STANDARDIZATION AND QUALITY EVALUATION OF GRAIN AMARANTH (*Amaranthus* spp.) FLOUR SUPPLEMENTED FOOD PRODUCTS

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Standardization and quality evaluation of grain amaranth (*Amaranthus* spp.) flour supplemented food products"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
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CERTIFICATE

Certified that this thesis entitled "**Standardization and quality evaluation of grain amaranth (*Amaranthus* spp.) flour supplemented food products**"is a bonafide record of research work done independently by **Ms. Nidhi Bhatiwada** under my guidance and supervision and that it has not formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of **Ms. Nidhi Bhatiwada,** a candidate for the degree of **Master of Science in Home Science**, with major field in **Food Science and Nutrition**, agree that the thesis entitled **"Standardization and quality evaluation of grain amaranth (*Amaranthus spp.*) flour supplemented food products"** may be submitted by Ms. Nidhi Bhatiwada in partial fulfillment of the requirements for the degree.

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Nidhi.

Nidhi Bhatiwada

Dedicated to
My Loving
Ma, Papa,
Gaurav &
Prachi

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Abbreviation

AOAC	Association of Official Analytical Chemists
^0C	Degree centigrade
cfu	Colony forming unit
CHD	Coronary Heart Diseases
cm	Centimeter
CRD	Complete Randomised Design
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agricultural Organisation
g	Gram
HDL	High Density Lipoprotein
ICMR	Indian Council of Medical Research
KAU	Kerala Agricultural University
Kcal	Kilo calorie
LDL	Low Density Lipoprotein
mg	Milligram
ml	Milliliter
mm	Millimeter
NIN	National Institute of Nutrition
nm	Nanometer
NPR	Net Protein Ratio
NPU	Net Protein Utilisation
OD	Optical density
%	Percentage
PEM	Protein Calorie Malnutrition
PER	Protein Efficiency Ratio
ppm	Parts per million
TIU	Trypsin Inhibitor Unit
RDA	Recommended Dietary Allowances
RNPR	Relative Net Protein Ratio
TCA	Trichloroacetic acid
WHO	World Health Organisation

Introduction

1. INTRODUCTION

Malnutrition continues to plague the Indian population particularly the vulnerable sections, despite the acceleration in the economic growth achieved by India in the past decades. The global prevalence of micronutrient deficiency is estimated to be about two billion and most of the afflicted people are living in the developing countries (Nair, 2006). Nearly one in three people, especially in developing countries, are affected by one or more micronutrient deficiencies. Food based strategy to combat malnutrition involves identification of optimal good sources of nutrients and ensuring their availability.

Grain amaranth, a multi-purpose drought tolerant crop grown for leaves, grains and for ornamental purpose is considered to be an underutilized crop. There are about 60 species of amaranth used as grain, pot herb or forage. Pale seeded amaranth was first grown in Germany in the 16^{th} century, India and Ceylon in the 18^{th} century, the Himalayas in the early 19^{th} century and interior China and Eastern Siberia in the late 19^{th} century (Sauer, 1977). Grain amaranth was considered to be one of the important food crops for the ancient middle and South American civilizations and even today this is an important food crop in Latin America. The plant is grown abundantly in Northern India, Manchuria, Southeast Asia and Africa (Irvin *et al.*, 1981; Kauffman and Weber, 1988). In India, grain amaranth is cultivated in the North Indian hills and in South India; cultivation is limited in the tribal region of Western Ghats (Mohideen *et al.*, 1983).

Some of the promising varieties of amaranthus species used for grain purpose are *Amaranthus hypochondriacus, Amaranthus curentus* and *Amaranthus caudatus*. Wide variation in the nutritive value of different species has been reported. However, it is considered to be rich in good quality protein with high lysine content and amino acid composition corresponding more closely to that of FAO / WHO recommended protein for optimum nutrition. If the biological value of an ideal protein is placed at 100, the protein of grain amaranth reaches 75, corn 44, wheat 60, soyabean 65 and cow's milk 72. The chemical score was reported to be higher than milk, soyabean, wheat and ground nut (Lehman, 1992). It is used as a staple food in the entire Himalayan region, Southern India and to some extent in Gujarat, Maharashtra, Karnataka and eastern parts of Uttar Pradesh.

Amaranth flour has found to be a good vehicle for iron fortification especially with ferrous fumarate to reduce the incidence of anaemia and also as an intervention strategy to combat Protein Energy Malnutrition (PEM) in infants and young children in the third world. Grain amaranth can be used to prepare value added products like chapathi, poori, cake, biscuits, weaning foods, health drinks, pizzas, snacks etc.

Grain amaranth is a unique, nutritionally rich non-cereal crop capable of combating malnutrition and has been identified as an alternative crop to traditional grain crops. It can be used to compliment other cereals, as an extender or as a supplement for added nutritional value in traditional foods in the developing countries. Commercialisation of underexploited grains like grain amaranth will help in solving problems related to malnutrition.

Since there is a great potential in value added products from underexploited grains like amaranth to eradicate malnutrition and micronutrient deficiencies, an attempt has been made to supplement grain amaranth flour with other available cereal flours in the preparation of nutrient dense acceptable products. Hence, the present study entitled "Standardization and quality evaluation of grain amaranth (*Amaranthus spp.*) flour supplemented food products" has been undertaken with the following objectives.

1. To study the changes in quality attributes of amaranth flour during storage.
2. To standardize amaranth flour supplemented recipes by incorporating it in wheat flour, maida (refined wheat flour) and rice flour at different proportions.
3. To select the most acceptable amaranth flour incorporated recipes.
4. To compute the nutritive value of amaranth flour incorporated recipes.

Review of Literature

2. REVIEW OF LITERATURE

Amaranth is in a "world" by itself!

Amaranth delivers a complete package of nutrients than many other grains and grain-like foods. Amaranth belongs to the so called improper cereals (pseudo-cereals). It contained high quality protein, oil with squalene and high proportion of unsaturated fatty acids, high quality roughage and starch. Grain amaranth can be considered as a promising food crop of the future from the nutritional point of view, valued for both the unconventional grains and leaves. Value added products like baby foods, candies, snacks, protein drinks, hypo-allergic foods etc. using amaranth had been reported by many workers.

Nowadays, interest of using amaranth grains in combination with other cereal sources to prepare products of improved nutritional quality is gaining importance due to its high nutritive value.

In this chapter, the literature pertaining to the study has been reviewed under the following sub headings.

2.1. Amaranth – A pseudo cereal

2.2. Physical characteristics of grain amaranth

2.3. Nutritive value of grain amaranth

- 2.3.1. Moisture
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2.6. Health benefits of grain amaranth.

2.1. AMARANTH – A PSEUDO CEREAL

The grains which resemble cereals in many ways but do not belong to the family of Graminae are generally referred as pseudo cereals. The Amaranthaceae family consists of hardy, herbaceous, fast growing cereal like plants (Opute, 1979). Amaranth is one of these rare plants whose leaves are eaten as a vegetable while the seeds are used as cereals (Kauffman and Hass, 1983; Oke, 1983; Saunders and Becker, 1984).

According to Verma and Jain (2007), pseudo cereal constituted an important component of the life-support species and these crops had a high degree of acceptability in the poor farming households. These underutilized crops included amaranth (*Amaranthus spp.*), buckwheat (*Fagopyrum spp.*), chenopod (*Chenopodium spp.*) and job'starch tears (*Coix lacrymajobi*).

According to Saunders and Becker (1984) and Singhal and Kulkarni (1988), amaranth grain is a pseudo cereal possessing the usual characteristics of cereals such as bland taste, ease of cooking with substantial quantity of protein and fat as compared to most cereals. Amaranth is considered as a non cereal food and used by certain communities as the sole food while fasting religiously (Vaidehi *et al.*, 1989).

Sauer (1993) evaluated the evidence of domestication of amaranth and concluded that amaranth came into use as a grain at least 6000 years ago in Central America. Grain amaranth was reported to be the native of the New world and is the staple food for Aztecs (National Academy of Sciences, 1984). Chavez-Jauregui *et al.* (2000) indicated that this pseudo cereal is largely consumed by the people of Andean countries due to its high nutritive value.

2.2. PHYSICAL CHARACTERISTICS OF GRAIN AMARANTH

Jain and Hauptli (1980) and Saunders and Becker (1984) studied the physical appearance of grain amaranth and reported that amaranth seeds are small and lenticular in shape with a seed diameter in the range of 1.0 to 1.5 mm and thousand grain weight in the range of 0.6 to 1.2 g. Bressani *et al.* (1987a) observed a seed weight of 0.6 mg, 0.92 mg and 0.73 mg per seed in *Amaranthus caudatus, Amaranthus hypochondriacus and Amaranthus curentus* respectively. Sudha (1989) also observed a grain weight of 0.6 g per thousand grains.

Smitha (2006) evaluated 23 accessions of grain amaranth collected from different parts of India and indicated that the grain yield per plant varied from 49.9 to 128 g with a mean grain yield of 87.14 g per plant.

Sanchez-Marroquin *et al.* (1980) highlighted that the seeds of *Amaranthus hypochondriacus* when milled, yielded 16.2 per cent coarse flour, 10.4 per cent fine flour, 20.1 per cent broken grains and 52.6 per cent bran. However, Sudha (1989) observed that the amaranth grains yielded 70 and 30 per cent of flour and bran respectively after milling.

Delahaye and Gomez (1987) indicated that alkaline isolate of amaranth had 200 per cent water absorption, 150 per cent oil absorption, 80.5 per cent emulsion activity and 92.4 per cent emulsion stability while succinylated isolate had 280 per cent water absorption, 180 per cent oil absorption, 96 per cent emulsion activity and 98 per cent emulsion stability. The water holding capacity of a blend of 80:20 amaranth and defatted maize gluten meal was found to be 34 per cent (Koeppe *et al.*, 1987).

Mendoza and Bressani (1987) conducted studies on functional characteristics of extrusion cooked amaranth flour and indicated higher water absorption, water retention and damaged starch in extruded flour than in raw flour. Sudha (1989) observed a water absorption capacity, fat absorption capacity and least gelation concentration of 110, 150 and 14 per cent respectively in amaranth flour. Effect of puffing on functional properties of *Amaranthus paniculatus* (Rajgeera) seed flour indicated higher water and fat holding capacities in puffed samples (Singhal and Kulkarni, 1991). However, there was no effect on gelation while a decrease in viscosity and foaming was noticed in puffed samples.

Goering (1967) studied the properties of starch chunks from *Amaranthus retroflexus* and found that the starch had low solubility and swelling power that makes it very strong and uniform with good capacity to hold the mass. The *Amaranthus caudatus* starch was reported to be completely non glutinous (Okuno and Sakaguch, 1981). Becker *et al.* (1981) indicated low swelling power for the starch obtained from *Amaranthus hypochondriacus* with high solubility, water binding capacity and gelatinisation temperature when compared to wheat.

The unique aspect of amaranth grain starch was found to be its smaller granular size (1 to 3 μm) when compared to other cereal grains (Becker *et al.*, 1981). Unique gelatinisation and freeze/thaw characteristics of starch granules due to their unique size and composition which are beneficial to the food industry was indicated by Becker *et al.* (1981). The size of the *Amaranthus hypochondriacus* starch was found to be only 1 mm with polygonal shape (Yanez *et al.*, 1986). Isolation and partial characterization of amaranth starch was studied by Paredes-Lopez and Escobedo-Mora (1989) and indicated that starch granules had a polygonal shape as revealed by scanning electron microscopy.

Tomita *et al.* (1981) reported that *Amaranthus caudatus* starch had 5 to 7 per cent amylose with amylopectin as the major constituent and there was high susceptibility of *Amaranthus hypochondriacus* and *Amaranthus caudatus* starch granules to amylases.

The gelatinisation temperature of amaranth flour varied from 65^0C to 74^0C and resembled with corn flour rather than wheat flour (Sanchez-Marroquin *et al.*, 1985).

Wahkhade *et al.* (1989) revealed that starch from grain amaranth had moderate swelling, higher solubility in water, low viscosity and little tendency to retrogradate when compared to other millet starch. Singhal and Kulkarni (1990) studied the paste viscosity, paste clarity, freeze/thaw stability and effect of shear on the viscosity of *Amaranthus paniculatus* (rajgeera) in comparison with corn starch and indicated higher paste viscosity, lower paste clarity and high freeze/thaw stability in amaranth. However, rajgeera starch underwent thinning when subjected to mechanical shear.

The solubility of proteins like albumin and globulin in grain amaranth was found to be very poor with water and 1 M NaCl. However, the solubility increased in 0.4 M NaCl at an alkaline pH (Soriano-Santos *et al.*, 1992).

2.3. NUTRITIVE VALUE OF GRAIN AMARANTH

2.3.1. MOISTURE

The moisture content of amaranth grains varied from 9.3 to 13.55 per cent (Conner *et al.*, 1980; Afolabi *et al.*, 1981; Osungton and Oke, 1983; Bressani *et al.*, 1987a; Arellano *et al.*, 1990).

2.3.2. PROTEIN CONTENT AND QUALITY

Downton (1973) indicated a protein content of 14.5 per cent in *Amaranthus edulis* seed with high lysine content of 6.2 g 100 g^{-1} of protein. The author also highlighted that *Amaranthus edulis* seed had 25 to 30 per cent more lysine than opaque-2 and floury-2 strains of maize, which are rich sources of lysine. Carlson (1974) indicated a crude protein content of 15 to 18 per cent in amaranth seeds. Abid and Sahib (1976) analysed seven species of amaranth seeds and reported a protein content in the range of 15 to 19.37 per cent and a lysine content in the range of 7.8 to 10.0 per cent. Schmidt (1977) indicated a protein content of 12.6 to 15.6 per cent in grain amaranth. However, Barker *et al.* (1979) observed higher protein content of 15.5 to 16.5 per cent in grain amaranth with a high biological value of 73 per cent.

Conner *et al.* (1980) indicated 16.5 per cent protein in *Amaranthus edulis* with a favourable essential amino acid composition of lysine (0.94%), methionine and cystine (0.66%), arginine (1.54%) and threonine (0.59%). However, National Institute of Nutrition (1980) reported a protein content of 14 per cent in grain amaranth with a lysine content of 4.4 g 16 g^{-1} N.

Betschart *et al.* (1981) observed a lysine content of 318 mg g^{-1} N in *Amaranthus curentus*, which was comparable with 340 mg g^{-1} N of FAO provisional scoring pattern. Afolabi *et al.* (1981) indicated a protein content of 12.5 per cent in grain amaranth with a lysine content of 4 g 16 g^{-1} N. Osungton and Oke (1983) indicated a protein content of 13.1 per cent in *Amaranthus hybridus* seed.

Evaluation of market samples of grain amaranth indicated a protein content of 15.6 per cent with lysine content in the range of 4.2 to 5.8 g 16 g^{-1} N (National Institute of Nutrition, 1983). Uzo and Okorie (1983) observed a lysine content in the range of 3.8 to 6.3 g 16 g^{-1} N in five varieties of *Amaranthus hybridus*. Bressani *et al.* (1987a) studied the composition of 14 selected amaranth species and observed a protein content in the range of 12.5 to 16.0 per cent with threonine as the limiting amino acid. Lysine and tryptophan content were found to be in the range of 0.73 to 0.84 per cent and 0.18 to 0.28 per cent respectively.

Pederson *et al.* (1987) studied the nutritive value of black and pale coloured amaranth grains and indicated high protein content in black grains. Nutritional composition of ten grain amaranth cultivars of China including *Amaranthus hypochondriacus, Amaranthus hybridus, and Amaranthus curentus* was studied by Yue *et al.* (1987) and observed higher levels of protein and lysine in grain amaranth when compared to other cereals. Arellano *et al.* (1990) studied the potential nutritive value of *Amaranthus curentus* seeds and observed a protein content of 15.5 per cent with threonine and leucine as limiting amino acids. Nutritive value of grain amaranth was evaluated by Raju (1990) and Reddy *et al.* (1992) and indicated that grain amaranth contained high quality protein with perfect amino acid balance and a protein content in the range of 14 to 15 per cent.

Prakash and Pal (1992) indicated a protein content in the range of 103 to 183 g Kg^{-1} in 41 species of grain amaranth. Bejosano and Corke (1998) reported that protein content of amaranth wholemeal flour and protein concentrate varied from 124 g kg^{-1} to 168 g kg^{-1} and 674 g kg^{-1} to 753 g kg^{-1} respectively. Munjal *et al.*, (1999) observed a protein content in the range 13 to 16 per cent in grain amaranth.

Kalac and Moudry (2000) compared the advantage of amaranth grains with conventional cereals and reported high content of proteins and balanced amino acid composition in amaranth grains. Total essential amino acid content of amaranth and soyabean was found to be 47.6 and 60.3 g 100 g^{-1} protein respectively and highest amount of lysine, methionine and arginine was found in pseudo cereals (Gorinstein *et al.*, 2002).

The protein content of *Amranthus curentus* flour was found to be 16.6 per cent with high lysine content and leucine, threonine and valine as the limiting amino acids (Escudero *et al.*, 2004). Smitha (2006) reported protein content in the range of 15.15 to 18.65 g 100 g^{-1} in 23 accessions of amaranth grains with a mean value of 16.57 g 100 g^{-1}.

Afolabi *et al.* (1981) studied the quality of protein in *Amaranthus caudatus* and indicated that it had a digestibility of 91.6 per cent, Net Protein Utilization (NPU) of 91.7, Biological Value (BV) of 45.6 and Protein Efficiency Ratio (PER) of 0.4. Protein quality of *Amaranthus hybridus* was estimated by Osungton and Oke (1983) and found an NPU of 71.6, BV of 77.7, true digestibility of 92.1 per cent and a PER of 2.3 which was almost comparable with casein. Pant (1983) observed significantly high Net Protein Ratio (NPR) of 3.92 in grain amaranth than that of wheat (2.6).

Bressani *et al.* (1987a) studied the protein quality of 14 cultivars of amaranthus and indicated a PER in the range of 2.23 to 2.59. Pederson *et al.* (1987) compared the digestibility of protein in pale and black coloured seeds of *Amaranthus caudatus* and concluded that pale seeds had better digestibility. However, Bressani *et al.* (1987a) indicated similar PER values of 2.36 in light and dark coloured seeds. A high PER was observed in amaranth seeds than wheat and it was found to be almost similar to casein (Gamel *et al.*, 2004).

2.3.3. FAT AND FATTY ACID PROFILE

The crude fat content of amaranth grains varied from 4.3 to 5.4 per cent (Schmidt, 1977). However, Conner *et al.* (1980); Afolabi *et al.* (1981) and Arellano *et al.* (1990) observed a higher fat content of 6.9, 7.1 and 6.95 per cent respectively in amaranth grains. Fat content in the range of 5.4 to 7.3 per cent (National Institute of Nutrition, 1980) and 5.6 to 8.1 per cent (Becker *et al.*, 1981) were also reported in grain amaranth. Osungton and Oke (1983) also observed a fat content of 7.5 per cent in *Amaranthus hybridus* seed. Fat content of grain amaranth varied from 1.5 to 6.2 per cent (Uzo and Okorie, 1983), 8.25 to 12.85 per cent (Bressani *et al.*,1987a), 60 to 69 g kg^{-1} (Prakash and Pal, 1992), 4.06 to 6.38 per cent (Munjal *et al.*, 1999) and 5.83 to 7.13 per cent (Berganza *et al.*, 2003).

Stoller and Weber (1970) studied the fatty acid composition of the lipids of 14 species of grain amaranth and observed linoleic acid as the predominant fatty acid in 14 species (36.5 to 76.5 %). Oleic (10.3 to 42.9 %), palmitic (6.0 to 22.1 %) and stearic acids (1.2 to 6.3 %) were also found in all species. Opute (1979), Carlson

(1980); Becker *et al.* (1981) and Fernando and Bean (1984) also reported linoleic acid as the predominant fatty acid in amaranth grains with relatively high degree of unsaturation.

Lorenz and Hwang (1985) studied the lipid composition of eight varieties of amaranth seeds and indicated that the free lipid content varied from 5.69 to 7.23 per cent and bound lipid from 0.42 to 0.91 per cent while linoleic, oleic, palmitic and stearic acids were in the range of 38 to 48 per cent, 22 to 35 per cent 19 to 21 per cent and 4 to 8 per cent respectively.

Ayorinde *et al.* (1989) studied the fatty acid composition of amaranthus species and indicated significant levels (2 - 5 %) of squalene and a combined form of linoleic and oleic acids (70 to 80 %) in all varieties.

Daulatabad and Hosamani (1992) reported that *Amaranthus paniculatus* seed oil contained 19.4 per cent palmitic, 3.9 per cent stearic, 21.9 per cent vernolic, 1.5 per cent manolic and 1.6 per cent sterculic acids.

Camacho *et al.* (2001) studied the oil of *Amaranthus curentus* and stated that seeds contained high content of squalene (4.16 g Kg^{-1} of seed), n-alkenes (332ppm) and n-alkanes (155 ppm).

