the appearance of the biscuits. It is obvious from results that quality score for the appearance of the biscuits ranged from 6.26 to 8.00.

Table 4.17 Analysis of Variance for Appearance:

Source of variation	Sum-of-square	Degree of freedom	Mean-square	f-ratio
Treatments	24.71	2	12.355	9.73*
Judges	27.25	14	1.94	1.486*
Error	36.54	28	1.305	-

*Significant at 5%

SEm	CD		
Treatments (3)	0.294		0.85
Judges (15)	0.294		0.80

Sum mean table

Treatments mean	A_2	A_1	A_3
Biscuit appearance	8.00	7.6	6.26

It can be concluded that biscuits composition A_2 (32% soy flour+ 8% jambul seed powder) gave the highest biscuit appearance (8.00) and was found significantly superior to that composition A_1 (34% soy flour+6 % jambul seed powder) and A_3 (30% soy flour+ 10%jambul seed powder) whereas its superiorly over that composition A_1 (34% soy flour+6 % jambul seed powder) only was not significant.

4.7.6 Overall Acceptability:

The statistical analysis regarding the overall acceptability of biscuits prepared from composite flours has been depicted in Table 4.12. It is obvious from the results that supplementation significantly effected the overall acceptability of the biscuits.

Table 4.18 Analysis of Variance for Overall Acceptability:

Source of variation	Sum-of-square	Degree of freedom	Mean-square	f-ratio
Treatments	33.91	2	16.955	9.8*
Judges	31.91	14	2.27	1.31*
Error	48.67	28	1.73	-

*Significant at 5%

SEm	CD	
Treatments (3)	0.339	0.97
Judges (15)	0.339	0.97

Sum mean table

Treatments mean	A_2	A_1	A_3
Biscuit overall acceptability	8.26	7.66	6.20

It can be concluded that biscuits composition A_2 (32% soy flour+ 8% jambul seed powder) gave the highest biscuit overall acceptability (8.26) and was found significantly superior to that composition A_1 (34% soy flour+6 % jambul seed powder) and A_3 (30% soy flour+ 10%jambul seed powder) whereas its superiorly over that composition A_1 (34% soy flour+6 % jambul seed powder) only was not significant.

The results of the sensory evaluation of the biscuits prepared from the different treatments of the composite flour are according to the findings of Gambus et al., 2003, Iqbal, Shearer., 1997, Alpers and Sawyer-Morse., 1996, Sharma et al.,2002 and Ullah., 2003 who reported increasing the level of flaxseed flour and soy flour in the biscuits resulted in the significant decrease in the sensory attributes of the biscuits. Unequal proportions of soy flour and jambul seed powder greatly affected the colour, texture, taste and overall acceptability of biscuits.

4.8 Storage studies:

From the sensory evaluation, A_2 composition (60% maida + 32% soy flour + 8% jambul seed powder) was most accepted by the judges of consumer panel. Therefore, A_2 composition was stored. Fig.4.16 through Fig 4.19 shows the variation in water activity, colour, fat and free fatty acids of A_2 composition biscuits, packed in three different air tight package such as plastic pouch, plastic container and steel box for storage of 60 days. The water activity, colour, fat and free fatty acid of the biscuits was determined at 15 ,30, 45 and 60 days and the data collected of these properties are given in Appendix F.2.

In general it can be seen that as the storage duration increases, the water activity values increased. It was expected also similar finding was also reported by (Dwivedi *et al*., 2007). Fig 4.16 showed that water activity of biscuits in plastic pouches, plastic containers and steel boxes were comparable, those of samples in plastic pouches up to 30 days were significantly lower. The values for storage period after 30 days in plastic containers and steel boxes were comparable, but significantly higher in plastic containers and steel boxes. Overall quality of biscuits followed a pattern similar to changes in water activity, indicating that the loss of crispness was proportional to increase in water activity.

Fig 4.17 shows the change in color evaluation of stored biscuits. It can be seen that a decrease in brightness with increased storage period. The biscuits stored in plastic pouches showed only minor variation in brightness (L* values), a* and b* values up to 30 days.

Variation in fat with storage duration for biscuits kept in various containers has been illustrated in Fig 4.18. In case of plastic pouches, biscuits stored at ambient temperature, there were no considerable changes in volatile oil contents up to 30 days, but infestation was observed after 30 days. Discoloration, sogginess and loss of volatile oil were observed after 30 days in all the three packages.

Fig 4.19 shows the initial fat acidity of biscuits stored in plastic pouches, plastic containers and steel boxes were same and it was slightly increased 0.6% in 30 days. The extractable fat acidity of biscuit after 30 days increased gradually from 0.6% to 0.8%. The increase in fat acidity in steel box and plastic container over the storage period after 30 days. Although there was a definite decrease in the volatile oil content during storage, especially plastic container and steel box after 30 days. Similar results were obtained by Selvaraj, (2002) for storage studies on biscuits containing finger millet flour.

It is therefore, concluded that overall acceptability scores of supplemented biscuits were still in the category of 'like moderately' up to 30 days of storage. Hence, supplemented biscuits can be stored safely in plastic pouch at room temperature for 30 days without any adverse changes. Result suggests a storage life of biscuits about 30 days in plastic pouch which is adequate for most of the purpose.

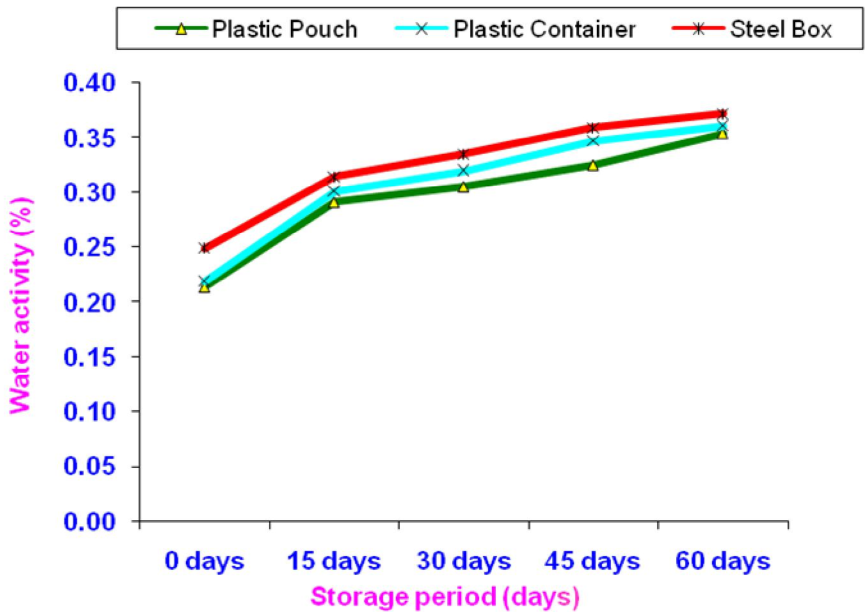

Fig 4.16 Variation in water activity with storage duration for biscuits kept in various containers