Berganza *et al.* (2003) observed palmitic acid (17.06 to 21.3 %), stearic acid (3.05 to 3.80 %), oleic acid (20.26 to 32.01 %) and linoleic acid (33.52 to 43.88 %) in the oil of five varieties of *Amaranthus caudatus.*

2.3.4. CARBOHYDRATES

The carbohydrate content of grain amaranth was found to be 61.8 per cent (Afolabi *et al.*, 1981), 62.4 to 65 per cent (Uzo and Okorie, 1983) and 63.13 to 68.78 per cent (Munjal *et al.*, 1999).

The starch content of pale seeded grain types was reported to vary from 48 per cent for *Amaranthus curentus* to about 62 per cent for *Amaranthus hypochondriacus* (Becker *et al.,* 1981; Saunders and Becker, 1984). The starch content of *Amaranthus curentus* was found to be 45.36 per cent (Arellano *et al.,* 1990). Smitha (2006) reported that the starch content of amaranth grain varied from 49.75 to 67.17 per cent.

The fibre content of amaranth seeds varied from 5.8 to 7.2 per cent (Conner *et al.*, 1980; Afolabi *et al.*, 1981). However, Becker *et al.* (1981) reported a lower fibre content of 3.2 to 5.8 per cent. The fibre content of *Amaranthus hybridus* seed was found to be 6.8 per cent (Osungton and Oke, 1983). Market samples of grain amaranth and *Amaranthus curentus* seeds had only 2.4 and 2.82 per cent fibre respectively (National Institute of Nutrition, 1983; Arellano *et al.*, 1990). Munjal *et al.* (1999) observed a fibre content in the range of 2.90 to 4.34 per cent in grain amaranth. Black coloured amaranth grains contained high quantity of fibre as compared to pale coloured grains (Pederson *et al.*, 1987; 1990). Smitha (2006) reported fibre content in the range of 1.15 to 4.7 g 100 g^{-1} in 23 accessions of amaranth grains with a mean value of 2.65 g.

2.3.5. MINERALS AND VITAMINS

Schmidt (1977) and Barker *et al.* (1979) reported a higher content of calcium, sodium, manganese, magnesium and iron in grain amaranth when compared to other cereals. Calcium content in the range of 225 to 300 mg 100 g^{-1} was noticed in amaranth grains (National Institute of Nutrition, 1980).

National Institute of Nutrition (1983) evaluated the market samples of grain amaranth and reported that they contained 222 mg calcium, 13.94 mg iron, 548 mg phosphorus and 0.75 mg niacin 100 g^{-1} of grains. Smitha (2006) reported a calcium content of 559.3 to 600.35 mg 100 g^{-1} with a mean value of 579.30 mg.

Mineral constituents of *Amranthus curentus* were found to be 710 mg potassium, 200 mg sodium, 140 mg calcium and 550 mg phosphorus 100 g^{-1} of grains (Arellano *et al.*, 1990). Joshi and Rana (1991) indicated calcium content in the range of 193 to 389 mg 100 g^{-1} of grain amaranth. Bressani (1992) indicated that amaranth grain had 217-303 mg of calcium, 21-104 mg of iron and 556-600 mg of phosphorus 100 g^{-1}. Munjal *et al.* (1999) reported calcium, phosphorus and iron in the range of 127.6-203.2, 310-470 and 8.58-17 mg 100 g^{-1} respectively in amaranth grain.

The iron content of brown variety of amaranth grains was found to be nearly twice than that present in white variety (National Institute of Nutrition, 1980). Pederson *et al.* (1987) observed high calcium and phosphorus contents in black coloured grains than in pale grains.

Becker *et al.* (1981) reported that *Amaranthus curentus* contained 0.19 to 0.23 mg riboflavin, 1.17 to 1.45 mg niacin, 45 mg ascorbic acid and 0.07 to 0.10 mg thiamine per 100 g of dry flour. Smitha (2006) reported a β carotene content in the range of 134.17 to 158.37 μg 100 g^{-1} in grain amaranth with a mean value of 145.62 μg.

2.3.6. ANTI-NUTRITIONAL FACTORS

Various anti-nutritional factors like tannin and phytates are present in cereals and millets, which interfere with the utilization of proteins, starch and several minerals. A brief review work on anti-nutritional factors of grain amaranth is presented below.

Osungton and Oke (1983) reported a high tannin content of 0.15 per cent in *Amaranthus hybridus* with no significant effect on the nutritional value. Pederson *et al.* (1987) also indicated high amount of tannin (0.35 %) in grain amaranth. Bejosano and Corke (1998) reported tannin content in the range of 1 to 5.2 mg 100 g^{-1} in the wholemeal flour of amaranth.

The phytate content of grain amaranth (0.52 to 0.61 %) was reported to be higher than that of rice and lower than that of maize and wheat (Lorenz and Wright, 1984).

Koeppe *et al.* (1985) found trypsin inhibitor activity of 0.52 TIU/mg in the crude extract isolated from the seeds of *Amaranthus hypochondriacus*.

Joshi and Rana (1991) observed anti nutritional factors like saponin, trypsin inhibitor and tannin in grain amaranth and indicated that the levels were similar to those found in legumes and sorghum

Gamel *et al.* (2006) studied the effect of cooking, popping, germination on the anti nutritional factors of *Amaranthus caudatus* and *Amaranthus curentus* seeds and indicated that cooking reduced the phenolic compound, phytate and enzyme inhibitors to a greater extent than popping. Germination followed by drying was also found to be effective in reducing these constituents.

2.4. EFFECT OF PROCESSING ON NUTRITIONAL QUALITY OF GRAIN AMARANTH

An improvement in the digestibility and Protein Efficiency Ratio of grain amaranth was observed during heat processing (Pant, 1985; Sanchez-Marroquin *et al.*; 1985, Bressani *et al.*, 1987b; Garcia *et al.*, 1987; Mendoza and Bressani, 1987; Singhal and Kulkarni, 1988).

Popped amaranth seeds possessed higher PER than either raw or toasted seeds. (Sanchez-Marroquin *et al.*, 1980).

Betschart *et al.* (1981) studied the effects of temperature on nutritional quality of *Amaranthus curentus* seeds and indicated that drying at 60 ^{0}C and hot air popping at 22^{0}C for 10 to 15 seconds had no significant effect on PER and apparent nitrogen digestibility. Exposing whole seeds at 60 ^{0}C did not effect amino acid composition, while hot air popping decreased the lysine content.

Pant (1985) studied the NPR (Net Protein Ratio) of unpopped, home popped and commercially popped amaranth grains and reported an NPR of 4.07, 3.42 and 4.0 respectively and indicated that well popped grains retained the protein quality. The author also indicated significant loss in total lysine during popping which was found to be high in home popped grains (36%) than in commercially popped grains (25%). Bressani (1989) also reported a better protein quality in processed grain amaranth.

An increase in the protein quality of grain amaranth was reported by Bressani *et al.* (1987b) during roasting, flaking, popping and wet cooking and roasting was found to be least effective. Pederson *et al.* (1987) also studied the effect of popping, toasting and flaking on the digestibility of protein in the pale and black coloured seeds of *Amaranthus caudatus* and noticed decreased digestibility in black coloured seeds during toasting.

Koeppe *et al.* (1987) found that extrusion cooking at 150 ^{0}C destroyed trypsin inhibitors and did not affect the availability of lysine. Mendoza and Bressani (1987) studied the PER of extruded *Amaranthus caudatus* flour and indicated a PER of 3.16 with almost equal digestibility for extruded flour (78 %) and raw flour (76 %) without any effect on available lysine. The authors also indicated higher NPR of 3.59 during extrusion at 154 ^{0}C than at 146 ^{0}C (3.04) in *Amaranthus curentus* flour and both were found to be higher than raw flour (2.19).

During germination of amaranth seeds an increase in crude protein and crude fibre and decrease in fat content was noticed by Paredes-Lopez and Escobedo-Mora

(1989). Balasubramanian and Sadasivam (1989) reported a 31 per cent increase in lysine content in *Amaranthus hypochondriacus* after 24 hours of sprouting.

Myers and Fox (1994) reported higher recovery of starch from unpearled amaranth due to the leaching of the starch granules during steeping. Gamel *et al.* (2004) noticed a decrease in crude protein content of *Amaranthus caudatus* and *Amaranthus curentus* (13 to 9%) during popping. The authors also reported a higher loss of tyrosine during popping followed by phenylalanine and methionine.

2.5. PRODUCT DEVELOPMENT AND SUPPLEMENTARY VALUE OF GRAIN AMARANTH

In Mexico, grain amaranth is used chiefly for making alegria candies from popped seeds and molasses (Early, 1977) and for preparing atole, a drink from roasted and powdered seeds mixed with syrup and water (Oke, 1983). In India, the seeds are popped and most commonly used in the form of candy known as laddoos (Vietmeyer, 1978). In Peru, seeds are popped and ground into flour or bound with syrup and made into belles (Sumar, 1983). Popped amaranth seeds were consumed with brown sugar in Mexico (Tovar *et al.*, 1989). In Nepal, Amaranth seeds are eaten as gruel called "Sattoo" or milled into flour to make chapathi (Thomas, 2005).

Amaranth grains could be utilised to prepare sweet balls (laddoos) or cakes and consumed after puffing and parching (CSIR, 1992). Manan *et al.* (1998) developed sweetmeats such as laddoos incorporating amaranth seeds with jaggary and sugar syrup. Kumari and Singh (2005) also reported that amaranth grain could be used as one of the ingredients for the preparation of laddoos for pregnant women. Protein and energy rich sweet laddoos were developed by combining grain amaranth, sesame, soya bean and jaggery (Sharma *et al.*, 2006).

Thomas (2005) reported that amaranth grain could be used in breakfast cereals or as an ingredient in confectionaries. The author also indicated that grains could be utilised to prepare a gruel or porridge after parching and as a snack item after popping and mixing with honey.

As per the report of Sanchez-Marroquin *et al.* (1980), processed amaranth seed flour could be used in the preparation of tortillas, breads, crackers, cookies, pasta and marzipan. Teutonico and Knorr (1985) reported that amaranth grain flour could be used as an ingredient in commercial breakfast cereal preparations. Seralathan *et al.* (1991) utilised amaranth grain flour to prepare chapathi, poori, cake and biscuits.

Vaidehi *et al.* (1993) utilized amaranth grains blending with other cereals in the preparation of mudde, roti, porridge, chikki and weaning mix. Sarojini *et al.* (1996) developed tasty recipes like chapathi, poori, dosa, porridge, chikki, laddoo and snack mixture from raw, popped and composite amaranth grain and stated that amaranth flour could be a good supplement to wheat and rice flour.

Begum *et al.* (2003) developed acceptable bakery products like biscuits, doughnut, cakes and stuff roll incorporating amaranth at 30 percent level. Chavez-Jauregui *et al.* (2003) developed acceptable pizza snack flavoured with amaranth which was comparable to commercial maize products.

Sanchez-Marroquin *et al.* (1986) suggested the utilization of 50:50 and 60:40 blends of whole amaranthus seeds with oats in the preparation of infant formulas. Weaning mixes with puffed amaranth flour along with puffed jowar and bajra flours were prepared by Reddy *et al.* (1990).

Twenty four weaning mixes containing malted, roasted or puffed grain amaranth, malted or roasted wheat, rice or rice flakes and a green leafy vegetable were prepared by Rathod and Udipi (1991) and weaning mix prepared with amaranth and rice flakes was found to be most acceptable. Seralathan *et al.* (1991) and Gupta and Senghal (1992) also developed highly nutritious weaning foods using grain amaranth.

Delvalle *et al.* (1992) developed two infant formulae containing oats and protein rich fraction of amaranth as well as oats, dehulled soybean and the starch-rich fraction of amaranthus seeds and indicated that both the formula satisfied the specification given by the Committee on Nutrition. Good quality weaning mix was prepared using roasted bengal gram flour, skimmed milk powder and amaranth flour (Bhuvaneshwari, 1995). Suma (1998) developed low cost infant foods using grain amaranth and acceptable weaning mix containing amaranth and italian millet in the ratio 70:30.

As per the report in American Health and Nutrition (1973) one-fourth cup of amaranth flour supplied 60 per cent of the RDA of iron.

Sanchez-Marroquin *et al.* (1980) found that cracker prepared by substituting 20 per cent amaranth flour with wheat flour was equally good as wheat cracker. Substitution of 10 to 15 per cent of amaranth flour in the preparation of white bread was found to be acceptable with pleasing flavour (Lorenz, 1981).

Whole amaranth flour and commercial corn flour in the proportion of 80:20 and 50:50 was found to be suitable for the preparation of arepas (Sanchez-Marroquin and Maya, 1985). Arepas prepared with 10 and 20 per cent substitution of amaranth flour with corn flour was found to have good acceptability with high lysine content (Delahaye and Portillo, 1990).

Significant increase in amino acid profile of the food was noticed due to the supplementation of amaranth with wheat, corn or sorghum. (Pederson *et al.*,1987). An increase in the protein, fat, phosphorus and linoleic acid content was noticed in tortillas when 15 per cent amaranth protein was incorporated in wheat flour (Sanchez-Marroquin *et al.*, 1987). Joshi and Rana (1991) identified that amaranth protein has nearly twice the lysine content of wheat protein, three times which of maize and the same as found in milk.

Morales *et al.* (1988) noticed that maize meal when supplemented with toasted amaranth flour at 12.7 per cent level provided nutritionally superior source of protein which was found to be sufficient to satisfy the protein requirement and to meet 70 per cent of the energy.

Nutritional evaluation of wheat bread substituted by popped amaranth flour was studied by Acevedo *et al.* (1991) and indicated an apparent digestibility of 75 to 80 percent with a calorie content of 390 Kcal 100 g^{-1}. The high lysine and tryptophan together with low leucine in amaranth grains was found to be beneficial to supplement maize which is rich in leucine but poor in lysine and tryptophan (Vetter, 1994). Inclusion of grain amaranth was found to improve the acceptability, protein quality and quantity of malt mixes when compared to ragi malt (Jyothi *et al.*, 1999).

Bhuvaneshwari (1995) developed different products like chapathi, cakes, biscuits, bread, porridge and weaning mixes from grain amaranth seeds and stated that biscuits and cakes with 50 per cent substitution, bread with 10 per cent substitution and porridge and weaning mixes with 100 per cent popped grain amaranth flour were acceptable.

An increase in the protein quality, food value and palatability of bread was reported by Chmeleva *et al.* (1996) when wheat flour and amaranth flour were used in the ratio of 85:15. Dodok *et al.* (1997) also concluded that due to the high essential amino acid and linoleic acid contents of amaranth flour it could be used to fortify cereal products.

Sandank and Hofi (2000) developed biscuits from amaranth incorporated with barley or wheat flour and substitution at 20 and 30 per cent were found to be most acceptable with good sensory quality.

Amaranth when incorporated with wheat, corn or brown rice resulted in production of complete protein like animal protein (Thomas, 2005). Incorporation of 25 per cent amaranth flour in the preparation of cookies improved the colour of cookies from pale cream to golden brown with a crisper texture (Sindhuja *et al.*, 2005).

Tovar and Carpenter (1982) reported an increase in PER from 1.55 to 2.22 when popped amaranth was supplemented with boiled maize and tortillas. Addition of whole amaranth flour and milling fraction of amaranth flour to maize flour in the preparation of tortillas and arepas in the ratio of 80:20 resulted in a PER of 2.2, compared with 2.5 for casein (Sanchez- Marroquin and Maya, 1985). The authors also indicated an increase in the mineral and fatty acid contents of tortillas when amaranth flour was incorporated.

Sanchez-Marroquin *et al.* (1985) studied the amaranth flour blends and fractions in baking and found that 80:20 mixture of wheat with whole raw amaranth flour in the preparation of french bread resulted in a PER of 2.46 and NPU of 4.35 as compared to 2.05 (PER) and 4.0 (NPU) with casein.

Sanchez -Marroquin *et al.* (1986) found that 50:50 and 60:40 blends of whole amaranth seeds with oats resulted in highest PER of 2.77 and 3.21 respectively which was comparable to casein and had a high digestibility of 90 per cent. Koeppe *et al.* (1987) observed an exceptionally high *in vitro* digestibility of 85.4 per cent with PER of 1.27 in extrusion product prepared with defatted amaranth seeds and maize meal.

Significant increase in the Net Protein Ratio (NPR) of wheat protein was indicated by Pant (1983) when wheat protein (6 %) was supplemented with amaranth protein (3 %)

Pant (1986) studied the effect of amino acid or protein supplementation on the nutritional quality of grain amaranth and indicated that supplementation of 2 per cent skimmed milk protein significantly increased NPR and Relative Net Protein Ratio (RNPR) of grain amaranth.

A combination of rice and amaranth in the ratio of 1:1 was found to be equal to the FAO/ WHO protein specifications (Singhal and Kulkarni, 1988). Amaranth when incorporated to the extent of 60 to 90 per cent with ragi and sorghum in the preparation of weaning mixes was found to have an amino acid pattern closer to FAO/ WHO standards (Sudha, 1989). When amaranth flour was mixed with either rice, maize or wheat flour in the ratio of 30:70, an increase in the protein quality from 72 to 90 per cent, 58 to 81 per cent and 32 to 52 per cent respectively were observed (Bressani, 1989).

2.6. HEALTH BENEFITS OF GRAIN AMARANTH

The effect of dietary amaranth on serum and liver lipid levels was studied by Danz and Lupton (1992) and indicated that amaranth decreased the serum and liver cholesterol levels. Chaturvedi *et al.* (1993) also indicated hypocholesterolemic effect of amaranth seeds in animal experiments

Non-fermentable fibers present in amaranth grains were found to be beneficial to lower serum cholesterol (Danz *et al.*, 1998). A reduction in LDL (Low Density Lipoprotein) and total cholesterol levels were observed in hypercholesterolemic rabbits when extruded amaranth was consumed (Plate and Areas, 2002)

Cholesterol lowering properties of amaranth grain and oil in hamsters was studied by Berger *et al.* (2003) and indicated a significant increase in HDL (High Density Lipoprotein) cholesterol and decrease in LDL (Low Density Lipoprotein) cholesterol. Czerwinski *et al.* (2004) reported that oat and amaranth meals had a positive effect on plasma lipid profile in rats fed cholesterol containing diet. Shin *et al.* (2004) also noticed hypocholesterolaemic effect of amaranth due to the presence of squalene.

Thomas (2005) indicated that tocotrienols, a form of vitamin E present in amaranth had beneficial effect in lowering the cholesterol levels in human beings. Kim *et al.* (2006) reported that animals exhibited a cholesterol lowering effect in hyperlipidemic animals fed with amaranth. The beneficial effect of amaranth oil on CHD (Coronary Heart Diseases) and hypertension was reported by Martirosyam *et al.* (2007).

Partial substitution of grain amaranth flour with wheat and rice flour was found to be beneficial for NIDDM (Non Insulin Dependent Diabetes Mellitus) patients because of its high amino acid, calcium and iron contents (Chaturvedi *et al.*, 1997).

Hibi *et al.* (2003) reported that amaranth grain (*Amaranthus hypochondriacus*) and its extract had an inhibitory effect on antigen- specific IgE production and reported its immunological effects *in vivo* or *in vitro*.

Importance of amaranth in the preparation of hypoallergic foods suited for patients who are allergic towards cereals was reported by Konoshi (2002). Czerwinski *et al.* (2004) also suggested that amaranth could be a valuable substitute for hypercholesterolaemic patients allergic to cereals. Schoenlecner *et al.* (2004) reported that pseudo cereals have beneficial effect when incorporated in the diet of patients suffering from celiac disease due to the lack of gluten.

Materials and Methods

3. MATERIALS AND METHODS

The materials used and the methods followed for the preparation and quality evaluation of the flour, standardization of recipes, organoleptic evaluation and computation of nutritive value of the recipes are given under the following headings.

3.1.Collection of grain amaranth

3.2.Preparation of the flour

3.3.Analysis of the chemical constituents of the flour

3.4.Organoleptic evaluation of the flour

3.5.Microbial enumeration and insect infestation of flour

3.6.Preparation of standard recipes

3.7.Standardization of recipes incorporating amaranth flour

3.8.Organoleptic evaluation of recipes

3.9.Computation of nutritive value of recipes

3.10. Analysis of data

3.1. Collection of grain amaranth

White and black coloured grain amaranth (*Amaranthus hypochondriacus*) seeds of different genotypes were collected from the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara (Plate1).

3.2. Preparation of the flour

Black and white grain amaranth seeds were mixed in the ratio of 4:1 respectively and the grains were sun dried for 4 to 6 hours. The above mixing of the two varieties of grain amaranth was done according to the availability of the grains. The dried grains were ground thoroughly in an electric mixer and sieved using a fine mesh sieve (Plate 2). The prepared flour was stored in glass bottles for further use.

Plate 1. Grain amaranth

Plate 2. Grain amaranth flour

3.3. Analysis of the chemical constituents of the flour

Amaranth flour was stored for six months and evaluated for the following chemical constituents initially, during third and sixth months of storage. Following analyses were carried out in triplicate samples.

3.3.1. Moisture
3.3.2. Protein
3.3.3. Starch
3.3.4. Fat
3.3.5. Fibre
3.3.6. Calcium
3.3.7. Magnesium
3.3.8. Iron
3.3.9. Potassium
3.3.10. Phosphorus
3.3.11. Tannin
3.3.12. Phytic acid

3.3.1. Moisture

Moisture content of the amaranth flour was estimated using the method of AOAC (1980).

To determine the moisture content, five gram of amaranth flour was taken in a petri dish and dried in a hot air oven at $60^0C \pm 5^0C$, cooled in a desiccator and weighed. The process of heating and cooling was repeated until a constant weight was achieved. The moisture content was calculated from the loss in weight during drying and expressed in percentage.

3.3.2. Protein

The protein content was estimated using the method of AOAC (1980).

Amaranth flour (0.3g) was digested with 6 ml Con. H_2SO_4 after adding 0.4 g of $CuSO_4$ and 3.5 g K_2SO_4 in a digestion flask until the colour of the sample is converted to green. After digestion, it was diluted with water and 25 ml of 40 per cent NaOH was pumped. This distillate was collected in 20 per cent boric acid containing mixed indicator and then titrated with 0.2 N HCl. The nitrogen content obtained was multiplied with a factor of 6.25 to get the protein content and expressed in percentage.

3.3.3. Starch

The starch content was estimated colorimetrically using anthrone reagent (AOAC, 1980).

The sample (0.5g) was extracted with 80 per cent ethanol to remove sugars. Residue was repeatedly extracted with hot 80 per cent ethanol to remove sugars completely. The residue was dried over a water bath and 5 ml water and 6.5 ml 52 per cent perchloric acid were added and extracted at 0^0C for 20 minutes. Centrifuged the sample and re extracted with fresh perchloric acid. The supernatant was pooled and made up to 100 ml. Pipette out 0.2 ml of the supernatant and made up to 1 ml with water and 4 ml of anthrone reagent was added, heated for 8 minutes, cooled and read the OD at 630 nm.

A standard graph was prepared using serial dilution of standard glucose solution. From the graph glucose content of the sample was obtained and multiplied by a factor of 0.9 to arrive the starch content.

3.3.4. Fat

The fat content of grain amaranth flour was estimated using the method of AOAC (1955).

Five gram of amaranth flour was taken in a thimble and plugged with cotton. The material was extracted with petroleum ether for 6 hours without interruption by gentle heating in a soxhlet apparatus. Extraction flask was then cooled, and ether was removed by heating and weight was taken. The fat content was expressed in g 100 g^{-1} of the sample.

3.3.5. Fibre

The fibre content was estimated by acid alkali digestion method as suggested by Chopra and Kanwar (1978).

Two gram of dried and powdered sample was boiled with 200 ml of 1.25 per cent sulphuric acid for thirty minutes. It was filtered through a muslin cloth and washed with boiling water and again boiled with 200 ml of 1.25 per cent sodium hydroxide for thirty minutes. Again, it was filtered through a muslin cloth and washed with sulphuric acid, water and alcohol. The residue was transferred to a pre weighed ashing dish, dried, cooled and weighed. The residue was then ignited for 30 minutes in a muffle furnace at 600^{0}C, cooled in a desiccator and reweighed. The fibre content of the sample was calculated from the loss in weight on ignition and expressed in percentage.

3.3.6. Calcium

The calcium content was estimated using titration method with EDTA as suggested by Page (1982).

Two gram of dried and powdered sample was predigested with 20 ml of 9:4 mixture of nitric acid and perchloric acid and volume was made upto 100 ml. To five ml of diacid extract, 10 ml water, 10 drops of hydroxylamine hydrochloride, 10 ml triethanolamine, 2.5 ml sodium hydroxide and 10 drops of calcone were added. Then, it was titrated with 0.02 N EDTA till the appearance of permanent blue colour. Calcium content was expressed in mg 100 g $^{-1}$ of the sample.

3.3.7. Magnesium

The magnesium content was estimated using titration method with EDTA as suggested by Page (1982).

In this method the magnesium and calcium contents were estimated together. Calcium content was subtracted from the value obtained to get the magnesium content. To five ml of diacid extract, 10 drops hydroxylamine hydrochloride, 10 drops triethanolamine, 15 ml distilled water, 15 ml ammonium buffer and 10 drops Erichrome Black T (EBT) indicator were added. Then, it was titrated with 0.02 N EDTA till the appearance of permanent blue colour. Magnesium content was expressed in mg 100 g^{-1} of the sample.

3.3.8. Iron

The iron content was analysed colorimetrically using ferric iron, which gives a blood red color with potassium thiocyanate (Raghuramulu *et al.*, 2003).

To an aliquot of 6.5 ml diacid solution, one ml of 30 per cent sulphuric acid, one ml of 7 per cent potassium persulphate solution and 1.5 ml of 40 per cent potassium thiocyanate solution were added. The intensity of the red color was measured within twenty minutes at 540 nm.

A standard graph was prepared using serial dilution of standard iron solution. The iron content of the sample was estimated from the standard graph and expressed in mg 100 g^{-1}.

3.3.9. Potassium

The potassium content was estimated using flame photometer as suggested by Jackson (1973).

One ml of the digested solution was made upto 25 ml and read directly in flame photometer and potassium content was expressed in mg 100 g^{-1}.

3.3.10. Phosphorus

The phosphorus content was analysed colorimetrically as suggested by Jackson (1973), which gives yellow colour with nitric acid vandate molybdate reagent.

To five ml of pre digested aliquot, 5 ml of nitric acid vandate molybdate reagent was added and made upto 50 ml with distilled water. After 10 minutes the OD was read at 420 nm.

A standard graph was prepared using serial dilution of standard phosphorus solution.

3.3.11. Tannin

The tannin content was determined as tannic acid by colorimetric method using Folin Denis reagent (Sadasivam and Manickam, 1992).

The powdered material (0.5 g) was transferred to a volumetric flask having 75 ml water. Then the contents were heated for 30 minutes and centrifuged. Supernatant was collected and made up to 100 ml. One ml of the sample was taken in 100 ml volumetric flask having 75 ml water, and added 5 ml Folin Denis reagent and 10 ml of sodium carbonate and made upto 100 ml. After 30 minutes the absorbance was read at 700 nm. The tannin content was expressed as percentage from the standard graph prepared using serial dilution of standard tannic acid.

3.3.12. Phytic acid

The phytic acid content was determined colorimetrically as phytate phosphorus (Sadasivam and Manickam, 1992).

The powdered sample (0.5 g) was extracted in 50 ml of 3 per cent trichloroacetic acid (TCA) with mechanical agitation. The content was centrifuged and aliquot of 10 ml was taken in a test tube. To this, 4 ml $FeCl_3$ solution was added. Then the contents were heated for 30 minutes in water bath. To an unclear liquid 1 or 2 drops of 3 per cent sodium sulphate in 3 per cent TCA was added and heated. The liquid obtained was centrifuged and precipitate was dispersed twice in 25 ml of 3 per cent TCA. The sample was heated in boiling water for 10 minutes and centrifuged. The precipitate so obtained was dispersed in a few ml of water and added 3 ml of 1.5 N NaOH and mixed. Volume was made upto 30 ml and heated for 30 minutes in water bath. Then the above contents were filtered and precipitate obtained was dissolved in 40 ml hot 3.2 N HNO_3 and volume was made upto 100 ml. Five ml of the aliquot was pipetted out to a 100 ml volumetric flask having 70 ml water, added 20 ml 1.5 M KSCN and made up to 100 ml and reading was taken immediately at 480 nm.

A standard graph was prepared using serial dilution of standard $Fe(NO_3)_3$ solution. The phytic acid content as phytate phosphorus was estimated from the standard graph and expressed in mg 100 g^{-1}.

3.4. Organoleptic evaluation of the flour

3.4.1. Selection of judges

A series of organoleptic trails were carried out using simple triangle test at laboratory level to select a panel of ten judges between the age group of 18 to 35 years as suggested by Jellinek (1985).

3.4.2. Preparation of score card

The score card used for the evaluation of amaranth grain flour is given in Appendix I.

3.4.3. Organoleptic evaluation

Organoleptic evaluation of amaranth flour was carried out in the morning time using the score card by a panel of ten selected judges. Five quality attributes namely appearance, colour, flavour, taste, texture and overall acceptability were evaluated using the score card.

3.5 Microbial enumeration and insect infestation of flour

The total microbial count of amaranth flour was enumerated at monthly intervals for a period of six months. The method used for evaluation was serial dilution and plate count method as described by Agarwal and Hasija (1986). Ten gram of sample was added to 90 ml sterile water and agitated for 20 minutes. One ml of this solution was transferred to a test tube containing 9 ml of sterile water to get 10^{-2} dilution and similarly 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} dilution were also prepared.

Enumeration of total microbial count was carried out using Nutrient agar media for bacteria, Potato dextrose agar media for fungus and Sabouraud's dextrose agar media for yeast, which was obtained from Himedia Lab, Mumbai. The dilution used for bacteria was 10^{-6} and for fungi and yeast 10^{-3} dilution was used.

By examining grain amaranth flour under the microscope, presence of storage insects were assessed. Flour was sieved first with 60 BL sieve and followed by 100 BL sieve and observed under microscope.

3.6 Preparation of standard recipes

Three products namely chapathi, biscuit and puttu having wheat flour, maida (refined wheat flour) and rice flour as the main ingredient respectively were prepared using the procedures described in 3.6.1, 3.6.2 and 3.6.3 respectively.

3.6.1 Chapathi

Wheat flour - 50 g
Ghee - 5 g
Salt - to taste
Water - 50 ml (approx.)

Dough was prepared with wheat flour and sprinkling salt water to it. Then, the dough was divided into two balls and rolled into thin chapathi. Little ghee was applied and folded into a circular shape and rolled again. It was placed on a hot tawa and both the sides were cooked by applying small quantity of ghee (Pasricha and Rebello, 1977).
Number of chapathi – 2 Nos.

3.6.2 Biscuit

Maida - 50 g
Powdered sugar - 30 g

Butter - 25 g
Salt - a pinch
Baking powder - a pinch
Vanilla essence - 2 to 3 drops

Maida (refined wheat flour), salt and baking powder were mixed together and sieved twice in a fine mesh sieve. Sugar and butter were creamed together and folded with the sieved ingredients and rolled. Cut the biscuit using a mould and baked at 218 ^{0}C for 25 minutes (Pasricha and Rebello, 1989).
Number of biscuits – 15 Nos.

3.6.3. Puttu

Raw rice - 50 g
Coconut (scraped) - 20 g
Salt - to taste

Rice was soaked in cold water for 4 to 6 hours, and water was drained. Then, soaked rice was spread over a clean cloth to remove excess water. Rice was powdered and sieved using a medium fine sieve and roasted slightly

.

After cooling, flour was moistened by sprinkling salt water, and lumps formed were crushed. Moistened flour (2 table spoon) and scraped coconut (1/2 tablespoon) were filled in puttu maker in alternative layers and steamed for 5 to 7 minutes (Pasricha and Rebello, 1989). .
Pieces of puttu – 2 Nos.

3.7. Standardization of recipes incorporating amaranth flour

Chapathi, biscuit and puttu were standardized by incorporating fresh grain amaranth flour at different levels. The recipes explained in 3.6.1, 3.6.2 and 3.6.3 were taken as the control. The treatments for standardization of recipes are given in Table 1.

Table 1. Percentage of flour used for the preparation of recipes

Treatments	Percentage of main ingredient (rice flour, wheat flour or maida)	Percentage of grain amaranth flour
Control	100	-
T_1	90	10
T_2	80	20
T_3	70	30
T_4	60	40
T_5	50	50

Design – CRD

Treatment – 6

Replication – 3

All the treatments were prepared using the procedures given in 3.6.1, 3.6.2 and 3.6.3. For preparing puttu, grain amaranth flour was roasted slightly. The exact quantity of flour used for different treatments is detailed in Table. 2.

Table 2. Quantity of flour used for the preparation of recipes

Treatments	Quantity of main ingredient (rice flour, wheat flour or maida)	Quantity of grain amaranth flour
Control	50 g	-
T_1	45 g	5 g
T_2	40 g	10 g
T_3	35 g	15 g
T_4	30 g	20 g
T_5	25 g	25 g

3.8. Organoleptic evaluation of recipes

Organoleptic evaluation of recipes was carried out in the morning time using score card by a panel of ten selected judges. Five quality attributes namely appearance, colour, flavour, taste, texture and overall acceptability were evaluated. The score card used for the evaluation of grain amaranth supplemented recipes is given in Appendix II.

3.8.1. Selection of recipes

The acceptability scores were analysed by Kendall's coefficient of variance to select the most acceptable treatment in each recipe. Statistically, Kendall's coefficient of concordance (W(a)) which expresses the degree of association among the ten judges was carried out for each treatment under study. After statistical analysis, the most acceptable treatment from each recipe was selected.

3.9. Computation of nutritive value of recipes

Protein, fibre, fat, total carbohydrates, calcium and iron contents of the three recipes were computed using the nutritive value of grain amaranth flour obtained in the present study. The nutritive value of other ingredients was taken from food composition table suggested by Gopalan *et al.* (1989). The nutrients present in the different treatments were expressed per serving.

3.10. Analysis of data

The observations recorded were tabulated and the data was analysed statistically using Complete Randomised Design (CRD). The scores of organoleptic evaluation were assessed by Kendall's coefficient of concordance (W) as detailed in 3.8.1. Logarithmic transform was affected to microbial count to satisfy the concept of analysis of variance. Friedman's test and t test were also used for the statistical analysis of data.

Results

4. RESULT

The results pertaining to the study entitled "Standardization and quality evaluation of grain amaranth (*Amaranthus spp.*) flour supplemented food products" are presented in this section under the following headings.

4.1. Chemical composition of amaranth flour
4.2. Enumeration of microbial population and insect infestation of the flour during storage
4.3. Organoleptic evaluation of the flour and changes during storage
4.4. Organoleptic evaluation of recipes
4.5. Computation of nutritive value of recipes

4.1. Chemical composition of amaranth flour

The chemical composition of amaranth flour stored in glass bottles under ambient storage condition was estimated initially, during the third and sixth months of storage. The constituents like moisture, protein, starch, fat, fibre, calcium, magnesium, iron, potassium, phosphorus, tannin and phytic acid were estimated. The different chemical constituents of amaranth flour and changes in the constituents during storage are presented in Table 3.

4.1.1. Moisture

The initial moisture content of amaranth flour was found to be 16.66g $100g^{-1}$ which increased to 17.46 g $100g^{-1}$ within a period of six months of storage. During third month of storage a decrease in moisture content (13.53 g $100g^{-1}$) was also noticed (Fig. 1).

Table 3. Chemical composition of grain amaranth flour during storage (per 100 g)

Constituents	Initial month	Third month	Sixth month
Moisture (g)	16.66	13.53	17.46
Protein (g)	14.70	13.90	12.49
Starch (g)	62.2	59.92	57.40
Fat (g)	6.73	6.3	5.79
Fibre (g)	2.87	2.61	1.66
Calcium (mg)	187.16	182.98	180.54
Magnesium (mg)	226	225.82	223.03
Iron (mg)	13.58	13.34	12.47
Potassium (mg)	248.2	248.12	248.08
Phosphorus (mg)	315.68	315.64	315.61
Tannin (mg)	1.23	1.25	1.30
Phytic acid (mg)	0.53	0.56	0.58

4.1.2. Protein

The fresh flour had a protein content of 14.70 g $100g^{-1}$ which decreased to 13.90 g and 12.49 g $100g^{-1}$during third and the sixth months of storage respectively (Fig. 2).

4.1.3. Starch

The starch content of the flour was found to be 62.2 g $100g^{-1}$ initially. The starch content registered a decreasing trend from initial to the sixth month of storage. During third and sixth months of storage, the starch contents were found to be 59.92 and 57.40 g $100g^{-1}$ respectively (Fig. 3).

4.1.4. Fat

The fat content of fresh flour was 6.73 g $100g^{-1}$ which gradually decreased to 6.3 g $100g^{-1}$ during third month and to 5.79 g $100g^{-1}$ during sixth month of storage (Fig. 4).

4.1.5. Fibre

The fibre content in fresh grain amaranth flour was found to be 2.87 g $100g^{-1}$ which gradually decreased to 2.61 and 1.66 g $100g^{-1}$ during third and sixth months of storage respectively (Fig. 5).

4.1.6. Calcium

The initial calcium content of the flour was 187.16 mg $100g^{-1}$, which decreased gradually on storage and at the end of third and sixth months of storage, the calcium content was found to be 182.98 mg and 180.54 mg $100g^{-1}$ respectively (Fig. 6).