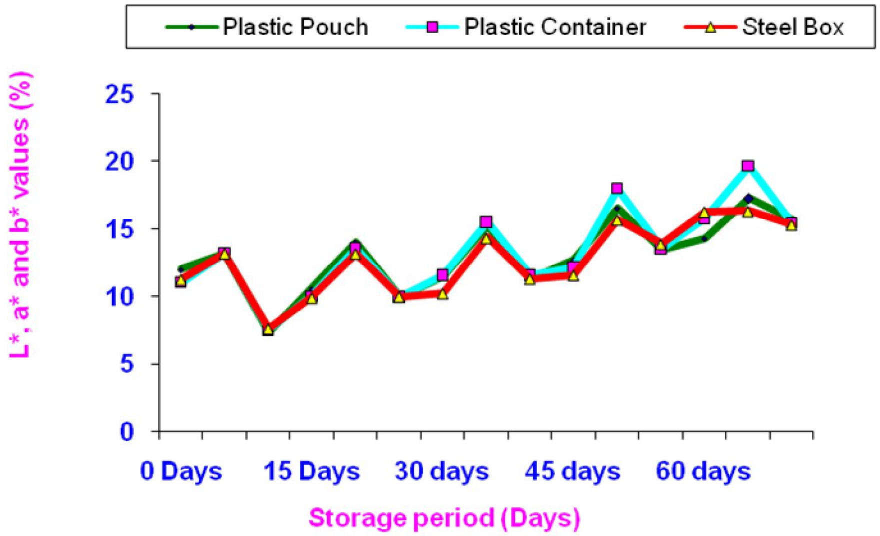

Fig 4.17 Variation in colour with storage duration for biscuits kept in various containers

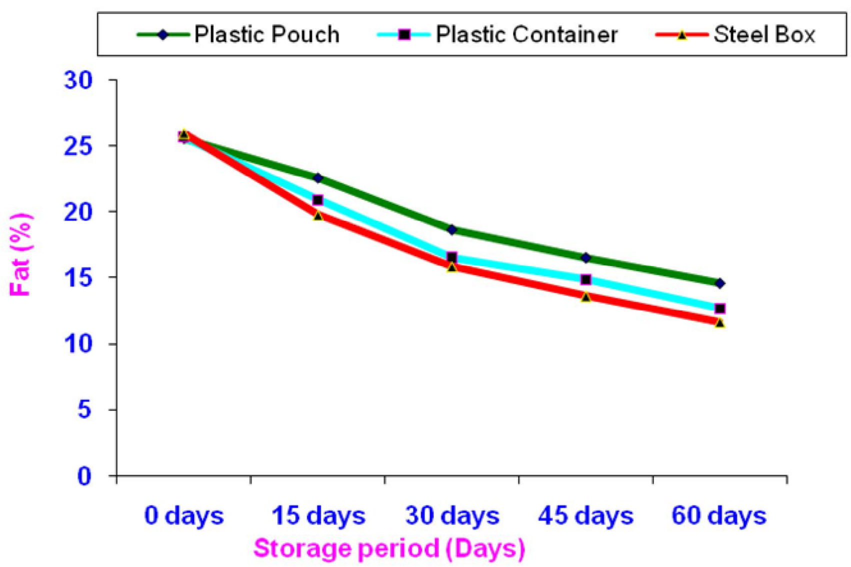

Fig 4.18 Variation in fat with storage duration for biscuits kept in various containers

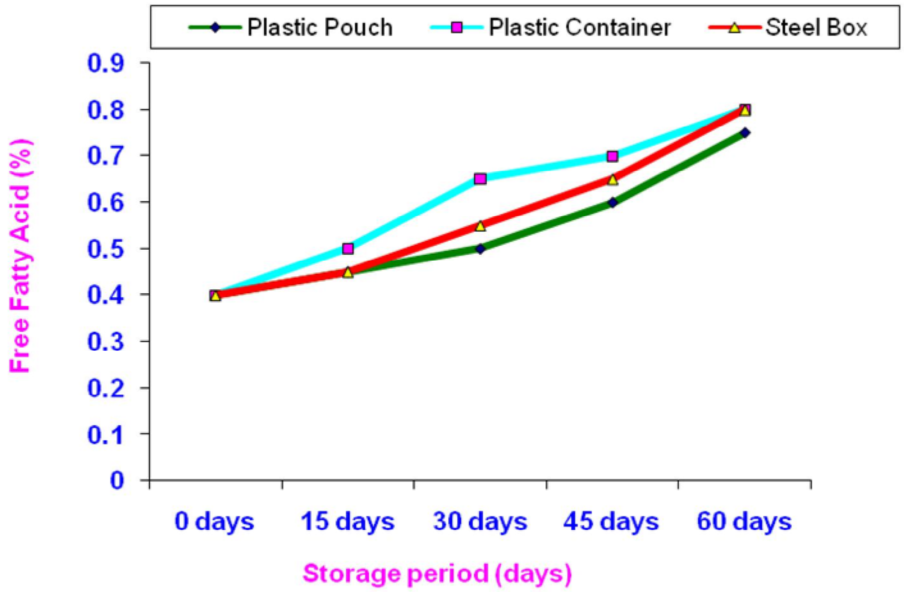

Fig 4.19 Variation in free fatty acid with storage duration for biscuits kept in various containers

CHAPTER V
SUMMARY AND CONCLUSION

India is one of the largest biscuit producers in the world and last few years have witnessed substantial increase in the consumption of bakery products including biscuits. Baking industry occupies an important position among Indian food processing industries with an annual turnover of about Rs. 3000 crores. Though bakery industry in India has been in existence since long, real fillip came only in the later part of the 21^{st} century Bakery products are ready to eat, convenient to use and have satisfactory nutritional quality. Bakery products once considered as sick man's diet have now become an essential food items of vast majority of population. The contributing factors were urbanization, resulting in increased demand for ready to eat profiles at reasonable costs etc.

More than two billion people or a third of the world's population are unable to enjoy their maximum physical and mental potential owing to an inadequate intake of nutrients. The prevalence of the problem is much higher in developing countries relative to developed countries. Fortification can often be implemented and be sustained over a long period of time, making it to be the most cost-effective way to overcome malnutrition. Fortification of commonly eaten foods, including cereals, pulses and vegetables, offers a low-cost and simple way of delivering nutrients to a large number of people who need them. Protein rich biscuits have been found to be useful in diet therapy for treating of nutritional oedema syndrome and malnutrition in children as well as adults. The use of soy flours and soy products in bakery products would not only improve nutritional quality of bakery products, but also increase profit margins of an entrepreneur due to improved product quality.

Jambul seed powder fortified soy biscuits of various combinations were prepared by using traditional creamy method. Biscuits from blend of maida, soy flour and jambul seed powder were prepared by mixing in different proportions viz., 60% Maida + 34% Soy flour + 6% jambul seed powder (A_1), 60% Maida + 32% Soy flour + 8% jambul seed powder (A_2) and 60% Maida + 30% Soy flour + 10% jambul seed powder (A_3). Length, width, thickness, mass, volume and spread ratios of biscuits were determined before and after baking. The heat and mass transfer coefficient must be known for mathematical simulation of heat and moisture transport in baking; and to control and optimize a baking a process in order to maximize the quality. Hence, efforts have been made to estimate the heat and mass transfer coefficients for baking of biscuit at 140^{o}C for 30 min. The moisture evaporation and temperature at surface of biscuits were recorded for complete baking process. These data were used for estimation of coefficients of convective heat and mass transfer which were mainly dependent on the rate of moisture transfer.

Blend of soy flour and jambul seed powder were formulated for studying the effect of the independent parametrs, *viz*., composition of ingredients (3 levels) on dependent parameters *viz*., firmness (hardness, fracturability and work of shear). By using Textural Analyzer, the three different tests *viz*., penetration, cutting and bending were conducted to evaluate textural properties of prepared biscuits. The 5 mm diameter stainless steel cylindrical probe, blade set and three point bend rig fixtures were used to get the typical textural profile (force-deformation) curve obtained with one complete run. The textures of the biscuits of various combinations were compared with the control biscuits obtained from local market.

The nutritional qualities such as moisture, ash, protein, soluble protein, carbohydrates, fat, free fatty acid, calorific value, reducing sugar, invert sugar, titrable acidity, ascorbic acid, water activity of biscuits were calculated for all treatments by using standard methods. Sensory evaluation was conducted on a nine-point hedonic scale by 15 members consumer test panel for colour, texture, flavour, taste, appearance and overall acceptability for soy- jambul seed powder based biscuits. The sensory evaluation data were statistically analysed by using the analysis of variance for various characteristics of biscuits. Storage study was conducted using three different packing devices such as plastic pouch, plastic container and steel box up to 60 days. Based on the results of the investigation, the following conclusions were drawn:

1. During baking the length and thickness of biscuits increased by 2.22% and 17.00% respectively. However, the spread ratio and mass of biscuits decreased by 12.41% and 20.76% respectively during baking.

2. The Reynolds number (Re) ranged between 1871.66 and 1793.03 for all the three treatments, whereas, Prandtl number (Pr) remained almost steady as 0.712 throughout the baking process. The Reynolds number ($Re<3 \times 10^5$) indicated that the entire baking fell within the laminar flow regime.

3. The convective heat transfer coefficients h_c for all combinations were almost similar as 18.9 W m^{-2} $^oC^{-1}$ and convective mass transfer coefficients k_G varied from 7.02×10^{-12} to 11.65×10^{-12} kg.mol/m^2sPa. Convective mass transfer coefficient increased with a decrease in moisture content of biscuits for all the three treatments.

4. The rational curve for biscuit combination A_2 exhibited best relation between convective mass transfer coefficients k_G and moisture content X_d. This model gives the maximum

coefficient of determination (r^2 =0.9753) with minimum root mean square error (E_{rms}= 0.1914). However, the goodness of fit of the model for heat transfer coefficient was found to be optimizes described by coefficient of determination 0.9537 and root mean square error (E_{rms}= 0.001833).

5. In penetration test, the hardness values of biscuit A_1, A_2 and A_3 were 0.0076, 0.0075 and 0.0066 kg m respectively. The fracturability value of A_2 biscuit (32.95) was greater than A_1 and A_3. Therefore, the combination A_2 (60% maida + 32% soy flour+8 % jambul seed powder) were more crispy or crunchy than A1 and A3.

6. In cutting test, the textural attributes were observed hard, firm and soft for biscuit combinations A_1, A_2 and A_3 respectively. The biscuit combination A_1 having 34% soy flour exhibited maximum hardness value of 5.56 kg and maximum work of shear of 0.024 kg m. Hence cutting force required to shear the biscuit having high percent of soy flour was maximum.

7. The better firmness and crispness/crunchiness were observed for biscuit combination A_2 in bending or snap test. Sample A_2 breaks at a very short distance at 2.42 mm and has a high fracturability compared to other combinations. The biscuit sample A_3 having high jambul seed powder has minimum peak force and it breaks at maximum distance 4.19 mm which indicates its texture is soft and less crispy. Hence decrease in soy flour and increase in jambul seed powder affected the texture of biscuits by making them soft and less crispy.

8. From all three tests it has bean observed that the control biscuit having 60% maida and 40 % soy flour exhibited maximum hardness for penetration, cutting and bending. The biscuits having high percentage of soy flour were harder. As the level of jambul seed powder increased from 6 to 10%, the hardness of the biscuit reduced and vice versa. The shearing force and bending strength was maximum for soy biscuits (control). The work of shear was also maximum for control biscuit which was about 0.028 kg m.