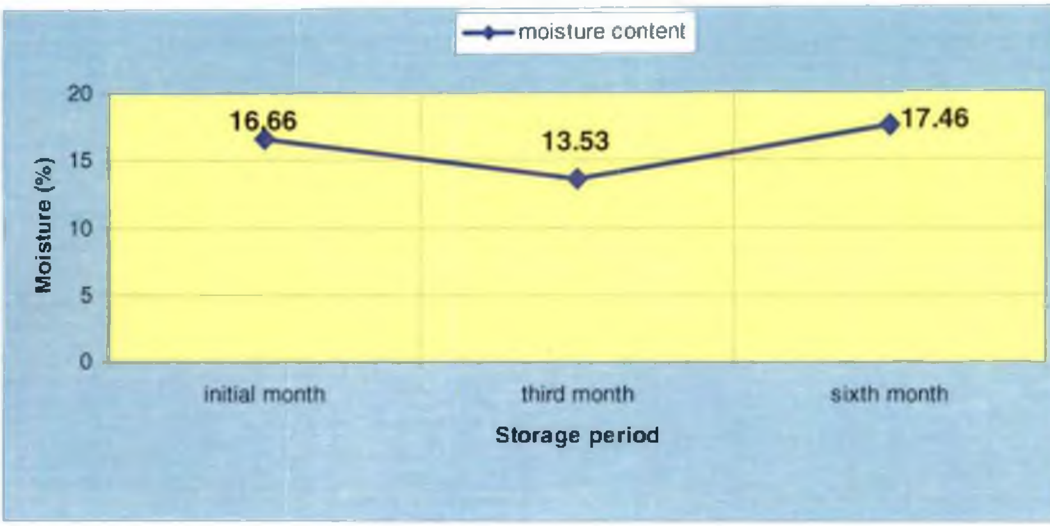

Fig 1. Moisture content of grain amaranth flour during storage

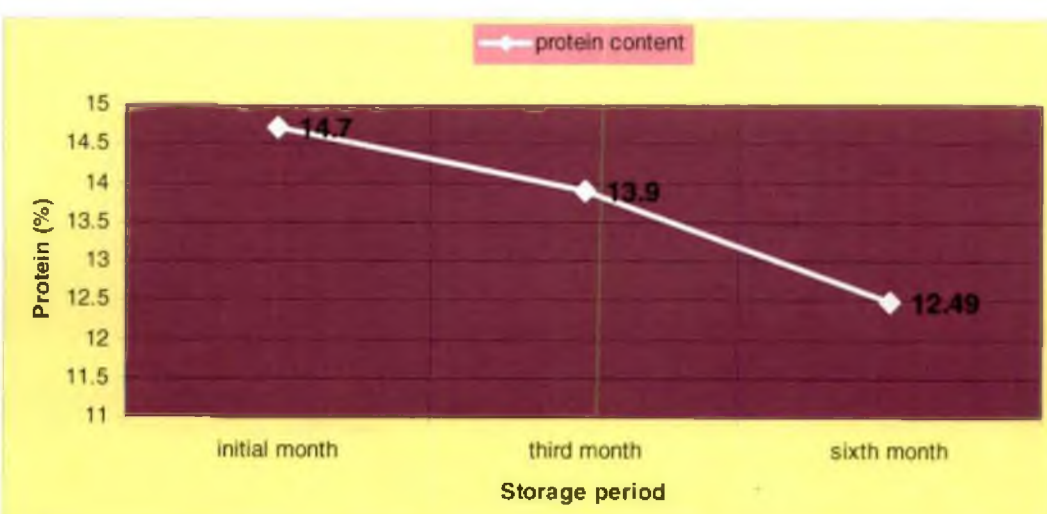

Fig 2. Protein content of grain amaranth flour during storage

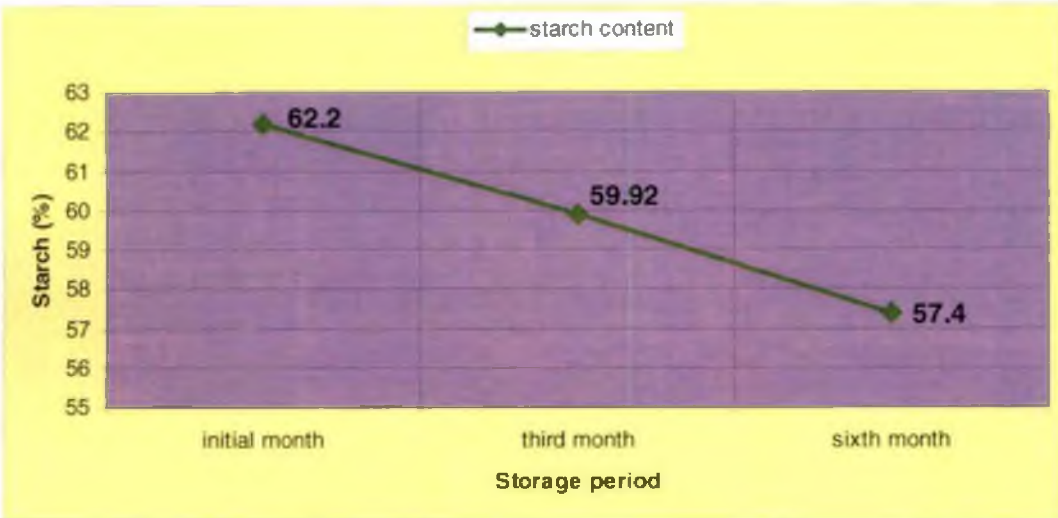

Fig 3. Starch content of grain amaranth flour during storage

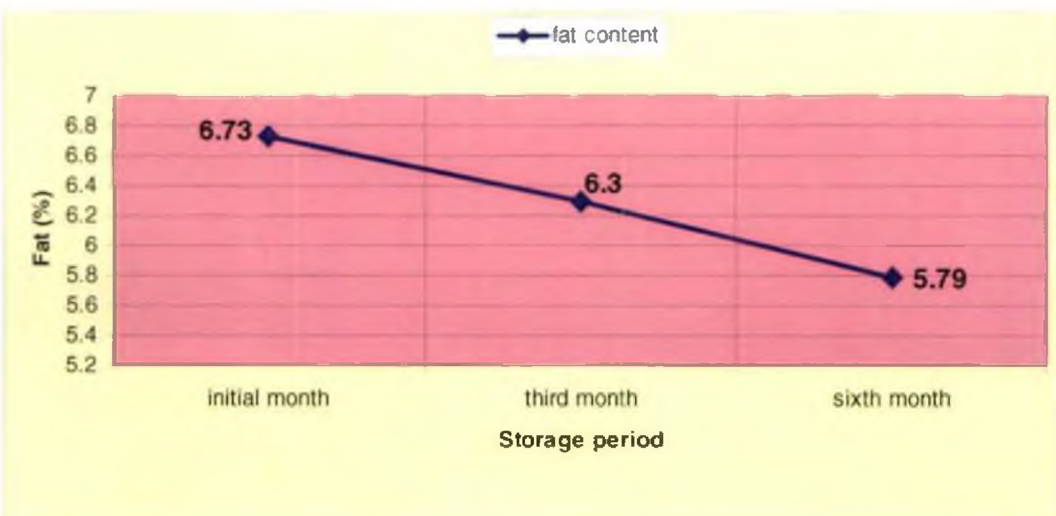

Fig 4. Fat content of grain amaranth flour during storage

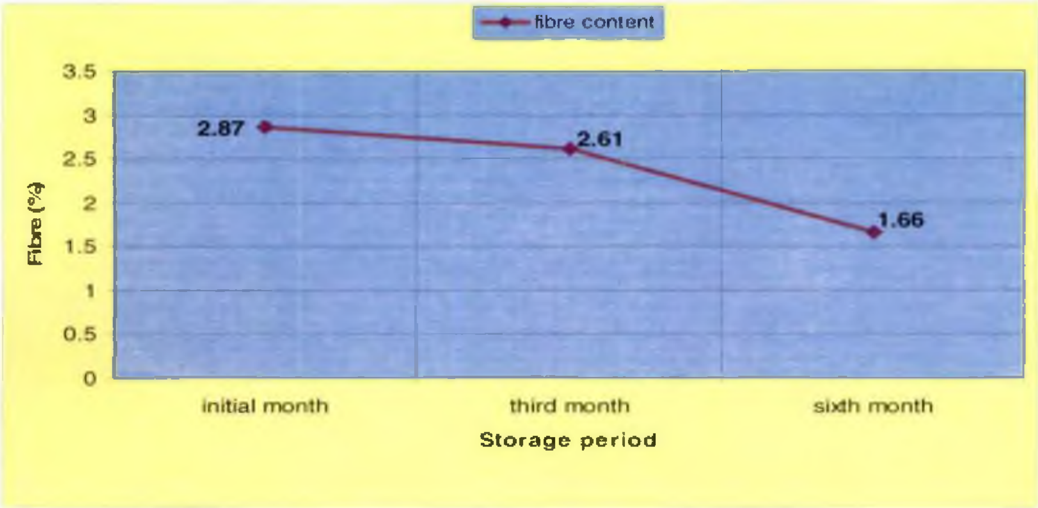

Fig 5. Fibre content of grain amaranth flour during storage

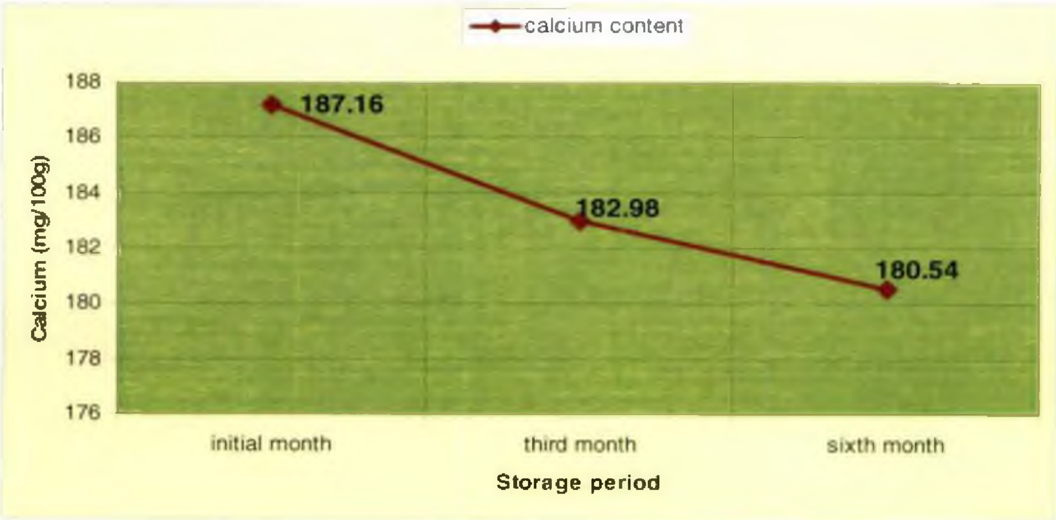

Fig 6. Calcium content of grain amaranth flour during storage

4.1.7. Magnesium

As calcium, the magnesium content of the flour also decreased with an increase in storage period. The magnesium content of fresh flour was 226 mg 100 g^{-1} which decreased to 225.82 mg and 223.03 mg 100 g^{-1} at the end of third and sixth months of storage respectively (Fig. 7).

4.1.8. Iron

Iron content in the fresh flour was 13.58 mg 100 g^{-1} which gradually decreased with storage. By the end of third and sixth months of the storage, the iron content of the flour reduced to 13.34 mg and 12.47 mg 100 g^{-1} respectively (Fig. 8).

4.1.9. Potassium

The initial potassium content of amaranth flour was found to be 248.2 mg 100 g^{-1}. During third and sixth months of storage, the potassium content decreased slightly to 248.12 mg and 248.08 mg 100 g^{-1} respectively (Fig. 9).

4.1.10. Phosphorus

Phosphorus content in the fresh flour was 315.68 mg 100 g^{-1} which gradually decreased with storage. By the end of third and sixth months of the storage the phosphorus content of the flour reduced to 315.64 mg and 315.61 mg 100 g^{-1} respectively (Fig. 10).

4.1.11. Tannin

Tannin content in the fresh flour was 1.23 mg 100 g^{-1}, which gradually increased with storage. By the end of third and sixth months of storage, the tannin content of flour increased to 1.25 and 1.30 mg 100 g^{-1} respectively (Fig.11).

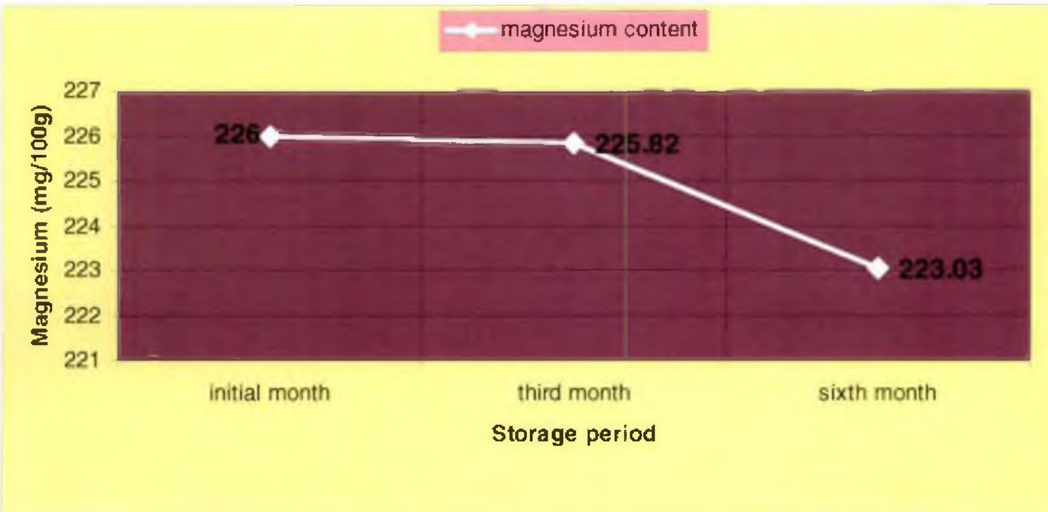

Fig 7. Magnesium content of grain amaranth flour during storage

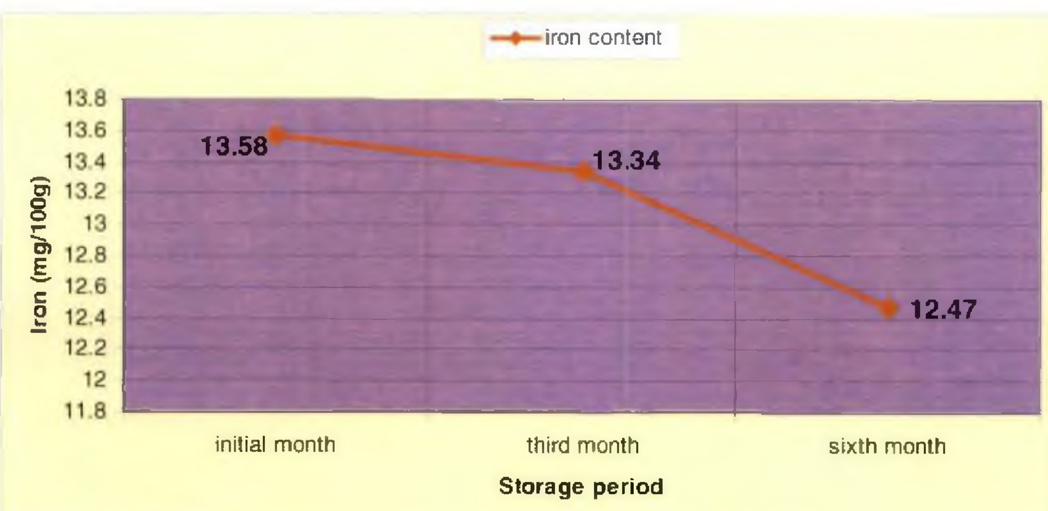

Fig 8. Iron content of grain amaranth flour during storage

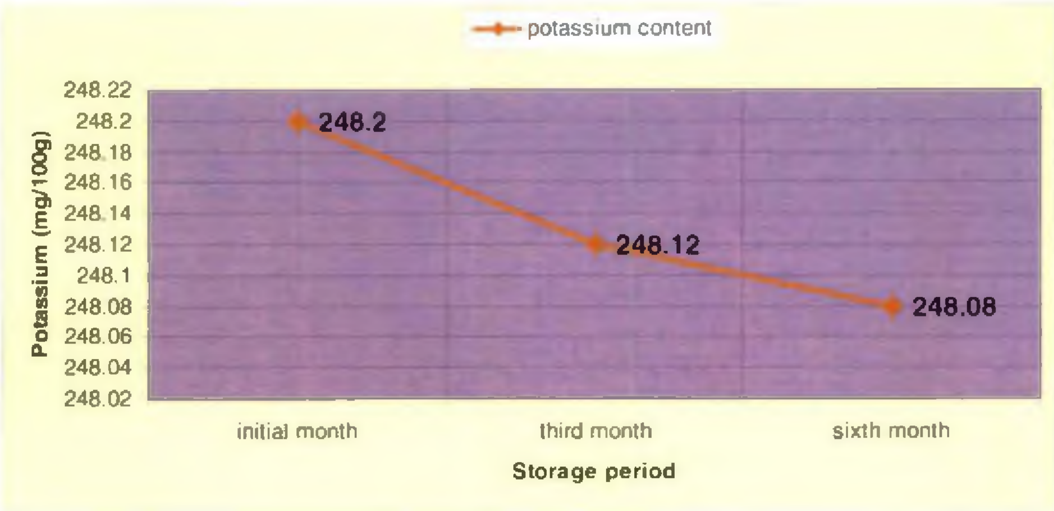

Fig 9. Potassium content of grain amaranth flour during storage

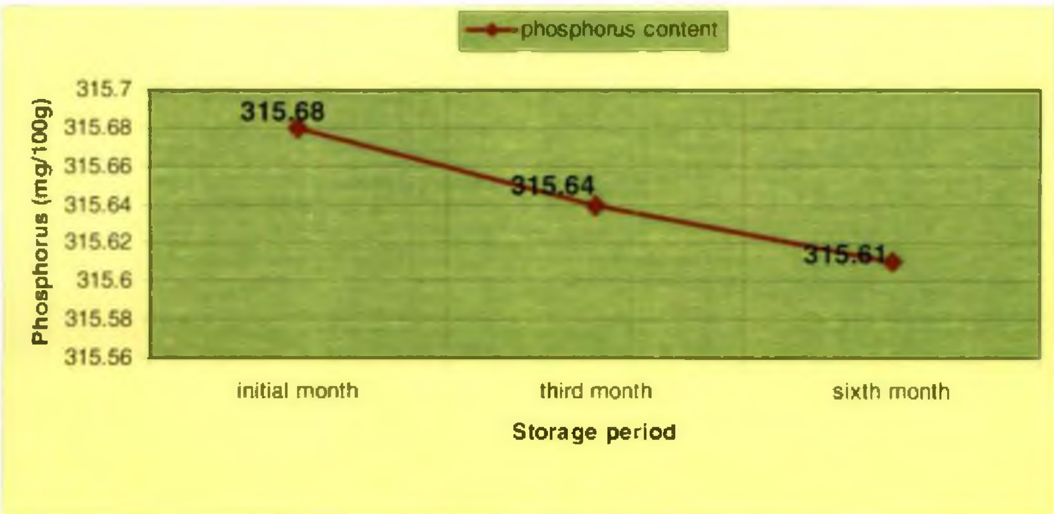

Fig 10. Phosphorus content of grain amaranth flour during storage

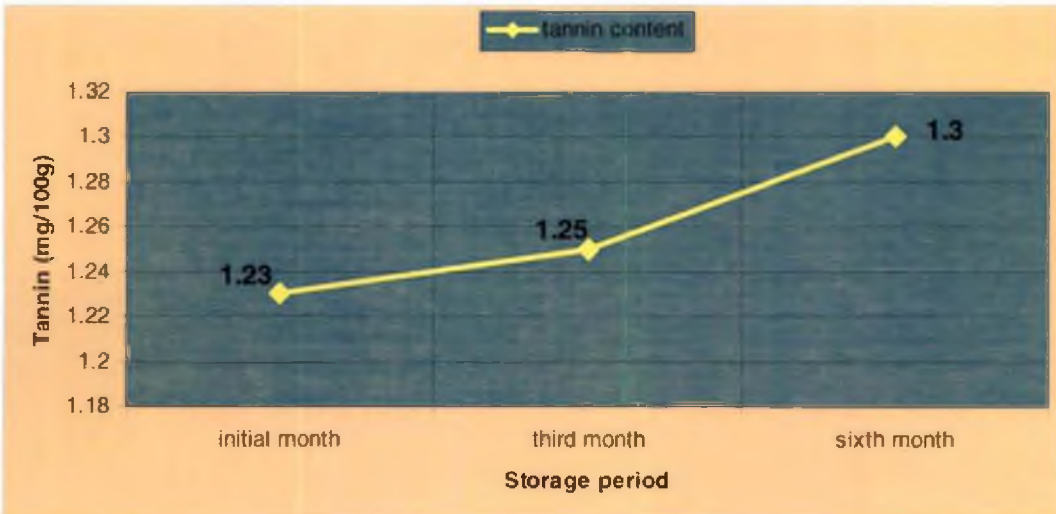

Fig 11. Tannin content of grain amaranth flour during storage

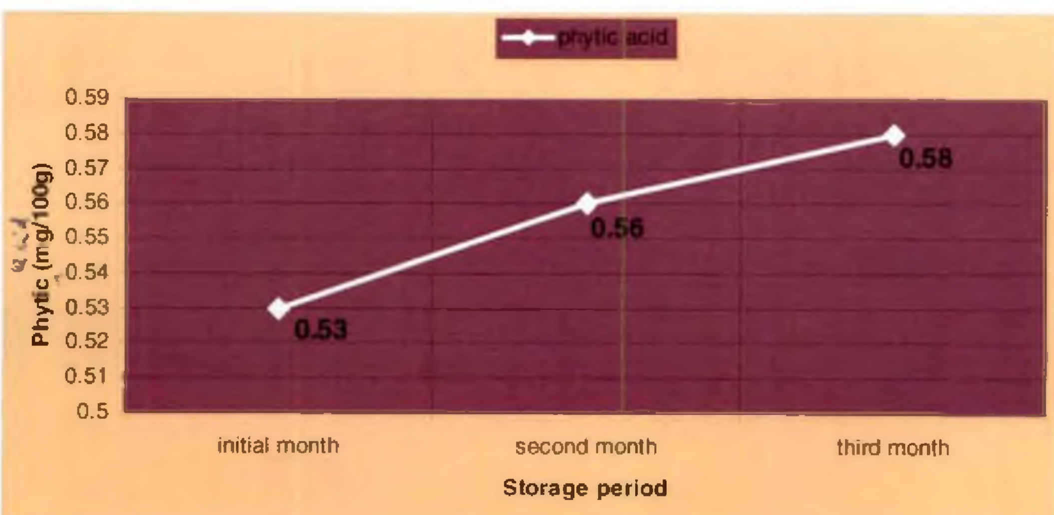

Fig 12. Phytic acid content of grain amaranth flour during storage

4.1.12. Phytic acid

Phytic acid which was present in the form of phytate phosphorus in the flour was found to be 0.53 mg100 g^{-1} which increased to 0.56 and 0.58 mg100 g^{-1} during third and sixth months of storage respectively (Fig. 12)

4.2. Enumeration of microbial population and insect infestation of the flour during storage

The amaranth flour was evaluated for bacteria, yeast and fungi at monthly intervals for a period of six months and results pertaining to microbial enumeration are presented in Table 4.

The initial bacterial load in the amaranth flour was found to be 2.6 x 10^6 cfu g^{-1} which increased gradually to 4.2 x 10^6 cfu g^{-1} (second month), 5.2 x 10^6 cfu g^{-1} (third month), 6.6 x 10^6 cfu g^{-1} (fourth month), 8.2 x 10^6 cfu g^{-1} (fifth month) and 8.8 x 10^6 (sixth month) cfu g^{-1} during storage of six months (Fig. 13). Maximum bacterial count observed in grain amaranth flour at the end of storage period is given in Plate 3.

Mean increment of bacterial count in amaranth flour during storage was found to be 1.6, 1.0, 1.4, 1.6 and 0.6 for five phases like phase I, phase II, phase III, phase IV and phase V respectively (Table 5). Mean rank scores on the basis of Friedman's test was found to be highest during phase I (4.67) and least rank score was obtained during phase V (1.33).

The rank scores observed on the basis of statistical analysis for bacteria were found to be statistically significant at 10 per cent level during different phases of storage.