9. The amount of protein, carbohydrates and total sugar were maximum for the soy rich biscuits of composition A1 (60% maida + 34% soy flour + 6% jambul seed powder), whereas, soluble protein, fat, ash and reducing sugar were rich in sample A_3 having 60% maida+30% soy flour+10% jambul seed powder. The moisture content of baked biscuits was ranged between 0.032 to 0.038 g H_2O/g DM. There was not difference in free fatty acids values among the all the compositions. The calorific value of all the three

compositions of biscuits was slightly different from each other. The average water activity values of all the products which ranged from 0.319 to 0.357

10. The calorific value of control biscuit (60% maida + 40% soy flour) was higher than other biscuits because of higher amount of fat content (35.20%). Higher level of minerals in soy bens and jambul seed powder may be responsible for increased value of ash content.
11. Unequal proportions of soy flour and jambul seed powder affected the colour, texture, taste and overall acceptability of biscuits. The composition 60% maida+32% soy flourr+8% jambul seed powder i.e.A_2 was best for colour, texture, flavour, appearance, overall acceptability and was most accepted by the judges of consumer panel. But the composition 60% maida+ 34 % soy flour + 6% jambul seed powder i.e. A1was best for taste because of lass amount of jambul seed powder.
12. In statistical analysis, it can be concluded that biscuit composition A2 (60% maida+32% soy flourr+8% jambul seed powder) was found significantly superior to the composition A1 (60% maida+34% soy flourr+6% jambul seed powder) and A3 (60% maida+30% soy flour+10% jambul seed powder)
13. Supplemented biscuits can be stored safely in plastic pouch at room temperature for 30 days without any adverse changes. Result suggests a storage life of biscuits about 30 days in plastic pouch which is adequate for most of the purpose.

Suggestions for Future Work

1. Other textural properties of biscuits may be studied. Viz, crispiness etc.
2. Storage studies may be done by using metalized polyester, polypropylene and HMHDPE material.
3. Storage study undertaken at accelerates conditions.

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APPENDIX-A.1

Composition	A1		A2		A3	
	Before baking	After baking	Before baking	After baking	Before baking	After baking
Thickness, T (cm)	0.70	0.80	0.75	0.85	0.75	0.85
	0.75	0.85	0.70	0.80	0.70	0.85
	0.70	0.80	0.70	0.85	0.75	0.85
Mean	**0.716**	**0.816**	**0.716**	**0.833**	**0.733**	**0.850**
Spread ratio, D/T	6.42	5.75	6	5.41	6	5.41
	6	5.41	6.42	5.75	6.42	5.41
	6.42	5.75	6.42	5.41	6	5.41
Mean	**6.28**	**5.63**	**6.28**	**5.52**	**6.14**	**5.41**
Mass, W (g)	12.11	9.20	12.48	9.88	13.00	11.02
	12.15	9.26	12.65	9.78	12.78	9.88
	12.13	9.32	12.64	10.85	12.56	10.00
Mean	**12.13**	**9.26**	**12.59**	**10.17**	**12.78**	**10.30**
Length (cm)	4.49	4.58	4.5	4.6	4.49	4.67
	4.5	4.6	4.49	4.75	4.5	4.6
	4.49	4.89	4.5	4.6	4.5	4.62
Mean	**4.5**	**4.69**	**4.5**	**4.65**	**4.5**	**4.63**
Width (cm)	4.5	4.66	4.49	4.67	4.49	4.55
	4.49	4.64	4.5	4.6	4.5	4.65
	4.5	4.67	4.5	4.62	4.5	4.60
Mean	**4.5**	**4.66**	**4.5**	**4.63**	**4.5**	**4.60**
Volume (cm^3)	14.14	17.07	14.10	18.25	15.12	18.06
	14.38	18.14	14.53	17.48	14.17	18.10
	14.14	18.26	14.065	18.06	15.18	18.06
Mean	**14.20**	**17.82**	**14.20**	**17.933**	**14.84**	**18.10**

Physical properties of Biscuits before and after baking

APPENDIX-B.1

Table B.1- Experimental Readings and moisture content of Biscuit A1

Sr. no	t	W (g)	W (Kg)	Me (g)	Me (Kg)	M (g)	M (Kg)	Xd Kg[H_2O]/Kg[Dry matter]	Xw Kg[H_2O]/Kg[Biscuit]
1	0	12.13	0.01213	-	-	3.03	0.00303	0.33333	0.25
2	3	10.35	0.01035	0.19	0.00019	2.84	0.00284	0.312431	0.238055
3	6	10.27	0.01027	0.35	0.00035	2.49	0.00249	0.273927	0.215026
4	9	10.11	0.01011	0.32	0.00032	2.17	0.00217	0.238724	0.192718
5	12	10.04	0.01004	0.28	0.00028	1.89	0.00189	0.207921	0.172131
6	15	9.78	0.00978	0.28	0.00028	1.61	0.00161	0.177118	0.150467
7	18	9.66	0.00966	0.23	0.00023	1.38	0.00138	0.151815	0.131805
8	21	9.52	0.00952	0.22	0.00022	1.16	0.00116	0.127613	0.113171
9	24	9.45	0.00945	0.19	0.00019	0.97	0.00097	0.106711	0.096421
10	27	9.32	0.00932	0.18	0.00018	0.79	0.00079	0.086909	0.07996
11	30	9.26	0.00926	0.14	0.00014	0.65	0.00065	0.071507	0.066735

Table B.-2- Experimental Readings and moisture content of Biscuit A2

Sr. no	t	W (g)	W (Kg)	Me (g)	Me (Kg)	M (g)	M (Kg)	Xd Kg[H_2O]/Kg[Dry matter]	Xw Kg[H_2O]/Kg[Biscuit]
1	0	12.59	0.01259	-	-	3.02	0.00302	0.33333	0.25
2	3	12.39	0.01239	0.2	0.0002	2.82	0.00282	0.311258	0.237374
3	6	12.03	0.01203	0.36	0.00036	2.46	0.00246	0.271523	0.213542
4	9	11.69	0.01169	0.34	0.00034	2.12	0.00212	0.233996	0.189624
5	12	11.42	0.01142	0.27	0.00027	1.85	0.00185	0.204194	0.169569
6	15	11.16	0.01116	0.26	0.00026	1.59	0.00159	0.175497	0.149296
7	18	10.93	0.01093	0.23	0.00023	1.36	0.00136	0.15011	0.130518
8	21	10.72	0.01072	0.21	0.00021	1.15	0.00115	0.126932	0.112635
9	24	10.52	0.01052	0.2	0.0002	0.95	0.00095	0.104857	0.094905
10	27	10.33	0.01033	0.19	0.00019	0.76	0.00076	0.083885	0.077393
11	30	10.17	0.01017	0.16	0.00016	0.6	0.0006	0.066225	0.062112

Table B-3- Experimental Readings and moisture content of Biscuit A3

Sr. no	t	W (g)	W (Kg)	Me (g)	Me (Kg)	M (g)	M (Kg)	Xd Kg[H_2O]/Kg[Dry matter]	Xw Kg[H_2O]/Kg[Biscuit]
1	0	12.78	0.01278	-	-	3.01	0.00301	0.33259	0.24958
2	3	12.57	0.01257	0.21	0.00021	2.8	0.0028	0.309392	0.236287
3	6	12.22	0.01222	0.35	0.00035	2.45	0.00245	0.270718	0.213043
4	9	11.88	0.01188	0.34	0.00034	2.11	0.00211	0.233149	0.189068
5	12	11.59	0.01159	0.29	0.00029	1.82	0.00182	0.201105	0.167433
6	15	11.31	0.01131	0.28	0.00028	1.54	0.00154	0.170166	0.14542
7	18	11.07	0.01107	0.24	0.00024	1.3	0.0013	0.143646	0.125604
8	21	10.85	0.01085	0.22	0.00022	1.08	0.00108	0.119337	0.106614
9	24	10.65	0.01065	0.2	0.0002	0.88	0.00088	0.097238	0.08862
10	27	10.46	0.01046	0.19	0.00019	0.69	0.00069	0.076243	0.070842
11	30	10.3	0.0103	0.16	0.00016	0.53	0.00053	0.058564	0.055324

Table B. 4 Heat and mass transfer coefficients during baking of biscuit A_1 at regular time intervals

t (Min)	T_s (^oC)	T_o (^oC)	T_i (^oC)	K_a W m^{-} $^{1o}C^{-1}$	Pa Kgm^{-3}	$\mu x10^5$ $kgm^{-1}s^{-1}$	C_a J/kg-$^{10}C^{-1}$	Re	Pr	h_c W m^{-2} $^oC^{-1}$	Volume X 10^6 m^3	Pa Kg m^{-3}	Cb J/kg-$^{10}C^{-1}$	K_g x 10^5 ms^{-1}	k_G x 10^{12} kg.mol/m^2 sPa
3	120	140	130.00	0.0332	0.8767	2.3186	1019.55	1871.66	0.712	18.949	14.49	824.01	877.48	2.620	7.81
6	125	140	132.50	0.0334	0.8713	2.33	1019.97	1850.91	0.712	18.941	14.81	782.57	875.19	2.765	8.19
9	127	140	133.50	0.0334	0.8692	2.3347	1020.14	1842.70	0.712	18.938	15.13	744.87	870.49	2.920	8.63
12	130	140	135.00	0.0335	0.8660	2.3417	1020.39	1830.50	0.712	18.934	15.45	711.32	868.38	3.065	9.03
15	132	140	136.00	0.0336	0.8638	2.346	1020.56	1822.43	0.712	18.931	15.77	679.13	860.30	3.240	9.52
18	135.2	140	137.60	0.0337	0.8605	2.353	1020.84	1809.63	0.713	18.926	16.09	651.33	856.43	3.392	9.93
21	136.5	140	138.25	0.0338	0.8591	2.356	1020.95	1804.46	0.713	18.925	16.41	625.22	851.79	3.553	10.38
24	137.2	140	138.60	0.0338	0.8584	2.358	1021.01	1801.69	0.713	18.924	16.73	601.91	849.41	3.701	10.81
27	138.5	140	139.25	0.0338	0.8570	2.361	1021.12	1796.57	0.713	18.922	17.05	580.05	844.91	3.860	11.25
30	139.1	140	139.55	0.0339	0.8564	2.362	1021.17	1794.21	0.713	18.921	17.37	561.31	842.79	3.999	11.65

Table B. 5 Heat and mass transfer coefficients during baking of biscuit A_2 at regular time intervals

t (Min)	T_s (^oC)	T_o (^oC)	T_i (^oC)	K_a W m^{-1} $^oC^{-1}$	Pa Kgm^{-3}	$\mu x10^5$ $kgm^{-1}s^{-1}$	C_a J/kg-$^{1 0}C^{-1}$	Re	Pr	h_c W m^{-2} $^oC^{-1}$	Volume X 10^6 m^3	Pa Kg m^{-3}	Cb J/kg-$^{10}C^{-1}$	K_g x 10^5 ms^{-1}	k_G x 10^{12} kg.mol/m^2 sPa
3	122.2	140	131.1	0.0332	0.8743	2.32	1019.74	1862.491	0.712	18.945	14.47	856.25	917.13	2.412	7.17
6	127.1	140	133.55	0.0334	0.8690	2.33	1020.154	1842.297	0.712	18.938	14.77	814.48	913.45	2.545	7.52
9	131.2	140	135.6	0.0335	0.8646	2.344	1020.501	1825.652	0.712	18.932	15.07	775.71	911.23	2.678	7.88
12	132.62	140	136.31	0.0336	0.8631	2.347	1020.621	1819.940	0.712	18.930	15.37	743.00	908.51	2.804	8.23
15	135.6	140	137.8	0.0337	0.8600	2.354	1020.874	1808.040	0.712	18.925	15.67	712.18	904.33	2.938	8.60
18	136.8	140	138.4	0.0337	0.8588	2.357	1020.976	1803.282	0.712	18.924	15.97	684.40	897.80	3.079	9.00
21	137.9	140	138.95	0.0338	0.8576	2.359	1021.07	1798.936	0.712	18.922	16.27	658.88	894.55	3.210	9.36
24	138.6	140	139.3	0.0338	0.8569	2.361	1021.129	1796.179	0.712	18.921	16.57	634.88	888.85	3.352	9.77
27	139	140	139.5	0.0338	0.8565	2.362	1021.163	1794.606	0.712	18.920	16.87	612.32	885.38	3.490	10.17
30	139.2	140	139.6	0.0338	0.8563	2.362	1021.18	1793.820	0.712	18.920	17.17	592.31	879.86	3.630	10.57