Initial fungal growth of amaranth flour was 1.8 x 10^3 cfu g^{-1} which gradually increased to 2.8 x 10^3 cfu g^{-1}, 3.6 x 10^3 cfu g^{-1}, 4.7 x 10^3 cfu g^{-1}, 5.5 x 10^3 cfu g^{-1} and

Table 4. Microbial count of amaranth flour during storage

Periods of storage in months	Microbial population (cfu g^{-1})		
	Bacteria ($x10^6$)	Fungi (10^3)	Yeast (10^3)
Initial	2.6	1.8	1.5
Second	4.2	2.8	1.8
Third	5.2	3.6	2.3
Fourth	6.6	4.7	3.1
Fifth	8.2	5.5	4.4
Sixth	8.8	5.8	5.3

Table 5. Changes in microbial count of amaranth flour during storage

Phases	Bacterial growth	Fungal growth	Yeast growth
Phase I	1.6 (4.67)	1.0 (3.83)	0.3 (1.77)
Phase II	1.0 (1.67)	0.8 (2.67)	0.5 (1.83)
Phase III	1.4 (3.67)	1.1 (4.33)	0.8 (3.83)
Phase IV	1.6 (3.67)	0.8 (2.0)	1.3 (4.17)
Phase V	0.6 (1.33)	0.3 (2.17)	0.9 (4.00)
Friedman's statistic	9.817	5.404	10.37
Probability of significance (%)	4.3	24.8	3.5

Figures in parenthesis are mean rank scores

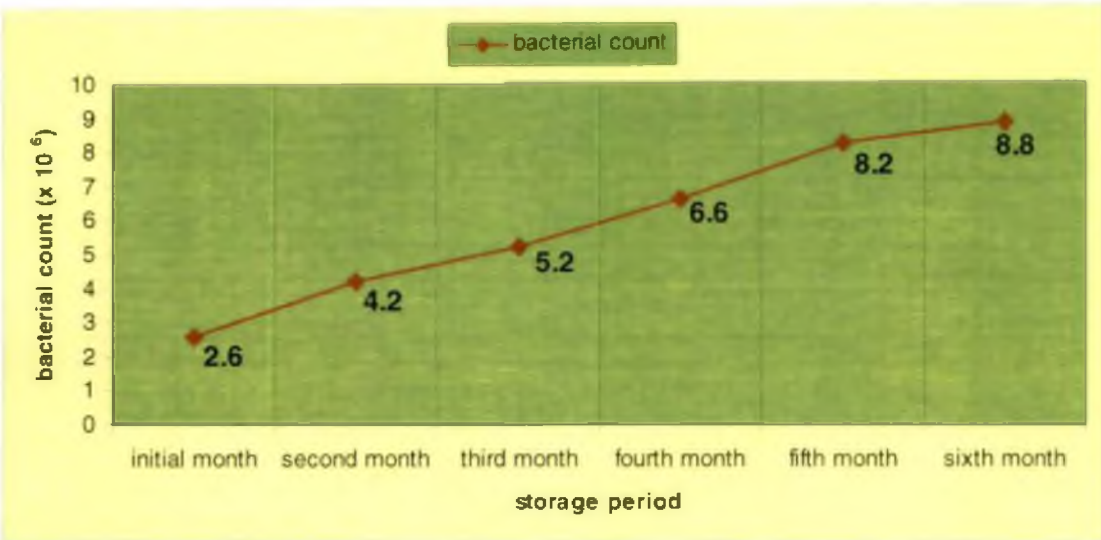

Fig 13. Bacterial count of grain amaranth flour during storage

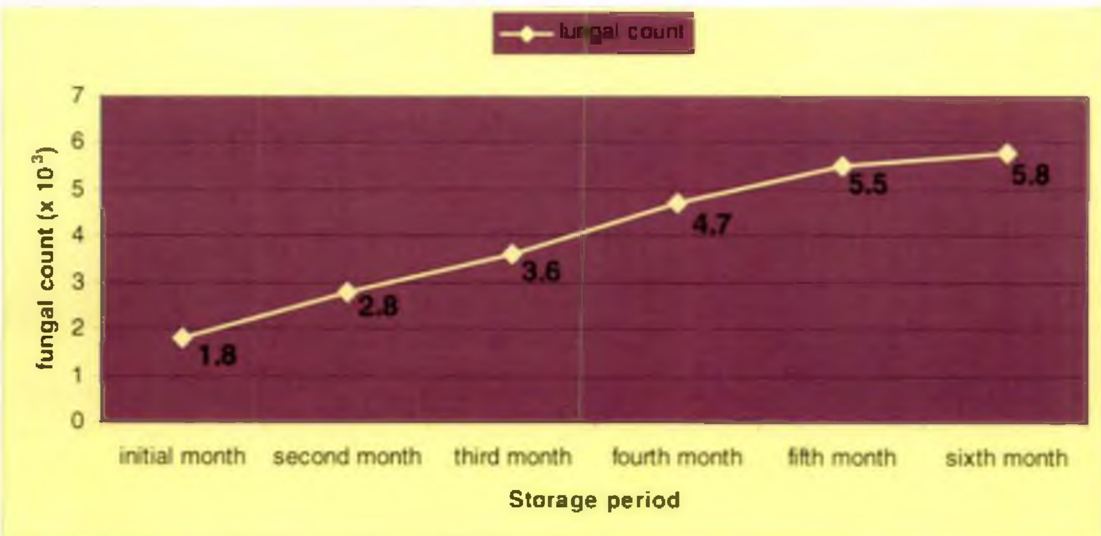

Fig 14. Fungal count of grain amaranth flour during storage

Plate 3. Maximum bacterial count of amaranth flour at the end of storage period

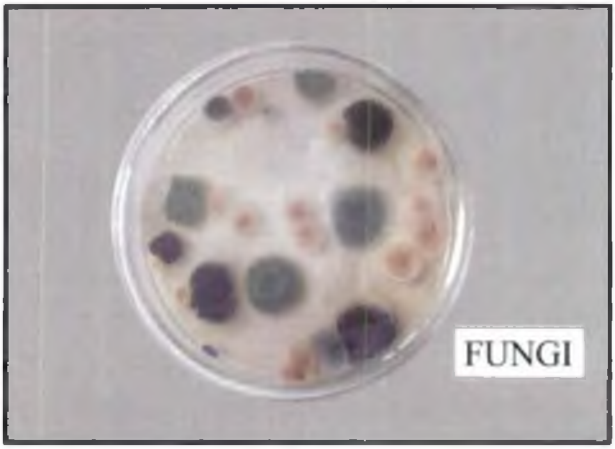

Plate 4. Maximum fungal count of amaranth flour at the end of storage period

Plate 5. Maximum yeast count of amaranth flour at the end of storage period

5.8 x 10^3 cfu g^{-1} during second, third, fourth, fifth and sixth months of storage respectively (Fig. 14). Maximum fungal count observed in grain amaranth flour at the end of storage period is given in Plate 4.

Mean increase of fungal count during six months of storage was 1.0 for Phase I and 0.8, 1.1, 0.8 and 0.3 for phase II, phase III, phase IV and phase V respectively (Table 5). The highest mean rank score was obtained during phase III (4.33) and least was found to be during phase IV (2.0) of the storage span.

The rank scores obtained during different phases of storage was found to be statistically insignificant indicating that the increase in fungal count noticed during different phases of storage was uniform.

The initial yeast count was 1.5 x 10^3 cfu g^{-1} which gradually increased to 1.8 x 10^3 cfu g^{-1}, 2.3 x 10^3 cfu g^{-1}, 3.1 x 10^3 cfu g^{-1}, 4.4 x 10^3 cfu g^{-1} and 5.3 x 10^3 cfu g^{-1} during second, third, fourth, fifth and sixth months of storage respectively (Fig. 15). Maximum yeast count observed in grain amaranth flour at the end of storage period is given in Plate 5.

The mean increment in yeast count of amaranth flour during different phases of storage was 0.3 (phase I), 0.5 (phase II), 0.8 (phase III), 1.3 (phase IV) and 0.9 (phase V). Mean rank scores on the basis of Friedman's test were found to be highest during phase IV (4.17) and least rank score of 1.77 was obtained during phase I (Table 5) of the storage period.

The rank scores observed for yeast was found to be statistically significant at 10 per cent level during different phases of storage.

Insect infestation of grain amaranth flour was also evaluated at monthly intervals for a period of six months and no insect infestation was noticed in the flour upto six months storage.

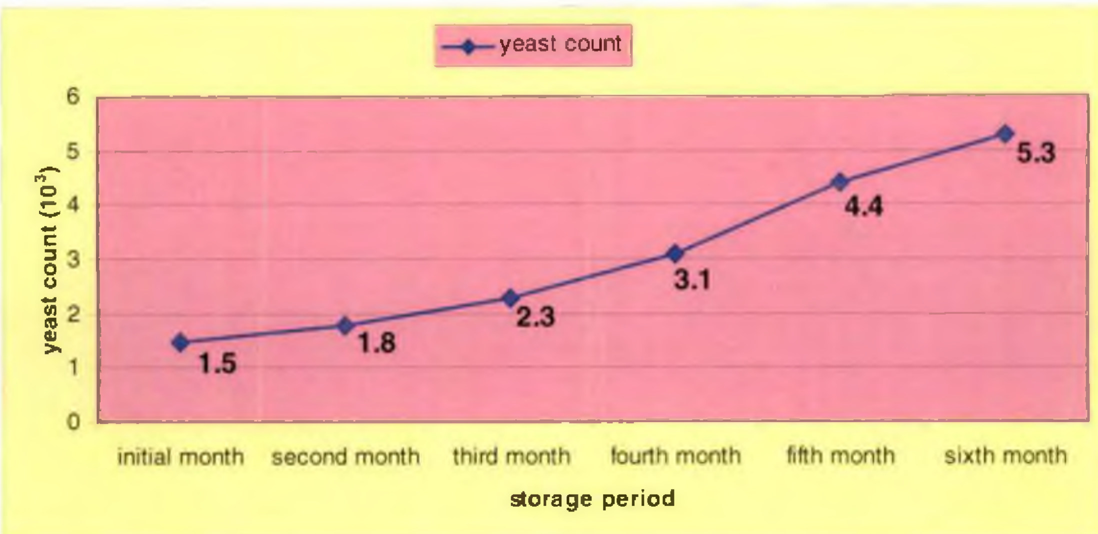

Fig 15. Yeast count of grain amaranth flour during storage

4.3. Organoleptic evaluation of the flour and changes during storage

The scores obtained for the organoleptic evaluation of amaranth flour for the quality attributes like appearance, colour, flavour, texture, taste and overall acceptability during storage are presented in Table 6.

The characteristic appearance of the fresh amaranth flour scored a maximum of 3.7 initially, which showed a decreasing trend during the storage period of six months and at the end of storage the score decreased to a minimum of 3.1.

The colour of the grain amaranth flour scored a maximum during the initial period (3.4) and the score decreased to 3.2 at third month of storage and no change in the score with respect to colour was observed at the end of storage. The attribute flavour scored a maximum of 3.2 which also decreased to 3.0 at third month and to 2.4 at sixth month of storage.

The texture of the amaranth flour remained almost the same for the storage period of six months. The maximum score of 3.6 was obtained for texture initially which decreased slightly to 3.5 during third month of storage and to 2.7 at the end of storage. Mean score obtained for the taste of the flour was 3.0 during initial period of storage, which decreased to a minimum score of 1.8 after six months of storage.

The overall acceptability of the amaranth flour was also high (3.5) initially which decreased to 3.0 at third month of storage and to 2.3 during sixth month of storage. There observed a gradual reduction of the total score, which was highest (20.4) initially and the least (15.5) after six months of storage. Changes in different quality attributes of amaranth flour during storage is presented in Fig. 16.

Effect of storage on the various quality parameters of amaranth flour over the period of storage of six months are presented in Table 7.

Table 6. Organoleptic score of grain amaranth flour during storage

Characters	Period of storage in months		
	Initial	Third	Sixth
Appearance	3.7	3.5	3.1
Colour	3.4	3.2	3.2
Flavour	3.2	3.0	2.4
Texture	3.6	3.5	2.7
Taste	3.0	2.6	1.8
Overall acceptability	3.5	3.0	2.3
Total score	20.4	18.8	15.5

Table 7. Changes in the organoleptic score for quality attributes of amaranth flour during storage.

Storage period	Characters					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Period I	-0.2	-0.2	-0.2	-0.1	-0.4	-0.5
Period II	-0.4	-0.0	-0.6	-0.8	-0.2	-0.7

Period I - Third month
Period II - sixth month

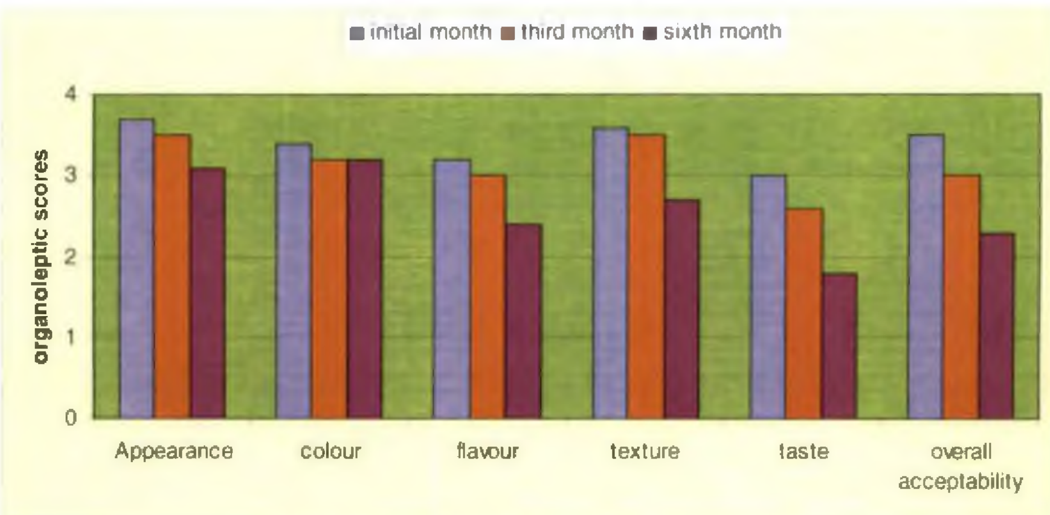

Fig 16. Changes in organoleptic scores for different quality attributes of grain amaranth flour during storage

As revealed in Table 7 the characters like appearance, colour, flavour, texture, taste and overall acceptability of the amaranth flour reduced significantly during storage and the overall acceptability scores decreased at a faster rate during the later period of storage. However, the colour of the flour did not show any change after third month of storage.

4.4. Organoleptic evaluation of recipes

The different recipes such as chapathi, biscuit and puttu prepared with different proportions of fresh grain amaranth flour were evaluated organoleptically using score card for different quality attributes like appearance, colour, flavour, texture, taste and overall acceptability. Each treatment was ranked for all these quality attributes based on mean rank score using Kendall's (W) test. The results of the organoleptic evaluation of different recipes are presented in this section.

4.4.1. Chapathi

The mean scores obtained for the different quality attributes of chapathi prepared with different combinations of wheat flour and fresh amaranth flour is given in Table 8. The mean rank scores obtained on the basis of Kendall's coefficient of concordance are also given in Table 8.

As revealed in the table, appearance of chapathi prepared exclusively with wheat flour (control) had a maximum score of 4.5 and the mean rank score of 5.58. The mean scores obtained for appearance of chapathi prepared with different proportions of wheat flour and amaranth flour were found to be 4.13 (T_1), 3.5 (T_2), 3.33 (T_3), 3.2 (T_4) and 2.83 (T_5). The mean rank scores of the above treatments were 4.62, 3.73, 2.77, 2.40 and 1.90 respectively.

Table 8. Mean scores for organoleptic evaluation of chapathi

Treatments	Characters					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Control	4.5 (5.58)	4.8 (5.77)	4.56 (4.88)	4.5 (5.03)	4.6 (5.23)	4.66 (5.25)
T_1	4.13 (4.62)	4.06 (4.65)	4.2 (4.17)	4.13 (4.30)	4.3 (4.60)	4.3 (4.60)
T_2	3.5 (3.73)	3.6 (3.37)	3.93 (3.33)	3.93 (3.60)	4.0 (3.47)	3.8 (3.70)
T_3	3.33 (2.77)	3.27 (2.88)	3.6 (2.82)	3.8 (3.12)	3.83 (3.33)	3.63 (3.02)
T_4	3.2 (2.40)	3.16 (2.58)	3.6 (3.33)	3.63 (2.83)	3.43 (2.47)	3.46 (2.65)
T_5	2.83 (1.90)	2.73 (1.75)	3.36 (2.47)	3.2 (2.12)	3.1 (1.90)	3.1 (1.78)
Kendall W value	0.706*	0.737*	0.367*	0.467*	0.586*	0.592*
Probability value	0.01	0.01	0.01	0.01	0.01	0.01

* means significant at 5 % level
Figures in parenthesis are mean rank scores

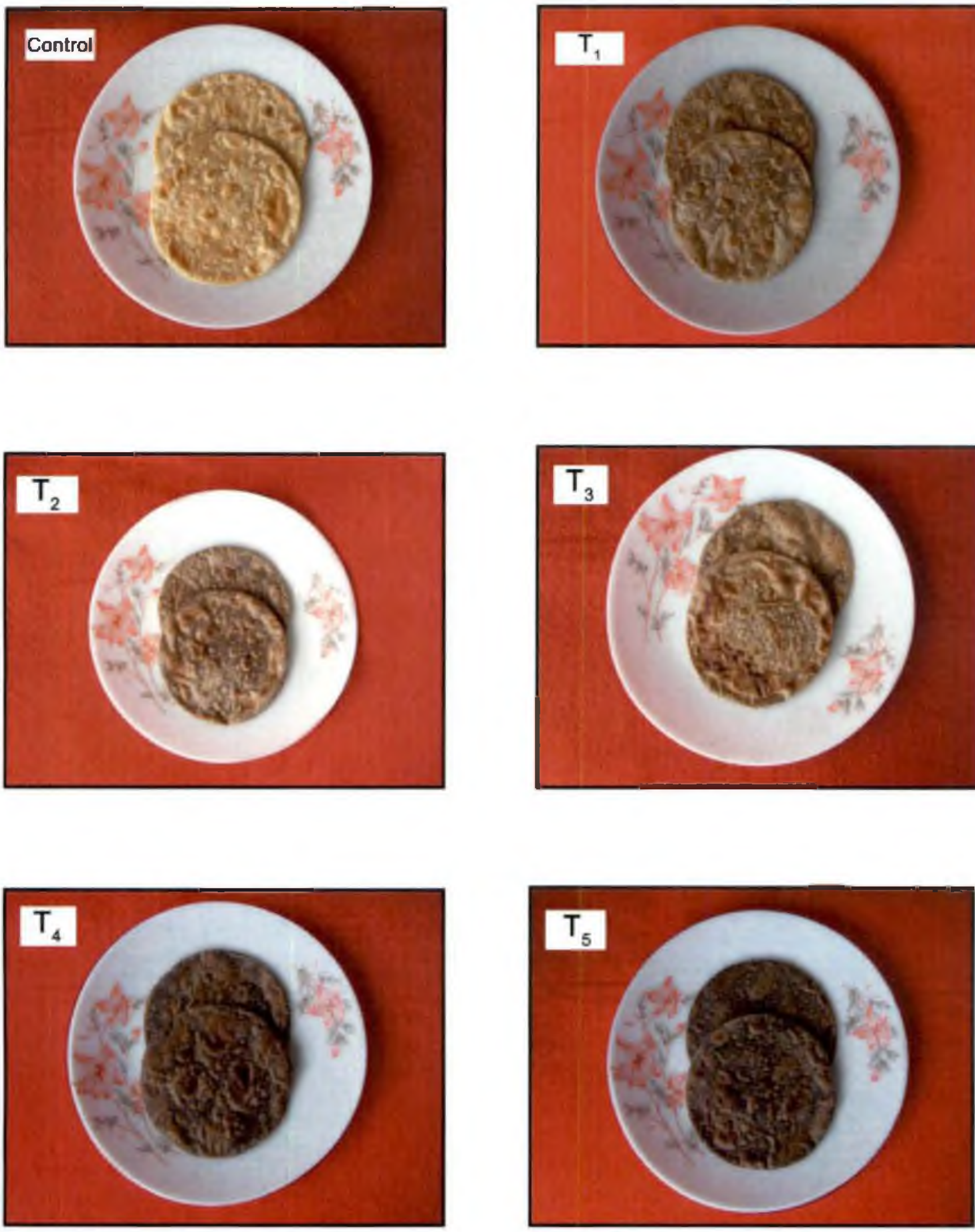

Plate 6. Chapathi prepared by different proportions of wheat flour and amaranth flour

Control - 100 % wheat flour

T_1- 90 % wheat flour + 10% amaranth flour

T_2- 80 % wheat flour + 20% amaranth flour

T_3- 70 % wheat flour + 30% amaranth flour

T_4- 60 % wheat flour + 40% amaranth flour

T_5- 50 % wheat flour + 50% amaranth flour

Among the six treatments, chapathi prepared with 100 per cent wheat flour (control) obtained the highest mean score (4.8) and mean rank score (5.77) for colour. The mean score of chapathi prepared with wheat flour and amaranth flour in the ratio of 90:10 (T_1) was found to be 4.06 which was followed by T_2 (3.6), T_3 (3.27), T_4 (3.16) and T_5 (2.73) respectively. The mean rank scores on the basis of Kendall's coefficient of variation with respect to colour was found to be 4.65 (T_1), 3.37 (T_2), 2.88 (T_3), 2.58 (T_4) and 1.75 (T_5)

The mean score for flavour of chapathi was found to be highest (4.56) for control (100 % wheat flour) which was followed by T_1 (4.2), T_2 (3.93), T_3 (3.6), T_4 (3.6) and T_5 (3.36). The mean rank scores were 4.88, 4.17, 3.33, 2.82, 3.33 and 2.47 for control, T_1, T_2, T_3, T_4 and T_5 respectively.

Mean score for texture and taste of the chapathi prepared with wheat flour was 4.5 and 4.6 respectively. The mean scores for texture of chapathi was found to be 4.13 (T_1), 3.93 (T_2), 3.8 (T_3), 3.63 (T_4) and 3.2 (T_5). For taste, the scores obtained for different treatments were 4.3 (T_1), 4.0 (T_2), 3.83 (T_3), 3.43 (T_4) and 3.1 (T_5). Mean rank scores was also found to be high for texture (5.03) and taste (5.23) for the chapathi prepared with 100 per cent wheat flour. For other treatments, the mean ranks for texture were 4.30 (T_1), 3.60 (T_2), 3.12 (T_3), 2.83 (T_4) and 2.12 (T_5). For taste T_1, T_2, T_3, T_4 and T_5 obtained the mean rank scores of 4.60, 3.47, 3.33, 2.47 and 1.90 respectively.

The overall acceptability of chapathi was highest for control (4.66) followed by T_1 (4.3) T_2 (3.8), T_3 (3.63), T_4 (3.46) and T_5 (3.1). The mean rank scores were found to be 5.25, 4.60, 3.70, 3.02, 2.65 and 1.78 for control, T_1, T_2, T_3, T_4 and T_5 respectively.

The variation observed in the scores of different quality attributes like appearance, colour, flavour, texture, taste and overall acceptability of chapathi prepared exclusively with wheat flour and with different combinations of wheat flour and grain amaranth flour was found to be statistically significant.

The organoleptic scores of different quality attributes and overall acceptability of chapathi are given in Fig. 17. Chapathi prepared with different proportions of wheat flour and amaranth flour is depicted in Plate 6.

4.4.2. Biscuit

The mean and rank scores obtained for various quality attributes like appearance, colour, flavour, texture, taste and overall acceptability of biscuit are presented in Table 9.

As revealed in the table appearance of biscuit prepared exclusively with maida (control) had a maximum score of 4.6 and the highest mean rank score of 5.00. The mean score of biscuit prepared with different proportions of maida and amaranth flour was found to be 4.06 (T_1), 4.13 (T_2), 3.66 (T_3), 3.36 (T_4) and 3.43 (T_5) for appearance and the mean rank scores were 4.03, 4.07, 2.95, 2.32 and 2.63 respectively.

Among the six treatments, the control obtained the highest mean score (4.66) and mean rank score (5.35) for colour. The mean score of colour for biscuit prepared with maida and amaranth flour in the ratio of 90:10 (T_1) was found to be 3.93 which was followed by T_2 (4.0), T_3 (3.66), T_4 (3.4) and T_5 (3.5). The mean rank scores for colour of different treatments were 3.65 (T_1), 4.12 (T_2), 3.05 (T_3), 2.33 (T_4) and 2.50 (T_5).

For flavour, biscuit prepared with 100 per cent maida obtained the mean score of 4.53 which was followed by T_1 (4.16), T_2 (4.03), T_3 (3.93), T_4 (3.7) and T_5 (3.63). The mean rank scores on the basis of Kendall's coefficient of variation was found to be 4.13 (T_1), 3.45 (T_2), 3.37 (T_3), 2.83 (T_4) and 2.55 (T_5).

Table 9. Mean scores for organoleptic evaluation of biscuit

Treatments	Characters					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Control	4.6 (5.00)	4.66 (5.35)	4.53 (4.67)	4.43 (4.82)	4.53 (4.73)	4.63 (5.07)
T_1	4.06 (4.03)	3.93 (3.65)	4.16 (4.13)	4.1 (3.98)	4.13 (3.93)	4.2 (4.17)
T_2	4.13 (4.07)	4.0 (4.12)	4.03 (3.45)	3.93 (3.75)	4.03 (3.67)	4.06 (3.67)
T_3	3.66 (2.95)	3.66 (3.05)	3.93 (3.37)	3.7 (2.93)	3.93 (3.68)	3.93 (3.45)
T_4	3.36 (2.32)	3.4 (2.33)	3.7 (2.83)	3.5 (2.62)	3.5 (2.57)	3.53 (2.38)
T_5	3.43 (2.63)	3.5 (2.50)	3.63 (2.55)	3.63 (2.90)	3.4 (2.42)	3.43 (2.27)
Kendall W value	0.438*	0.479*	0.304*	0.278*	0.324*	0.468*
Probability	0.01	0.01	0.01	0.01	0.01	0.01

*means significant at 5 % level
Figures in parenthesis are mean rank scores

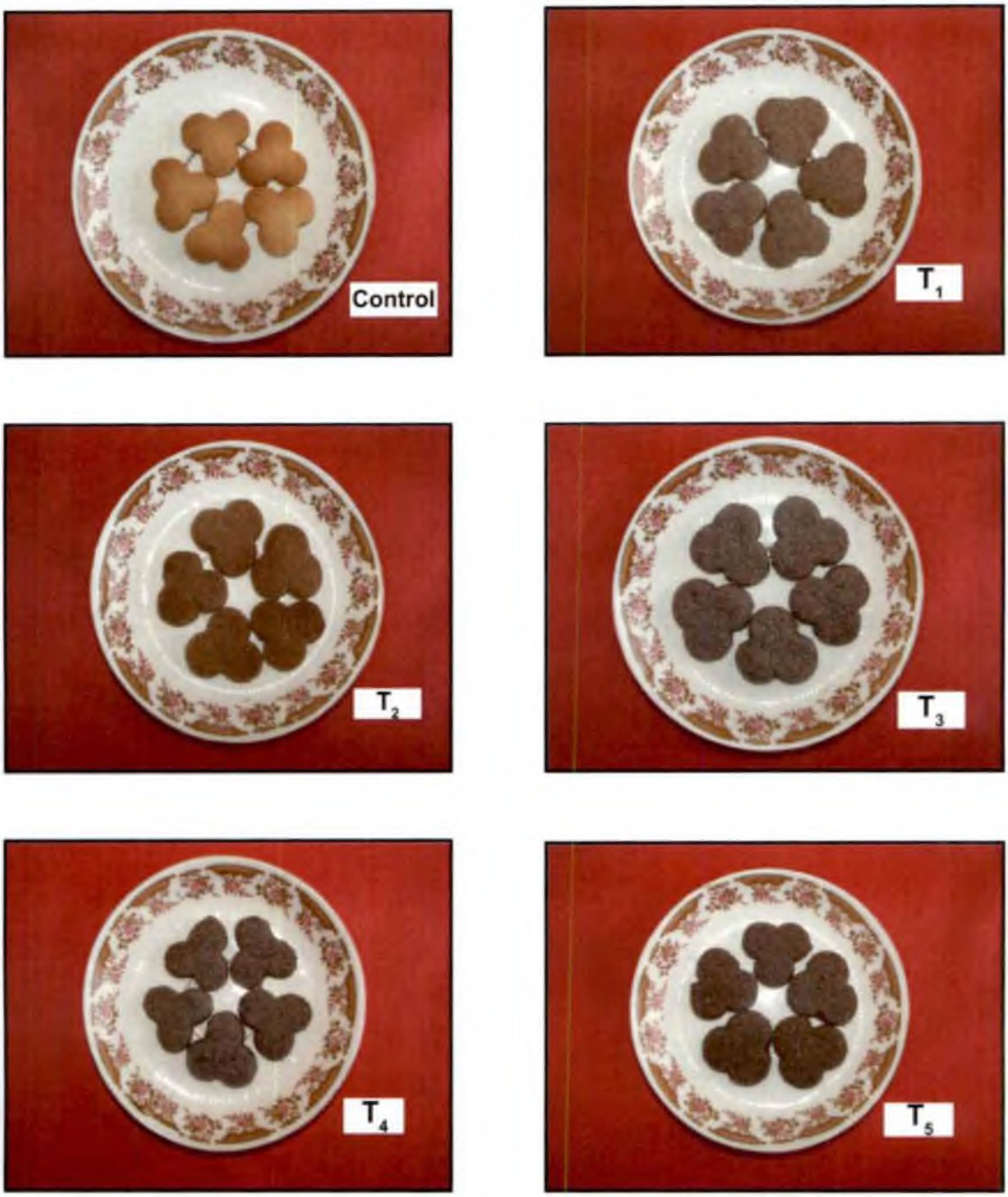

Plate 7. Biscuit prepared by different proportions of maida and amaranth flour

Control - 100 % maida

T_1- 90 % maida + 10% amaranth flour

T_2- 80 % maida + 20% amaranth flour

T_3- 70 % maida + 30% amaranth flour

T_4- 60 % maida + 40% amaranth flour

T_5- 50 % maida + 50% amaranth flour

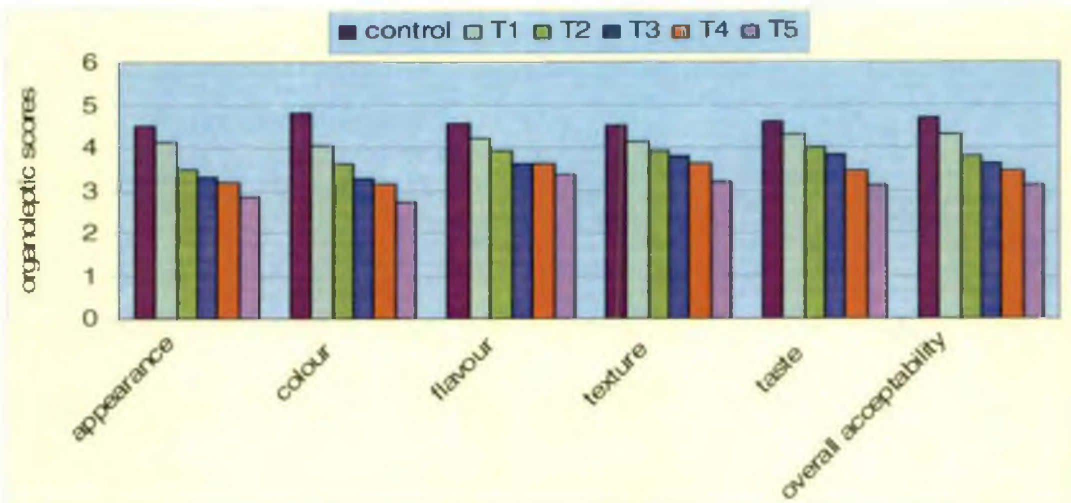

Fig 17. Organoleptic scores obtained for different quality attributes of chapathi

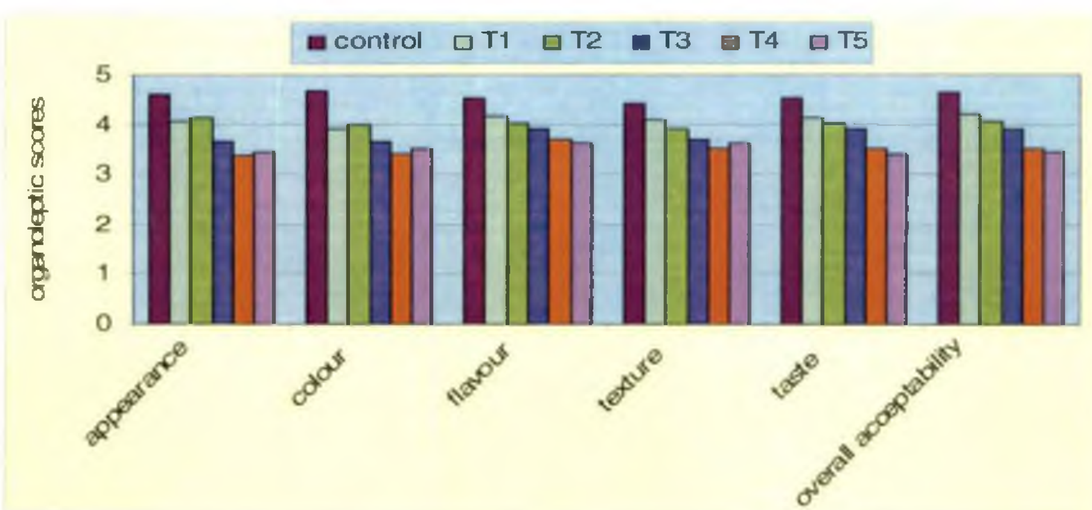

Fig 18. Organoleptic scores obtained for different quality attributes of biscuit

The mean and mean rank scores for texture was found to be 4.43 and 4.82 (control), 4.1 and 3.98 (T_1), 3.93 and 3.75 (T_2), 3.7 and 2.93 (T_3), 3.5 and 2.62 (T_4) and 3.63 and 2.90 (T_5) respectively.

Among the different treatments, biscuit made with 100 per cent maida obtained the highest mean (4.53) and mean rank scores (4.73) for taste which was followed by T_1 (4.13 and 3.93), T_2 (4.03 and 3.67), T_3 (3.93 and 3.68), T_4 (3.5 and 2.57) and T_5 (3.4 and 2.42) respectively.

The overall acceptability of biscuit was highest for control (4.63) which was followed by T_1 (4.2), T_2 (4.06), T_3 (3.93), T_4 (3.53) and T_5 (3.43). The mean rank scores on the basis of Kendall's coefficient of variation were found to be 5.07 (control), 4.17 (T_1), 3.67 (T_2), 3.45 (T_3), 2.38 (T_4) and 2.27 (T_5).

The scores obtained for different quality attributes of biscuit was found to be statistically significant between different treatments as well as control. The organoleptic scores of different quality attributes and overall acceptability of biscuit are given in Fig. 18. Biscuit prepared by different proportions of maida and amaranth flour is represented in Plate 7.

4.4.3. Puttu

The mean and rank scores obtained from the organoleptic evaluation of puttu prepared with different proportions of rice flour and fresh grain amaranth flour are given in Table 10.

As revealed in the table, mean score of puttu prepared with 100 per cent rice flour was found to be the highest for different quality attributes like appearance (4.73), colour (4.70), flavour (4.33), texture (4.3), taste (4.43) and overall acceptability (4.53). The mean rank scores of the control also was the highest for different quality attributes like appearance (4.95), colour (4.90), flavour (4.68), texture (4.88), taste (4.88) and overall acceptability (4.80).

The mean scores for appearance of puttu prepared with different proportions of rice flour and grain amaranth flour were found to be 4.23 (T_1), 4.2 (T_2), 3.96 (T_3), 3.5 (T_4) and 3.9 (T_5) and mean rank scores were 3.23, 3.63, 3.18, 3.03 and 2.97 for T_1, T_2, T_3, T_4 and T_5 respectively.

The mean scores for colour were found to be 4.16, 3.96, 3.36, 3.86 and 3.76 for T_1, T_2, T_3, T_4 and T_5 respectively. The mean rank scores of different treatments were 3.72 (T_1), 3.40 (T_2), 2.95 (T_3), 3.22 (T_4) and 2.82 (T_5).

The character flavour, had the mean scores of 4.0 (T_1), 3.8 (T_2), 3.53 (T_3), 3.73 (T_4) and 3.5 (T_5) and the mean rank scores of 3.92 (T_1), 3.37 (T_2), 3.27 (T_3), 2.72 (T_4) and 3.05 (T_5).

The mean scores for texture for T_1, T_2, T_3, T_4 and T_5 were found to be 3.83, 3.76, 3.63, 3.53 and 3.5 respectively. The mean rank scores on the basis of Kendall's coefficient of variation with respect to texture was 3.62 (T_1), 3.43 (T_2), 2.85 (T_3), 3.23 (T_4) and 2.98 (T_5).

The mean and rank scores for taste of puttu prepared with different combinations of rice flour and grain amaranth flour were found to be 4.0 and 3.90 (T_1), 3.86 and 3.50 (T_2), 3.6 and 3.13 (T_3), 2.76 and 2.82 (T_4), 3.5 and 2.77 (T_5).

The overall acceptability of puttu was found to be 4.13 (T_1), 3.5 (T_2), 3.7 (T_3), 3.6 (T_4) and 3.53 (T_5). The mean rank scores obtained for different treatments were 4.02 (T_1), 3.17 (T_2), 3.12 (T_3), 3.00 (T_4) and 2.90 (T_5).

The variation observed in the scores of different quality attributes like appearance, colour, flavour, texture, taste and overall acceptability of puttu prepared

Table 10. Mean scores for organoleptic evaluation of puttu

Treatments	Characters					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Control	4.73 (4.95)	4.7 (4.90)	4.33 (4.68)	4.3 (4.88)	4.43 (4.88)	4.53 (4.80)
T_1	4.23 (3.23)	4.16 (3.72)	4.0 (3.92)	3.83 (3.62)	4.0 (3.90)	4.13 (4.02)
T_2	4.2 (3.63)	3.96 (3.40)	3.8 (3.37)	3.76 (3.43)	3.86 (3.50)	3.5 (3.17)
T_3	3.96 (3.18)	3.36 (2.95)	3.53 (3.27)	3.63 (2.85)	3.6 (3.13)	3.7 (3.12)
T_4	3.5 (3.03)	3.86 (3.22)	3.73 (2.72)	3.53 (3.23)	2.76 (2.82)	3.6 (3.00)
T_5	3.9 (2.97)	3.76 (2.82)	3.5 (3.05)	3.5 (2.98)	3.5 (2.77)	3.53 (2.90)
Kendall W value	0.251*	0.247*	0.220*	0.235*	0.257*	0.223*
Probability value	0.01	0.01	0.01	0.01	0.01	0.01

* means significant at 5 % level
Figures in parenthesis are mean rank scores

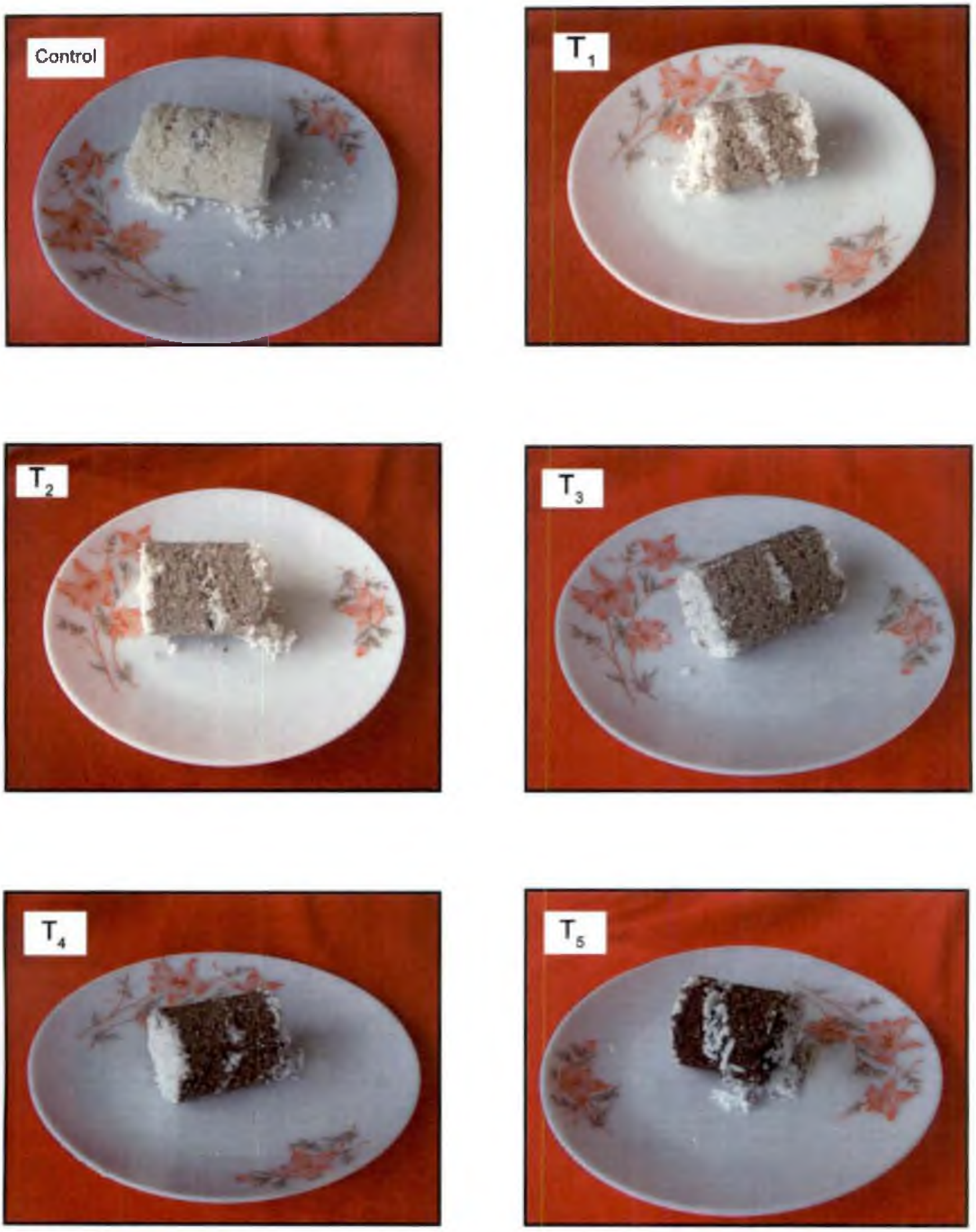

Plate 8. Puttu prepared by different proportions of rice flour and amaranth flour

Control - 100 % rice flour

T_1- 90 % rice flour + 10% amaranth flour

T_2- 80 % rice flour + 20% amaranth flour

T_3- 70 % rice flour + 30% amaranth flour

T_4- 60 % rice flour + 40% amaranth flour

T_5- 50 % rice flour + 50% amaranth flour

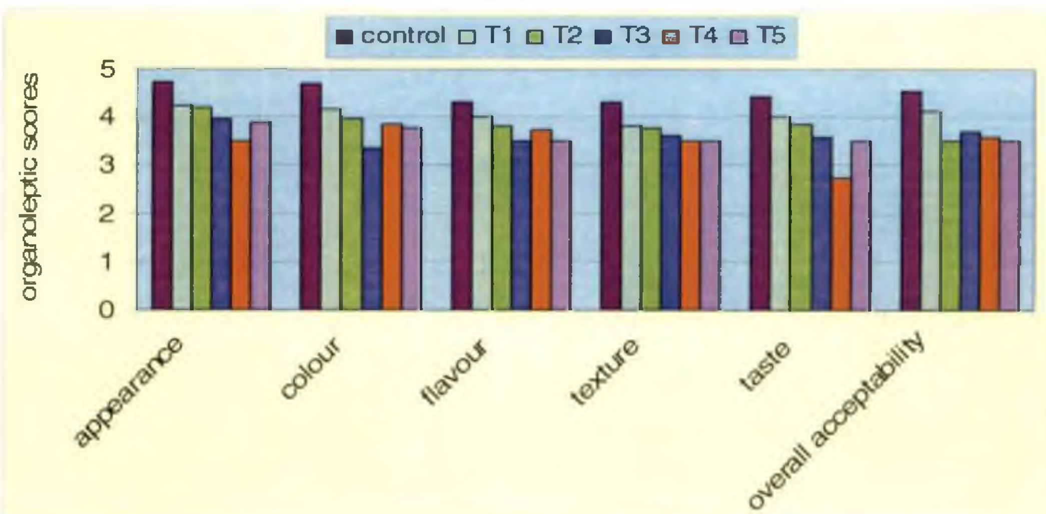

Fig 19. Organoleptic scores obtained for different quality attributes of puttu

exclusively with rice flour and with different combinations of rice flour and grain amaranth flour was found to be statistically significant.