Table B. 6 Heat and mass transfer coefficients during baking of biscuit A_3 at regular time intervals

t (Min)	T_s (^oC)	T_o (^oC)	T_i (^oC)	K_a W m^- $^{1o}C^{-1}$	Pa Kgm^{-3}	$\mu x10^5$ $kgm^{-1}s^{-1}$	C_a J/kg-$^{10}C^{-1}$	Re	Pr	h_c W m^{-2} $^oC^{-1}$	Volume X 10^6 m^3	Pa Kg m^{-3}	Cb J/kg-$^{10}C^{-1}$	K_g x 10^5 ms^{-1}	k_G x 10^{12} kg.mol/m^2 sPa
3	125.4	140	132.7	0.0333	0.8708	2.331	1020.01	1849.266	0.7121	18.940	14.45	869.89	918.48	2.370	7.02
6	127.6	140	133.8	0.0334	0.8685	2.336	1020.196	1840.255	0.7122	18.937	14.73	829.59	914.83	2.495	7.37
9	129.9	140	134.95	0.0335	0.8660	2.341	1020.391	1830.905	0.7123	18.933	15.01	791.47	912.40	2.621	7.72
12	132.3	140	136.15	0.0336	0.8635	2.347	1020.594	1821.225	0.7124	18.930	15.29	758.01	907.88	2.750	8.08
15	135.2	140	137.6	0.0337	0.8604	2.353	1020.84	1809.631	0.7125	18.926	15.57	726.39	898.11	2.901	8.49
18	136.3	140	138.15	0.0337	0.8593	2.356	1020.934	1805.262	0.7126	18.924	15.85	698.42	888.90	3.048	8.91
21	137.8	140	138.9	0.0338	0.8577	2.359	1021.061	1799.33	0.7126	18.922	16.13	672.65	883.52	3.183	9.29
24	137.5	140	138.75	0.0337	0.8580	2.359	1021.036	1800.514	0.7126	18.923	16.41	648.99	868.51	3.357	9.80
27	138.2	140	139.1	0.0338	0.8573	2.36	1021.095	1797.753	0.7127	18.922	16.69	626.72	861.36	3.505	10.22
30	139.4	140	139.7	0.0338	0.8560	2.363	1021.197	1793.035	0.7127	18.920	16.97	606.95	855.52	3.643	10.61

APPENDIX C.1

SPECIFICATIONS OF TEXTURE ANALYZER

Main supply

The TA-XT plus / TA-HD plus has an IEC style main inlet and requires a mains supply of frequency and voltage that fall within the following limits:-

Table-1 Manual of TA.HD plus Texture Analyzer

Mains Supply Requirements	
Supply Voltage	100v A.C. to 240v A.C.
Supply Frequency	47 Hz to 63 Hz
Supply V.A.	120VA (TA.XT plus) 250 VA (TA.HD plus)

Only three pin mains plugs should be used for safety reasons

The main inlet on the TA-XT plus /TA-HD plus contains two 200 mm mains fuse, one fuse in the live circuit and the other in the neutral circuit. Both fuses must be fitted and working for the texture analyzer to operate.

Fuse Rating

These main fuses must be 1.6 amp anti-surge cartridge fuses, e.g. 1.6A (T) for TA-XT plus and 10A (T) for TA-HD plus.

The TA-XT plus / TA-HD plus are factory fitted with fuses of type BEL 5TT(P)1.6A and 10A(T) respectively, which carry safety agency approvals from underwriters Laboratories, UL listed file number E20624 and CSA certified file number LR39772.

Table-2 Manual of TA.HD plus Texture Analyser

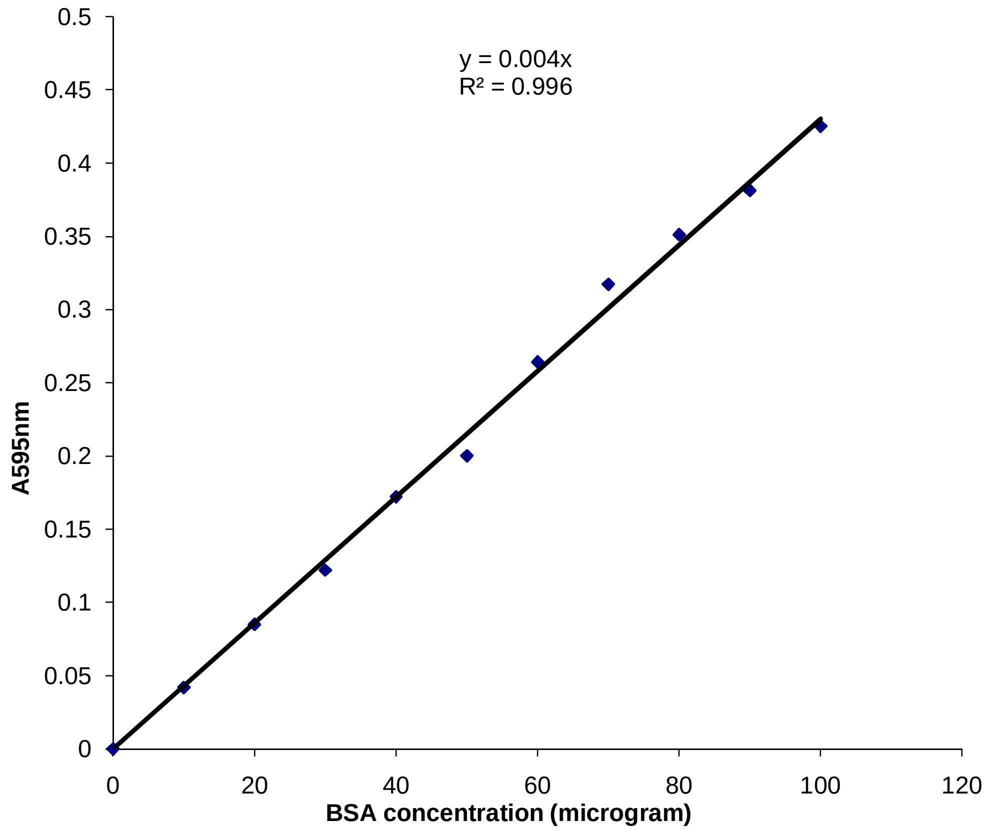
	TA.XT plus	TA.HD plus
Net weight	16.2 kg	38kg
Load cell capacity	5kg 30kg 50kg	5kg 30kg 50kg 100kg 250kg 500kg 750kg
Distance capacity	0.1 – 295mm (545mm for extended height version	0.1-524mm
Distance resolution	0.001mm	0.001mm
Speed capacity	40mm/s to 0.01mm/s	500kg capacity and lower: 20 mm/s to 0.001mm/s 750kg capacity:13mm/s to 0.001mm/s

APPENDIX-C.2

Table C.2 Texture Analyzer readings for various combinations of biscuits

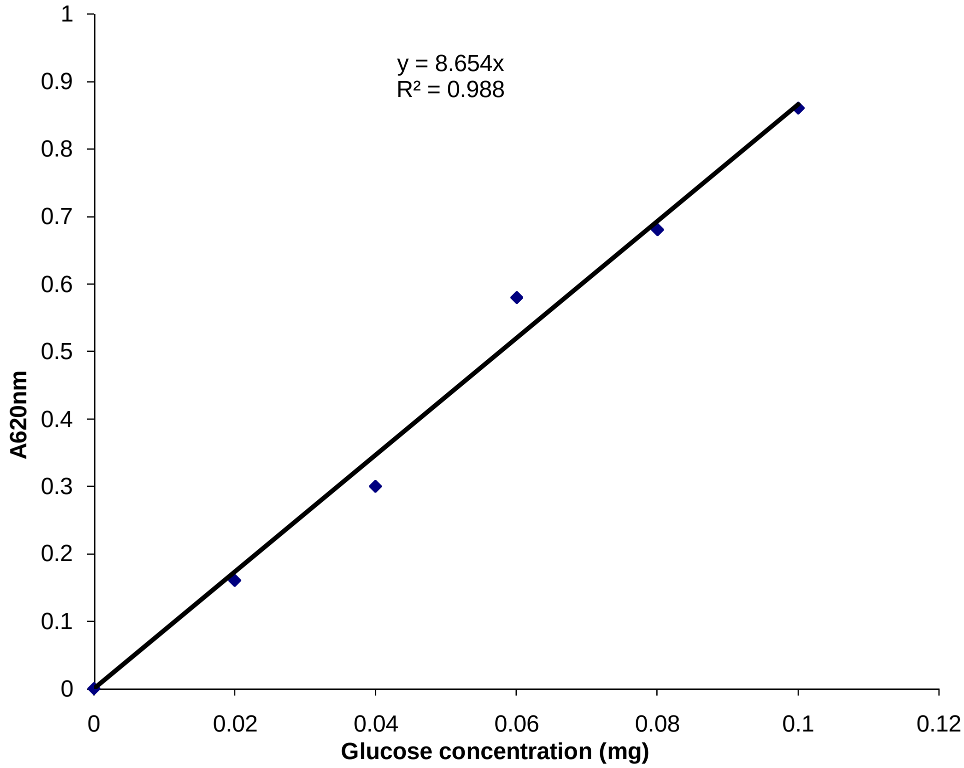
Samples		**Tests**					
		Penetration		**Cutting**		**Bending**	
		Hardness (Kg gm) Area	**Fracturability (Kg m) Linear Distance**	**Hardness (kg) First Peak force**	**Work Of shear**	**Hardness (Kg) Maximum Force**	**Fracturability (mm) Distance at Break**
Control	1	0.008	32.999	5.8178	0.027	2.7975	3.94
	2	0.009	33.166	6.9746	0.028	3.2	3.56
	3	0.008	32.205	5.5976	0.028	3.1225	3.47
A1	1	0.008	33.027	5.4226	0.025	2.539	2.84
	2	0.007	33.097	5.9489	0.024	2.4724	2.87
	3	0.008	32.126	5.3085	0.023	2.1886	2.74
A2	1	0.008	33.205	5.7394	0.021	1.9	2.18
	2	0.007	32.13	4.2819	0.022	1.8706	2.47
	3	0.008	33.514	4.3879	0.02	1.6894	2.63
A3	1	0.007	33.264	3.3788	0.021	1.601	4.17
	2	0.006	32.559	3.229	0.022	1.5191	4.25
	3	0.005	32.187	4.0896	0.022	1.4399	4.15

APPENDIX-D.1



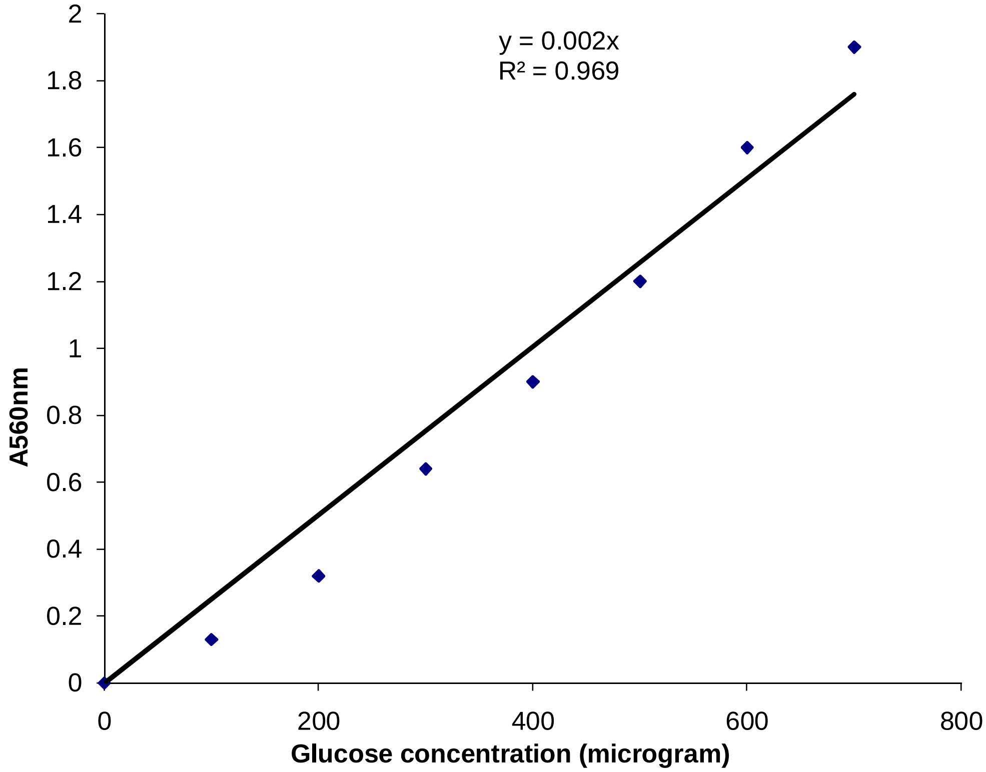
Standard curve for soluble protein by Bradford method (595nm)