The organoleptic scores of different quality attributes and overall acceptability of puttu are given in Fig. 19. Puttu prepared by different proportions of rice flour and amaranth flour is represented in Plate 8.

4.5. Computation of nutritive value of recipes

Nutrients like protein, fat, fibre, carbohydrates, calcium and iron contents of chapathi, biscuit and puttu per serving were computed using the food composition table (Gopalan *et al.*, 1989). Nutritive value was computed per serving for control and different treatments separately and the results are presented in Table 11, 13 and 15. One serving of chapathi, biscuit and puttu was taken as 3 nos., 4 nos. and 2 pieces respectively.

The percentage of Recommended Dietary Allowances (RDA) met from one serving with respect to each nutrient on the basis of RDA for reference woman is also given in this section (Table 12, 14 and 16). The RDA suggested by ICMR (1989) was taken as the base to compute the percentage of RDA met per serving for protein, fat, calcium and iron. For fibre and carbohydrates, the RDA suggested by Ramulu (2006) and Antia and Abraham (1986) respectively were taken as the base for computation.

4.5.1. Chapathi

4.5.1.1. Protein

Protein content of chapathi varied from 9.07 g (control) to 10.05 g (T_5) (Table 11). About 18.14 to 20.1 per cent of protein requirement was met from one serving of chapathi prepared with wheat flour and with different combinations of wheat and amaranth flour (Table 12).

4.5.1.2. Fat

Fat content of chapathi prepared with 100 per cent wheat flour was found to be 8.77 g per serving (Table 11). The fat content of chapathi prepared with different combinations of wheat and amaranth flour were found to be 9.15 g (T_1), 9.52 g (T_2), 9.9 g (T_3), 10.27 g (T_4) and 10.66 g (T_5).

From Table 12, it can be seen that chapathi made with 100 per cent wheat flour met 43.85 per cent of RDA while other treatments met 45.75 per cent (T_1), 47.6 per cent (T_2), 49.5 per cent (T_3), 51.35 per cent (T_4) and 53.3 per cent (T_5) of RDA.

4.5.1.3. Fibre

Fibre content of chapathi prepared exclusively with wheat flour was 1.42 g and other treatments were 1.49 g (T_1), 1.57 g (T_2), 1.64 g (T_3), 1.71 g (T_4) and 1.78 g (T_5) per serving.

About 4.73 to 5.93 per cent of fibre requirement was met from chapathi prepared with wheat flour and with different combinations of amaranth and wheat flour (Table 12).

4.5.1.4. Carbohydrates

Carbohydrate content of one serving of chapathi was found to be 52.05 g per serving for control which was followed by 51.57 g (T_1), 51.09 g (T_2), 50.61 g (T_3), 50.13 g (T_4) and 49.65 g (T_5).

As revealed in Table 12, chapathi prepared with 100 per cent wheat flour met 13.62 per cent of RDA while from other treatments like T_1, T_2, T_3, T_4 and T_5,13.50 per cent, 13.37 per cent, 13.24 per cent, 13.12 per cent and 12.99 per cent of RDA were met from one serving of chapathi respectively.

Table 11. Nutritive value of chapathi
(Per serving of 3 chapathi)

Treatment	Nutrients					
	Protein (g)	Fats (g)	Fibre (g)	Carbohydrates (g)	Calcium (mg)	Iron (mg)
Control	9.07	8.77	1.42	52.05	36	3.67
T_1	9.26	9.15	1.49	51.57	46.42	4.32
T_2	9.46	9.52	1.57	51.09	56.87	4.94
T_3	9.64	9.9	1.64	50.61	67.30	5.62
T_4	9.85	10.27	1.71	50.13	77.74	6.27
T_5	10.05	10.66	1.78	49.65	88.18	6.93
t value	3.722*	3.791*	3.687*	-3.794*	3.793*	3.79*

* means significant at 5% level

Table 12. Percentage of RDA met from one serving of chapathi

Treatment	Percentage of RDA					
	Protein	Fats	Fibre	Carbohydrates	Calcium	Iron
Control	18.14	43.85	4.73	13.62	9.0	12.23
T_1	18.52	45.75	4.96	13.50	11.60	14.4
T_2	18.92	47.6	5.23	13.37	14.21	16.46
T_3	19.28	49.5	5.46	13.24	16.82	18.73
T_4	19.7	51.35	5.7	13.12	19.43	20.9
T_5	20.1	53.3	5.93	12.99	22.0	23.1
RDA	50	20	35	380	400	30

4.5.1.5. Calcium

Calcium content of one serving of chapathi varied from 36 mg for control to 88.18 mg for T_5.

About 9 per cent of RDA of calcium was met from chapathi made with 100 per cent wheat flour (control) which was followed by 11.60 per cent (T_1), 14.21 per cent (T_2), 16.82 per cent (T_3), 19.43 per cent (T_4) and 22 per cent (T_5).

4.5.1.6. Iron

The iron content of chapathi prepared with different proportions of wheat flour and amaranth flour was found to be 3.67 mg, 4.32 mg, 4.94 mg, 5.62 mg, 6.27 mg and 6.93 mg for control, T_1, T_2, T_3, T_4 and T_5 respectively.

About 12.23 to 23.1 per cent of iron requirement was met from chapathi prepared with wheat flour and different combinations of amaranth and wheat flour (Table 12).

The variation observed in the nutritive value of chapathi between the different treatments was found to be statistically significant at 5 per cent probability level.

4.5.2. Biscuit

Nutritive value of biscuit per serving of four biscuits and percentage of RDA met per serving of biscuits is presented in Table 13 and 14 respectively.

Table 13. Nutritive value of biscuits

(Per serving of 4 biscuits)

Treatment	Nutrients					
	Protein (g)	Fats (g)	Fibre (g)	Carbohydrates (g)	Calcium (mg)	Iron (mg)
Control	1.47	5.52	0.04	17.81	4.02	0.37
T_1	1.52	5.59	0.07	17.66	6.21	0.52
T_2	1.57	5.67	0.08	17.51	8.40	0.66
T_3	1.62	5.75	0.14	17.36	10.59	0.81
T_4	1.67	5.83	0.17	17.09	12.78	0.95
T_5	1.72	5.90	0.21	17.07	14.97	1.09
t value	3.797*	3.560*	3.164*	-3.796*	3.797*	3.856*

* means significant at 5% level

Table 14. Percentage of RDA met from one serving of biscuits

Treatment	Percentage of RDA					
	Protein	Fats	Fibre	Carbohydrates	Calcium	Iron
Control	2.94	27.6	0.13	4.66	1.0	1.23
T_1	3.04	27.95	0.20	4.62	1.55	1.72
T_2	3.14	28.35	0.22	4.58	2.10	2.18
T_3	3.24	28.75	0.40	4.54	2.64	2.66
T_4	3.34	29.10	0.50	4.47	3.19	3.16
T_5	3.44	29.50	0.60	4.46	3.74	3.63
RDA	50	20	35	380	400	30

4.5.2.1. Protein

The protein content of biscuit prepared with maida and different combinations of amaranth flour and maida was found to be 1.47 g (control), 1.52 g (T_1), 1.57g (T_2), 1.62 g (T_3), 1.67 g (T_4) and 1.72 g (T_5) (Table 13).

From Table 14 it can be seen that biscuit made with 100 per cent maida met 2.94 per cent of RDA while from other treatments about 3.04 per cent (T_1), 3.14 per cent (T_2), 3.24 per cent (T_3), 3.34 per cent (T_4) and 3.44 per cent (T_5) of RDA were met.

4.5.2.2. Fat

The fat content of one serving of biscuit varied from 5.52 g for control to 5.90 g for T_5 (Table 13).

About 27.6 per cent of RDA for fat was met from biscuit prepared with maida (control) which was followed by 27.95 per cent (T_1), 28.35 per cent (T_2), 28.75 per cent (T_3), 29.1 per cent (T_4) and 29.5 per cent (T_5).

4.5.2.3. Fibre

Fibre content of biscuit was found to be 0.04 g (control) which was followed by 0.07 g (T_1), 0.08 g (T_2), 0.14 g (T_3), 0.17 g (T_4) and 0.21 g (T_5).

As revealed in Table 14, biscuit prepared with 100 per cent maida met only 0.13 per cent of RDA while different treatments like T_1, T_2, T_3, T_4 and T_5 met 0.2 per cent, 0.22 per cent, 0.4 per cent, 0.5 per cent and 0.6 per cent of fibre requirement respectively.

4.5.2.4. Carbohydrates

The carbohydrates content of biscuit prepared with different proportions of maida and amaranth flour was found to be 17.81 g, 17.66 g, 17.51 g, 17.36 g, 17.09 g and 17.07 g for control, T_1, T_2, T_3, T_4 and T_5 respectively (Table 13).

About 4.66 per cent of carbohydrate requirement was met from biscuit prepared with 100 per cent maida. However, the percentage of RDA met by different treatments were 4.62 per cent, 4.58 per cent, 4.54 per cent, 4.47 per cent and 4.46 per cent for T_1, T_2, T_3, T_4 and T_5 respectively (Table 14).

4.5.2.5. Calcium

Calcium content of biscuit varied from 4.02 mg (control) to 14.97 mg (T_5).

About 1 to 3.74 per cent of calcium requirement was met from one serving of biscuit prepared with different combinations of amaranth flour and maida (Table 14).

4.5.2.6. Iron

Iron content of biscuit prepared exclusively with maida was 0.37 mg which was followed by T_1 (0.52 mg), T_2 (0.66 mg), T_3 (0.81 mg), T_4 (0.95 mg) and T_5 (1.09 mg).

From Table 14, it can be seen that biscuit prepared with 100 per cent maida met 1.23 per cent of RDA while other treatments met 1.72 per cent (T_1), 2.18 per cent (T_2), 2.66 per cent (T_3), 3.16 per cent (T_4) and 3.36 per cent (T_5) of RDA.

The variation observed in the nutritive value of biscuit between treatments was found to be statistically significant at 5 per cent probability level.

4.5.3. Puttu

The nutritive value of puttu per serving of two pieces is presented in Table 15 and percentage of RDA met from one serving with respect to each nutrient is presented in Table 16.

4.5.3.1. Protein

Protein content of puttu prepared with 100 per cent rice flour was found to be 4.1 g per serving and with different combinations of amaranth flour and rice flour were found to be 4.51 g (T_1), 4.93 g (T_2), 5.54 g (T_3), 5.76 g (T_4) and 6.17 g (T_5).

As revealed in Table 16, percentage of RDA met for protein from a serving of puttu was found to be 8.2 per cent (control), 9.02 per cent (T_1), 9.86 per cent (T_2), 11.08 per cent (T_3), 11.52 per cent (T_4) and 12.35 per cent (T_5).

4.5.3.2. Fat

Fat content of puttu varied in the range of 8.52 g (control) to 10.1 g (T_5) per serving (Table 15).

About 42.6 per cent of RDA of fat was met from puttu prepared with 100 per cent rice flour (control) which was followed by 44.15 per cent (T_1), 45.76 per cent (T_2), 47.3 per cent (T_3), 48.9 per cent (T_4) and 50.5 per cent (T_5) of RDA of fat.

4.5.3.3. Fibre

Fibre content of puttu varied from 0.82 g for control to 1.48 g for T_5 per serving.

Table 15. Nutritive value of puttu
(Per serving of 2 pieces of puttu)

Treatment	Nutrients					
	Protein (g)	Fats (g)	Fibre (g)	Carbohydrates (g)	Calcium (mg)	Iron (mg)
Control	4.10	8.52	0.82	42.1	6.13	0.84
T_1	4.51	8.83	0.95	41.3	15.4	1.46
T_2	4.93	9.15	1.06	40.5	24.31	2.07
T_3	5.54	9.46	1.22	39.7	33.22	2.72
T_4	5.76	9.78	1.35	38.9	42.13	3.35
T_5	6.17	10.10	1.48	38.1	51.04	3.98
t value	3.866*	3.750*	3.649*	-3.663*	3.846*	2.501*

* means significant at 5% level

Table 16. Percentage of RDA met from one serving of puttu

Treatment	Percentage of RDA					
	Protein	Fats	Fibre	Carbohydrates	Calcium	Iron
Control	8.2	42.60	2.34	11.02	1.53	2.8
T_1	9.02	44.15	2.72	10.81	3.85	4.86
T_2	9.86	45.76	3.10	10.61	6.07	6.90
T_3	11.08	47.30	3.48	10.39	8.30	9.06
T_4	11.52	48.90	3.86	10.18	10.53	11.16
T_5	12.35	50.50	4.22	9.97	12.76	13.28
RDA	50	20	35	380	400	30

About 2.34 per cent of fibre requirement per day was met from puttu prepared exclusively with rice flour (control) while other treatments met 2.72 per cent (T_1), 3.1 per cent (T_2), 3.48 per cent (T_3), 3.86 per cent (T_4) and 4.22 per cent (T_5) of RDA.

4.5.3.4. Carbohydrates

The carbohydrate content of puttu per serving prepared with rice flour and different combinations of amaranth and rice flour was found to be 42.1 g (control), 41.3 g (T_1), 40.5 g (T_2), 39.7 g (T_3), 38.9 g (T_4) and 38.1 g (T_5).

As revealed in table 16, percentage of RDA met for carbohydrate from a serving of puttu was found to be 11.02 per cent, 10.81 per cent, 10.61 per cent, 10.39 per cent, 10.18 per cent and 9.97 per cent for control, T_1, T_2, T_3, T_4 and T_5 respectively.

4.5.3.5. Calcium

Calcium content of puttu prepared exclusively with rice flour was only 6.13 mg which was followed by 15.4 mg (T_1), 24.31 mg (T_2), 33.22 mg (T_3), 42.13 mg (T_4) and 51.04 mg (T_5).

About 1.53 per cent of calcium requirement was met from control followed by T_1 (3.85 %), T_2 (6.07 %), T_3 (8.30 %), T_4 (10.53 %) and T_5 (12.76 %).

4.5.3.6. Iron

For all six treatments, the iron content per serving was found to be 0.84 mg (control), 1.46 mg (T_1), 2.07 mg (T_2), 2.72 mg (T_3), 3.35 mg (T_4) and 3.98 mg (T_5) and it met 2.8 per cent (control), 4.86 per cent (T_1), 6.9 per cent (T_2), 9.06 per cent (T_3), 11.16 per cent (T_4) and 13.28 per cent (T_5) of RDA of iron.

Discussion

5. DISCUSSION

The discussion pertaining to the study entitled "Standardization and quality evaluation of grain amaranth (*Amaranthus spp.*) flour supplemented food products" is presented in this section under the following headings.

5.1. Quality evaluation of grain amaranth flour

5.2. Acceptability and nutritive value of grain amaranth supplemented food products

5.1. Quality evaluation of grain amaranth flour

5.1.1. Chemical composition of grain amaranth flour and changes during storage

Moisture content of grain amaranth flour was found to be 16.66 g 100 g^{-1} which was slightly higher than the moisture content of grain amaranth reported by Afolabi *et al.* (1981), Bressani *et al.* (1987a), Arellano *et al.* (1990) and Bhuvaneshwari *et al.* (2001). The above authors indicated a moisture content in the range of 9.3 to 13.55 per cent in grain amaranth.

In the present study, moisture content of grain amaranth flour decreased with an increase in storage period up to third month and then increased afterwards. The initial decrease may be due to relatively low relative humidity in the storage vicinity during summer season. The increase in the moisture content of the flour may be due to the moisture pick up by the flour during the later phases of storage and due to higher relative humidity in the storage vicinity during the rainy season as suggested by Balasubramanyam (1995) and Sharif *et al.* (2003). Similar findings were also reported by Chellammal (1995) in sweet potato flour and Liya (2001) in taro flour. During storage, changes in moisture content occur due to the hygroscopic properties of the flours as reported by Kirk and Sawyer (1991) and Rehman and Shah (1999).

Grain amaranth flour had a protein content of 14.70 g 100 g^{-1}. Bressani *et al.* (1987a), Munjal *et al.* (1999) and Bhuvaneshwari *et al.* (2001) reported almost similar protein content of 12.5 to 16 g 100 g^{-1} in grain amaranth. However, a slightly higher protein content in the range of 15 to 18.5 g 100 g^{-1} was reported in grain amaranth by Escudero *et al.* (2004) and Smitha (2006).

During storage, protein content of the grain amaranth flour decreased to 12.49 g 100 g^{-1} which could be due to browning reaction as reported by Sharif *et al.* (2003). The decrease in protein content of amaranth flour during storage was found to be in close agreement with the findings reported by Leelavathi *et al.* (1984), Upadhyay *et al.* (1994) and Mirsa and Kulshrestha (2003).

The fresh amaranth flour exhibited a starch content of 62.2 g 100 g^{-1}. The starch content of the flour was found to be almost similar to the starch content of 62 per cent and 63.5 per cent reported by Becker *et al.* (1981) and Smitha (2006) respectively in grain amaranth. However, Arellano *et al.* (1990) reported slightly lower starch content (45.36 %) in grain amaranth.

The gradual decrease in starch content of the flour with advancement of storage period observed in the present study may be due to hydrolysis of polysaccharides like starch to simple sugars as reported by Upadhyay *et al.* (1994) and Pillai (2001).

The fat content of the amaranth flour was found to be 6.73 g 100 g^{-1} and it decreased during storage. The initial fat content of the flour was found to be slightly higher than the content reported by Conner *et al.* (1980), Arellano *et al.* (1990) and Bhuvaneshwari *et al.* (2001) in grain amaranth. The authors observed a fat content in the range of 6.9 to 7.1 g 100 g^{-1} in grain amaranth. But, Munjal *et al.* (1999) and Berganza *et al.* (2003) reported almost similar fat content in the range of 6.38 to 7.13 g 100 g^{-1} in grain amaranth.

The decrease in fat content observed during storage may be attributed to the lipolytic activity of enzymes like lipase and lipoxidase (Sharif *et al.*, 2003). Haridas *et al.* (1983) and Leelavathi *et al.* (1984) also indicated a decrease in fat content in whole wheat flour during storage.

The fibre content of the amaranth flour was found to be 2.87 g 100 g^{-1} initially which decreased to 1.66 g 100 g^{-1} at the end of storage. National Institute of Nutrition (1983), Munjal *et al.* (1999) and Smitha (2006) also indicated a fibre content in the range of 2.40 to 4.34 g 100 g^{-1} in grain amaranth. However, Afolabi *et al.* (1981) and Osungton and Oke (1983) reported a slightly higher fibre content of 5.8 to 7.2 g 100 g^{-1} in grain amaranth.

The decrease in crude fibre content observed during storage may be due to the degradation of hemicellulose and other structural polysaccharide materials in the flour during storage as reported by Mirsa and Kulshrestha (2003) and Sharif *et al.* (2003).

Amaranth flour had a calcium content of 187.16 mg 100 g^{-1}. Joshi and Rana (1991), Munjal *et al.* (1999) and Bhuvaneshwari *et al.* (2001) reported almost similar calcium content in the range of 127.6 to 203.2 mg 100 g^{-1} in grain amaranth. But, National Institute of Nutrition (1980) and Bressani (1992) reported a higher calcium content of 217 to 303 mg 100 g^{-1} in amaranth grain.

The decrease in calcium content observed during storage may be due to phytate that can bind with calcium and other minerals and make it unavailable.

The magnesium content of the amaranth flour was found to be 226 mg 100 g^{-1} which is slightly lower than the value (253.62 mg 100 g^{-1}) as reported by Mendonca *et al.* (2004) in whole amaranth flour. Magnesium content of the flour decreased with advancement of storage.

The fresh amaranth flour exhibited an iron content of 13.58 mg 100 g^{-1} which is in line with the findings of Joshi and Rana (1991) and Munjal *et al.* (1999). The iron content obtained in the present study was slightly higher than those obtained by Mendonca *et al.* (2004) who reported an iron content of 11.72 mg 100 g^{-1} in whole amaranth flour.