APPENDIX-D.2



Standard curve for carbohydrate by Anthrone method (620 nm)

APPENDIX-D.3



Standard curve for reducing sugar by DNSA method (560 nm)

Appendix D.4

Specifications of Hunter lab Colorimeter

Sr. No.	Particulars	Details
1.	Manufacturer's Name	Hunter Associates Laboratory, Inc.
2.	Product Name	Colourflex
3.	Model	CFLX-DIEF, CLFX-45
4.	Illumination and viewing (i) Source (ii) Source UV (iii) Integrating Sphere	Dual beam Xenon flash lamp Nominal match to D65 63.5 mm diameter, high efficiency, white coating
5.	Port diameters/view diameters (i) 45/0 model (ii) Diffuse/8^o	 31.8 mm/25.4 mm 14.9 mm/8.0 mm

APPENDIX-E.1

Development of Soy-jambul Seed powder fortified Biscuits

(**Sensory evaluation of soy-jambul seed fortified biscuits)**

Score Card No. Date:

Scale:

Like extremely - 9	Like slightly-6	Dislike moderately- 3
Like very much- 8	Neither like nor dislike-5	Dislike very much- 2
Like moderately-7	Dislike slightly-4	Dislike extremely - 1

S.No	Colour	Texture	Flavour	Taste	Appearance	Over all acceptability
A_1						
A_2						
A_3						
B_1						
B_2						
B_3						
C_1						
C_2						
C3						

Signature:

Name:

APPENDIX-E.2

Table F. 1 Score of sensory evaluation of biscuits.

Sensory Attributes	Treatments	Judges														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Colour	A1	8	6	7	7	9	8	9	8	9	9	8	8	8	9	9
	B1	7	5	6	6	8	8	8	9	7	9	7	8	8	8	8
	C1	6	6	5	5	7	8	6	8	5	6	8	8	5	6	7
Texture	A1	9	6	6	8	8	8	9	9	8	9	8	8	8	9	9

	B1	8	6	6	7	7	9	8	8	8	8	8	9	8	7	9
	C1	5	5	6	5	7	7	5	7	6	5	7	7	5	8	6
Flavour	A1	9	5	7	7	9	7	9	8	8	8	8	7	8	8	9
	B1	7	5	7	7	8	9	6	9	7	8	9	9	8	8	8
	C1	5	5	6	4	7	5	5	7	5	7	7	5	7	7	6
Taste	A1	8	6	7	7	9	8	9	9	9	9	8	8	9	9	9
	B1	8	5	7	7	7	9	7	8	8	8	8	9	9	9	8
	C1	5	5	5	4	7	6	6	7	6	7	8	6	6	8	6
Appearance	A1	8	6	7	7	9	8	9	9	8	8	9	8	8	8	8
	B1	8	5	6	6	8	9	8	9	8	8	8	8	8	8	7
	C1	5	6	5	5	7	7	7	6	6	6	7	7	7	7	6
Overall Acceptability	A1	8	6	7	7	9	8	9	9	9	9	9	8	8	9	9
	B1	8	5	6	6	8	9	7	9	8	8	8	8	9	8	8
	C1	5	6	5	5	7	7	6	7	6	4	7	7	7	8	6

APPENDIX-F.1

Storage stability of biscuit composition A2 upto 60 days

Table G. 1 Storage stability of biscuit composition A2 for 0 days

Ingredients	Water activity	colour			Fat	Free fatty acid
		L*	a*	b*		
Plastic Pouch	0.214	11.97	13.13	7.35	25.56	0.4
Plastic Container	0.219	11.02	13.14	7.50	25.68	0.4
Steel Box	0.249	11.23	13.15	7.60	25.93	0.4

Table G. 2 Storage stability of biscuit composition A2 for 15 days

Ingredients	Water activity	colour			Fat	Free fatty acid
		L*	a*	b*		
Plastic Pouch	0.291	10.57	14.01	9.93	22.57	0.4
Plastic Container	0.301	10.03	13.53	9.96	20.93	0.5
Steel Box	0.314	9.89	13.11	9.98	19.74	0.4

Table G. 3 Storage stability of biscuit composition A2 for 30 days

Ingredients	Water activity	colour			Fat	Free fatty acid
		L*	a*	b*		
Plastic Pouch	0.305	11.45	15.23	11.23	18.62	0.5
Plastic Container	0.320	11.56	15.48	11.56	16.54	0.6
Steel Box	0.335	10.21	14.29	11.29	15.84	0.6

Table G. 4 Storage stability of biscuit composition A2 sample for 45 days

Ingredients	Water activity	colour			Fat	Free fatty acid
		L*	a*	b*		
Plastic Pouch	0.325	12.69	16.52	13.41	16.52	0.6
Plastic Container	0.347	12.11	17.96	13.52	14.87	0.7
Steel Box	0.359	11.54	15.65	13.84	13.61	0.7

Table G. 5 Storage stability of biscuit composition A2 for 60 days

Ingredients	Water activity	colour			Fat	Free fatty acid
		L*	a*	b*		
Plastic Pouch	0.354	14.28	17.24	15.69	14.56	0.7
Plastic Container	0.361	15.74	19.63	15.41	12.68	0.8
Steel Box	0.372	16.24	16.29	15.27	11.63	0.8