The iron content of the flour decreased slightly during storage and at the end of storage the iron content was found to be 12.47 mg 100 g^{-1}. Rubin *et al.* (1997), Misfa *et al.* (2000) and Sharif *et al.* (2003) observed reduction in iron content of wheat flour during storage.

The potassium content of amaranth flour was found to be 248.2 mg 100 g^{-1} which was lower than the potassium content of 433.94 100 g^{-1} reported by Mendonca *et al.* (2004) in whole amaranth flour. The variation observed may be due to the difference in the variety and also due to the loss occurred by removing the bran of grain amaranth during preparation of the flour. Potassium content of the flour decreased with advancement of storage.

The phosphorus content of the grain amaranth flour was found to be 315.68 mg 100 g^{-1} which is in line with the finding of Munjal *et al.* (1999) who reported a phosphorus content of 310 mg 100 g^{-1} in grain amaranth. However, Bressani (1992) and Mendonca *et al.* (2004) indicated a phosphorus content upto 600 mg 100 g^{-1} and 441.05 mg 100 g^{-1} respectively in grain amaranth.

The decrease in phosphorus content observed during storage may be due to the increase in phytic acid content and phytic acid will bind phosphorus to form phytate phosphorus.

The grain amaranth flour exhibited a tannin content of 1.23 mg 100 g^{-1}. The result obtained is in line with the tannin content of 1.0 to 5.2 mg 100 g^{-1} as reported by Bejosano and Corke (1998). However, Osungton and Oke (1983) and Pederson *et* *al.* (1987) reported very high tannin content of 0.15 per cent and 0.35 per cent respectively in grain amaranth which may be due to the presence of bran in the whole grains. The tannin content of the flour gradually increased during storage.

The phytic acid content of amaranth flour was found to be 0.53 mg 100 g^{-1} which increased slightly during storage. The result obtained is in line with the finding of Lorenz and Wright (1984) who indicated a phytic acid content of 0.52 to 0.61 per cent in grain amaranth. The phytic acid content showed a gradual increase during storage.

Microbial count and insect infestation in grain amaranth flour

Initially, bacterial count was 2.6 x 10^6 cfu g^{-1} in grain amaranth flour which increased gradually during storage. Livingstone *et al.* (1992) observed a total bacterial count of 5 x 10^4 cfu g^{-1} and 110 x 10^4 cfu g^{-1} in wheat and chickpea flours respectively. Bhaskar (2000) reported a bacterial load of 6 x 10^6 cfu g^{-1} in banana powder. Tsav-wvo *et al.* (2004) observed a bacterial count in the range of 2.7 to 1.2 x 10^7 cfu g^{-1} in fermented cassava flour.

The bacterial count increased from 2.6 x 10^6 cfu g^{-1} to 8.8 x 10^6 cfu g^{-1} during storage. The increase in bacterial count may be due to the increase in moisture content in the amaranth flour. Sharon (2003) reported a bacterial count of 5.2 x 10^6 cfu g^{-1} initially in bread fruit flour which increased to 8.9 x 10^6 cfu g^{-1} at the end of third month of storage. Mirsa and Kulshrestha (2002) detected a total bacterial count of 1.71 x 10^3 cfu g^{-1} in potato flour which gradually increased to 1.88 x 10^3 cfu g^{-1} at ambient temperature and to 1.80 x 10^3 cfu g^{-1} at refrigerated temperature during the storage period of six months.

The fungal load in amaranth flour increased gradually from 1.8 x 10^3 cfu g^{-1} to 5.8 x 10^3 cfu g^{-1} during storage.Richter *et al.* (1995) detected a fungal count 760 g^{-1} in wheat flour. The increase in fungal count during storage may be due to the increase in moisture content of the flour, which was also reported by Kapoor and Kapoor (1990) in sweet potato flour. Sharon (2003) also observed an increase in fungal count from 4.6 x 10^4 cfu g^{-1} to 8.3 x 10^4 cfu g^{-1} in breadfruit flour during storage.

The yeast count in the grain amaranth flour also increased gradually during storage. The yeast count of the flour increased from 1.5 x 10^3 cfu g^{-1} to 5.3 x 10^3 cfu g^{-1} during storage which may be due to the increase in moisture content in the flour during storage. Richter *et al.* (1995) observed a mean yeast count of 130 g^{-1} in wheat flour. Tsav-wvo *et al.* (2004) observed a yeast and mould count in the range of 1.9 x 10^3 cfu g^{-1} to 3.9 x 10^3 cfu g^{-1} in traditionally processed fermented cassava flour.

There were no traces of insect in the flour throughout the storage period that could be due to the fresh amaranth grains used to prepare the flour after proper drying and appropriate storage conditions used for the study.

5.1.3. Organoleptic evaluation of grain amaranth flour

A gradual decrease in the total mean scores for each quality attributes was observed during storage of grain amaranth flour. The overall acceptability scores of amaranth flour decreased from the initial score of 3.5 to 3.0 at third month, then to 2.3 at the end of sixth month. A decrease in the organoleptic scores of all the quality attributes like appearance, flavour, texture and taste was also noticed during storage.

However, there was no change in the score of colour after third month of storage. Sharon (2003) also indicated a reduction in all the quality attributes in breadfruit flour during storage and found that the flour was unacceptable at the end of the storage period of three months due to the astringent taste developed during storage.

Slight brownish greyish discolouration was seen in the flour after third month of storage which may be due to the browning reaction and increased microbial load during storage. Bhaskar (2000) and Sharon (2003) also indicated a slight discolouration in banana and breadfruit flours respectively during later period of storage due to enzymatic and ascorbic acid browning.

5.2. Acceptability and nutritive value of grain amaranth supplemented food products

Chapathi made with 100 per cent wheat flour was found to be most acceptable as compared to the chapathi made by substituting amaranth flour in different proportions for wheat flour. Chapathi prepared exclusively with wheat flour obtained the highest score for all the quality attributes and overall acceptability (Table 8). A decreasing trend in the scores of chapathi was observed in different quality attributes like appearance, colour, flavour, texture, taste and overall acceptability with an increase in the quantity of grain amaranth flour used to prepare chapathi. The decreasing trends observed in the scores of quality attributes may be due to the leathery texture and blackish brown colour of chapathis prepared by substituting grain amaranth flour.

The better acceptability noticed for chapathi prepared exclusively with wheat flour might be due to the familiarity and preference given by the judges for wheat flour chapathi. However, in a study conducted by Sudha (1989), better acceptability of chapathi was noticed with 70 per cent and 65 per cent substitution of amaranth flour for ragi and sorghum flours.

Among the five treatments tried, chapahti prepared with wheat and amaranth flours in the ratio 90:10 (T_1) and 80:20 (T_2) were found to be highly acceptable. Seralathan *et al.* (1991) also indicated that chapathi and poori prepared with 25 per cent substitution of amaranth flour with wheat flour was most acceptable with an organoleptic score of 3.5 for colour, 3.8 for appearance, 3.8 for flavour, 3.2 for texture and 3.7 for taste for chapathi and 3.4 for colour, 3.7 for appearance, 3.7 for flavour, 3.1 for texture and 3.5 for taste for poori. In the present study, almost similar scores in the range of 3.27 to 4.3 for different quality attributes was obtained for the chapathi prepared with a substitution of 10 per cent, 20 per cent and even 30 per cent amaranth flour for wheat flour.

Sarojini *et al.* (1996) also observed high acceptability of chapathi, poori and phulkas prepared with amaranth flour and wheat flour in the ratio of 1:3 in which scores in the range of 4.0 to 4.7 out of 5 was obtained for chapathi, poori and phulkas for different quality attributes. In the present study also chapathi prepared even with 40 per cent substitution of amaranth flour obtained a score of above 3.0 for all quality attributes including overall acceptability indicating that chapathi could be prepared by substituting nutritious grain amaranth flour for wheat flour.

Biscuit prepared by incorporating amaranth flour with maida at different proportions obtained lower score for all quality attributes when compared to biscuit prepared exclusively with maida. This may be due to the gritty texture of biscuits prepared by incorporating grain amaranth flour. However, the biscuits prepared by substituting different proportions of grain amaranth flour scored a score of above 3.36 for different quality attributes and overall acceptability.

Biscuits prepared by substituting 10 and 20 per cent of grain amaranth flour obtained a score of above 4.0 for almost all quality attributes and overall acceptability. From this it could be concluded that grain amaranth flour could also be used to prepare acceptable biscuits. The better preference obtained for biscuits prepared with maida could be due to the familiarity of judges for maida biscuits.

Seralathan *et al.* (1991) also observed a score of 3.7 for colour, 3.5 for appearance, 3.8 for flavour, 3.2 for texture and 3.8 for taste for biscuits prepared with 25 per cent incorporation of amaranth flour. Seralathan *et al.* (1991) also indicated better acceptability for cake prepared with 25 per cent incorporation of amaranth flour. Bhuvaneshwari (1995) revealed high acceptability for cakes prepared even with 50 per cent substitution of grain amaranth flour.

Puttu made with 100 per cent rice flour was found to be most acceptable as compared to the grain amaranth flour incorporated puttu. The lower acceptability noted in grain amaranth flour incorporated puttu may be due to the dark colour observed as compared to rice puttu. Among the different treatments, puttu prepared with rice and amaranth flours in the ratio 90:10 (T_1) secured highest score for different quality characters and overall acceptability.

However, puttu prepared even by incorporating 50 per cent grain amaranth flour with rice flour secured scores of above 3.0 for different quality attributes and overall acceptability indicating that amaranth grain could be incorporated to prepare highly acceptable puttu. Sarojini *et al.* (1996) developed acceptable dosa by incorporating amaranth grain flour in rice flour and black gram dhal and secured 3.8 for appearance, 3.9 for flavour, 3.9 for taste, 4.0 for texture and 3.2 for overall acceptability.

When the nutritive value of chapathi was computed there was an increase in the nutritive value with increase in the incorporation with amaranth flour. For chapathi an increase in all nutrients except carbohydrate was observed with an increase in the quantity of grain amaranth flour. The decrease in carbohydrate content of chapathi in different treatments is due to the lower carbohydrate content of grain amaranth flour (62%) when compared to wheat flour (69.4%).

In the present study, nutritive value of chapathi prepared exclusively with wheat flour was found to be 9.07g (protein), 8.77g (fat), 1.42g (fibre), 52.05g (carbohydrate), 36 mg (calcium) and 3.67 mg (iron) per serving which was found to be similar to the nutritive value of chapathi per serving reported by Pasricha (1989).

Nutritive value of biscuit was computed and it was seen that except carbohydrate all other nutrients increased with an increase in the quantity of grain amaranth flour. The decrease in the carbohydrate content noticed with an increase in the quantity of grain amaranth flour is due to the high carbohydrate content of maida (73.9 %) when compared to grain amaranth flour (62%).

Biscuits prepared with maida had 1.47 g protein, 5.52 g fat, 0.04 g fibre, 17.81 g carbohydrate, 4.02 mg calcium and 0.37 mg iron which were found to be almost similar to the nutritive value of biscuits per serving reported by Pasricha (1989). Pasricha and Rebello (1977) also indicated 6.8 g protein, 10.1 g fat, 58.1 g carbohydrate, 21 mg calcium and 3.9 mg iron for 100 g of sweet biscuits.

When nutritive value of puttu was computed, an increase in the nutritive value occurred when the quantity of amaranth flour was increased. There is an increase in all the nutrients except carbohydrates with an increase in the quantity of amaranth flour. The decrease in the carbohydrate is due to the lower carbohydrate content of grain amaranth flour when compared to rice flour (79 %). Nutritive value of puttu prepared exclusively with rice flour contained protein (4.1g), fat (8.52g), fibre (0.82g), carbohydrate (42.1g), calcium (6.13mg) and iron (0.84mg) which was in line with the nutritive value computed by Pasricha (1989) for rice puttu.

Summary

6. SUMMARY

The present study entitled "Standardization and quality evaluation of grain amaranth (*Amaranthus spp.*) flour supplemented food products" was undertaken with the aim of evaluating the quality of grain amaranth flour and to develop value added acceptable products with grain amaranth flour. Grain amaranth seeds were collected from Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara and the flour was prepared after sun drying.

Prepared grain amaranth flour was stored for a period of six months in glass bottles at ambient storage conditions. Quality evaluation of the flour with respect to chemical constituents and organoleptic qualities was conducted at three monthly intervals upto a period of six months. Microbial enumeration of flour with respect to bacteria, fungi and yeast was conducted at monthly intervals up to six months.

The moisture content of grain amaranth flour was found to be 16.66 per cent during initial period of storage. A gradual decrease in the moisture content was noticed during third month (13.53%) and then the moisture content increased to 17.46 per cent at the end of the storage period.

The protein content of amaranth flour was found to be 14.70 per cent and it decreased to 13.90 per cent at third month and to 12.49 per cent at sixth month of storage.

The starch content of grain amaranth flour was 62.2 g 100 g^{-1} during the initial period of storage. The starch content decreased upto 57.40 g 100 g^{-1} at the end of the storage period.

Initially, the fat content of amaranth flour was found to be 6.73 g 100 g^{-1}. After six months of storage a decrease in the fat content was observed in the flour and the content was found to be 5.79 g 100 g^{-1}.

The fibre content of amaranth flour was found to be 2.87 per cent. During storage the fibre content decreased to 2.61 per cent at third month and to 1.66 per cent at sixth month of storage.

Initially, the flour contained 187.16 mg calcium, 226 mg magnesium, 13.58 mg iron, 248.2 mg potassium and 315.68 mg phosphorus per 100 g of flour. All minerals gradually decreased with advancement of storage period.

The anti-nutritional content of the grain amaranth flour was found to be 1.23 mg 100 g^{-1} tannin and 0.53 mg 100 g^{-1} phytic acid. The content increased to 1.30 mg 100 g^{-1} and 0.58 mg 100 g^{-1} for tannin and phytic acid respectively at the end of storage period.

Initially, bacterial content of the amaranth flour was found to be 2.6 x 10^{6} cfu g^{-1}, which increased to 8.8 x 10^{6} cfu g^{-1} at the end of storage. The fungal count also increased from 1.8 x 10^{3} cfu g^{-1} to 5.8 x 10^{6} cfu g^{-1} during storage. Yeast count of the grain amaranth flour initially was 1.5 x 10^{3} cfu g^{-1} which increased to 5.3 x 10^{3} cfu g^{-1} during six months of storage.

With regard to the organoleptic evaluation of the flour, reduction in various quality attributes including overall acceptability was noticed during storage. Amaranth flour stored under ambient condition in glass bottles was found to be unacceptable after a storage period of six months due to the slight rancid flavour developed in the flour.

Three products namely chapathi, biscuit and puttu were prepared by substituting the main ingredients with amaranth flour at different proportions. The products prepared were evaluated for organoleptic qualities and nutritive value of the products was computed. Chapathi made exclusively with wheat flour was found to be acceptable than the chapathis made with wheat flour and grain amaranth flour at different proportions. However chapathi prepared even with 40 per cent substitution of amaranth flour obtained a score of above 3.0 for different quality attributes and overall acceptability.

Nutritive value of chapathi made with 100 per cent wheat flour contained protein (9.07 g), fat (8.77 g), fibre (1.42 g), carbohydrate (52.05 g), calcium (36 mg) and iron (3.67 mg). However, the nutrient content of chapathi made with wheat and amaranth flours contained high quantity of nutrients except carbohydrates than wheat flour chapathi. As the quantity of grain amaranth flour increased, an increase in the nutritive value of the products was seen.

On the basis of mean rank scores of biscuits, biscuits prepared with 100 per cent maida were most acceptable. Biscuits prepared with different proportions of amaranth flour also got scores above 3.0 for all quality attributes and overall acceptability. Hence, it can be concluded that acceptable biscuits could be prepared by substituting grain amaranth flour for maida even up to 50 per cent.

Biscuit prepared with 100 per cent maida contained 1.47g protein, 5.52 g fat, 0.04 g fibre, 17.81 g carbohydrate, 4.02 mg calcium and 0.37 mg iron per serving. But the biscuits prepared by substituting maida with amaranth flour at different proportions were found to be more nutritious than maida biscuits. As the percentage of amaranth flour increased, the nutritive value also increased except carbohydrates.

On the basis of ranking, puttu prepared with rice flour was most acceptable. On the other hand all the five treatments obtained a score above 3.0 for almost all the quality attributes and overall acceptability. Even though, grain amaranth flour is not much familiar to the judges, puttu prepared even with 50 per cent substitution of amaranth flour obtained high scores and hence could be considered as acceptable.

Nutritive value per serving of puttu prepared exclusively with rice flour was found to be 4.1 g (protein), 8.52 g (fat), 0.82 g (fibre), 42.1 g (carbohydrate), 6.13 mg (calcium) and 0.84 mg (iron). The nutrients except carbohydrate in the grain amaranth substituted puttu was found to be more.

Hence, it can be concluded that the nutrient rich grain amaranth flour can be incorporated to prepare acceptable and nutritious chapathi, biscuit and puttu. The challenge is to find ways to incorporate amaranth grain with existing food products, as well as to create new products from it. Future work can be conducted to develop shelf stable value added products like bakery and confectionery products, snacks, health foods, weaning foods, fermented products etc. Work can also be carried out to know the increase in nutritive value after subjecting grain amaranth with various processing techniques like popping, germination etc. Emphasis can be also given on bioavailability studies to find out the availability of nutrients and to popularise the developed value added products.

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* original not seen

Appendices

APPENDIX I

Score card for the organoleptic evaluation of grain amaranth flour

Sl. No.	Parameters	Scores						
1	**Appearance** Excellent Good Fair Poor Very poor	 5 4 3 2 1						
2	**Colour** Excellent Good Fair Poor Very poor	 5 4 3 2 1						
3	**Flavour** Excellent Good Fair Poor Very poor	 5 4 3 2 1						
4	**Texture** Excellent Good Fair Poor Very poor	 5 4 3 2 1						
5	**Taste** Excellent Good Fair Poor Very poor	 5 4 3 2 1						
6	**Overall acceptability** Excellent Good Fair Poor Very poor	 5 4 3 2 1						

Date:

Name and Signature:

APPENDIX II

Score card for the organoleptic evaluation of grain amaranth supplemented food products

Sl. No.	Parameters	Scores					
1	**Appearance** Excellent Good Fair Poor Very poor	 5 4 3 2 1					
2	**Colour** Excellent Good Fair Poor Very poor	 5 4 3 2 1					
3	**Flavour** Excellent Good Fair Poor Very poor	 5 4 3 2 1					
4	**Texture** Excellent Good Fair Poor Very poor	 5 4 3 2 1					
5	**Taste** Excellent Good Fair Poor Very poor	 5 4 3 2 1					
6	**Overall acceptability** Excellent Good Fair Poor Very poor	 5 4 3 2 1					

Date:

Name and Signature:

STANDARDIZATION AND QUALITY EVALUATION OF GRAIN AMARANTH (*Amaranthus* spp.) FLOUR SUPPLEMENTED FOOD PRODUCTS

By

NIDHI BHATIWADA

ABSTRACT OF THE THESIS

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ABSTARCT

Grain amaranth belonging to the family, Amaranthaceae is considered as an underexploited grain and suggested as a food for future having an important role in the human food system due to its easy cultivation and nutritional aspects. In the present study an attempt was made to estimate the quality of grain amaranth flour and to develop value added products using grain amaranth flour

Grain amaranth was collected from the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur and flour was prepared from the grains after sun drying. The prepared grain amaranth flour was stored for a period of six months and chemical constituents and organoleptic qualities was analysed initially, during third and sixth months of storage. The microbial load of the flour was also studied at monthly intervals for six months.

Amaranth flour was found to be rich in protein, starch, fibre and minerals like iron, calcium, magnesium, potassium and phosphorus and low in anti-nutritional factors such as tannin and phytic acid. The moisture, tannin and phytic acid contents increased whereas the protein, starch, fat, fibre, calcium, magnesium, iron, potassium and phosphorus contents decreased gradually with advancement of the storage period. A gradual increase in the bacteria, fungi and yeast count in amaranth flour was also observed with advancement of storage period.

The products like chapathi, biscuit and puttu were prepared by substituting grain amaranth flour for respective main ingredients namely wheat flour, maida and rice flour. The organoleptic evaluation of the products showed significant variation between treatments. Chapathi prepared by substituting wheat flour upto 30 per cent amaranth flour was found to be acceptable. However, biscuit and puttu prepared even upto 50 per cent substitution of grain amaranth flour with maida and rice flour respectively, obtained high organoleptic scores indicating that these products are also highly acceptable.

The result of the above study revealed that as the percentage of amaranth flour increased, nutritive value of the recipes also increased except carbohydrates. Therefore, products prepared by substituting main ingredient with amaranth flour at different proportions were found to be more nutritious than the prevailing food products.

One serving of amaranth supplemented recipes if incorporated in our diet will met 3.04 to 20.1 per cent protein, 28 to 53.3 per cent fat, 0.20 to 5.93 per cent of fibre, 4.46 to 13.5 per cent carbohydrates, 1.55 to 22 per cent calcium and 1.72 to 23.1 per cent iron requirement.

The study highlighted the significance of value added products from underutilised grain amaranth as a solution to the problems related to malnutrition.