

**STUDIES ON PHYSIOLOGICAL AND BIOCHEMICAL
CHANGES DURING LONG TERM STORAGE OF PADDY
AND RICE UNDER DIFFERENT PACKAGING MATERIALS**

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INTRODUCTION

Food storage is an important problem from the time mankind learnt to grow crops. Million tons of food grains are either damaged or lost due to inadequacy of scientific methods of storage. Post harvest losses of food grains in storage are very substantial and such losses thwart our attempt to boost agricultural production and maintain self-sufficiency in food grains. The primary cause leading to loss in quality and quantity of agricultural produce during its storage is due to presence of higher moisture content in the stocks at the time of storage cause sprouting, molding and heating. Various chemical changes take place during storage, which cause acidity, deterioration of gluten, vitamins, etc. Insects and rodents apart from eating away the produce, pollute it by contamination with their urine, excreta and carcass. Insects and mites eat away the germ portion of the grain rendering it unfit for germination and impart objectionable odor. These losses can be avoided by using modern techniques based on scientific storage (Anon., 2004).

With a population growth rate roughly estimated at two per cent a year, this translates into more than 18 million new mouths to be fed each year. If this rate of population growth continues with this pace, India will overtake China in population, but not in agricultural and industrial progress which is a matter of great concern. According to World Watch estimates, India may be importing 40 to 45 MT food grains by 2025. In view of stagnating productivity in the northern zone's rice-wheat cropping system due to declining productivity as well as the area devoted to non food crop cultivation, this statement should serve as a wake-up call to agricultural policy planners in government and industry. A better solution to this could be the safe storage of the existing stocks (Anon., 2004).

India produces about 250 million tons of food grains per year intended to feed the country's 1.2 billion people. Production has been steadily increasing due to advancement in production technology, but losses have remained static at 10 per cent. This means that the loss of food grains is also increasing with an increase in food production. The main reason for this is improper storage, leading to an average of 6 out of a total 10 per cent post harvest losses. Storage of food grains in India is done at different levels. The major portion is stored at farmers level and the root cause of massive storage loss lies here. The use of dryers and scientific storage practices, if followed, can reduce the loss by about 6 per cent and this will save Rs. 13,500 millions every year and make available an additional 9 million tons of grains to feed the population (Anon., 2005).

Selection of grain storage facilities and the management practices depend on the grain to be stored, local weather conditions and the availability of construction material and labour. The stored grain bulk is an ecological system in which deterioration results from interactions among physical, chemical and biological variables such as temperature, moisture content of the grains, relative humidity of the storage environment, microorganisms, insects, mites and rodents. More prominent variables among these are, the temperature of the grain mass, moisture content and relative humidity. A small increase in the atmospheric relative humidity above 70 –75 per cent results in large increase in the grain moisture content which deteriorates food grain quality to a large extent. The safe storage moisture content for long-term storage of cereals is in the range of 12 to 14 per cent.

Seed quality is a multiple concept comprising several physical, chemical and biological components. Seed being a biological or living entity, deterioration in its quality is inevitable, irreversible and inexorable. It occurs with an advance in ageing, which is common for all the living organisms. Seed deterioration is a phenomenon, which begins immediately after attaining physiological maturity even on the mother plant itself (Helmer *et al.*, 1962).

Paddy is the most important and extensively grown food crop in the world and is the staple food of more than 60 per cent of the world population. India has the largest area under paddy in the world and ranks second in production after China. Rice is primarily a high energy caloric food. The major part of rice consists of carbohydrate in the form of starch, which is about 72-75 per cent of the total grain composition. The protein content of rice is around 7 per cent, which is mainly glutelin, also known as oryzenin.

Rice stands second in the world after wheat in area and production. It occupies an area of 159.22 million ha with an annual production of 465.8 million tons, with a productivity of 4.36 tons/ha in the world. Asia produces and consumes 90 per cent of world's rice. Among the rice growing countries, India ranks first in area followed by China and Bangladesh. Rice is a major cereal crop of India occupying an area of 44.1 million ha and a production of 105.3 million tons with an average productivity is 3.58 tons/ha (Anon., 2013). In Karnataka, rice is cultivated in an area of 1.54 million ha

with an annual production of 4.19 million tons, with an average productivity of 2.72 tons/ha (Anon., 2011).

Storage of seeds till the next sowing season is an essential segment of seed industry. The knowledge of seed storability is also essential to avoid the huge financial losses due to non selling of the seeds and to carry over the seed stock for use in next season. Storage is a critical operation for rice, representing between 4 to 6 per cent of total post-harvest losses. In rice, upon storage, many enzymatic changes, oxidation and respiration occur. Thus, its nutritive value is lost because of chemical changes in starch, protein and lipid contents. If the viability and vigour is not maintained properly during storage period, it will be difficult to sell it as a seed material for the next season. Post harvest storage life of rice largely depends on the genotypes, production conditions, mechanical injury to the seed, initial seed quality, seed treatment, packaging material and storage conditions.

Seed storage is an essential segment of seed industry. In storage, viability and vigour of the seeds is regulated by many physico-chemical factors like moisture content of the seed, atmospheric humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure and packaging materials. As the seed is hygroscopic in nature, seed quality is affected by variation in moisture content, relative humidity and temperature. To combat these factors, it is better to store the seeds in moisture vapour proof containers like polythene bags, aluminium foil, tin or any sealed container to maintain the quality for longer period.

Vacuum packaging is the simplest and the most common means of modifying the internal gaseous atmosphere in a pack. The product is placed in a pack made from film of low oxygen permeability. Air is evacuated and the package is sealed. An evacuated pack collapse around the product so that the pressure inside is seldom much less than atmosphere (Kothari and Jadhav, 1998). Thus to increase post harvest storage life of paddy and rice, the present investigation is taken up with the following objectives.

1. To study the physiological and biochemical changes in seeds during long term storage in different packaging materials
2. To study the seed quality attributes during long term storage under different packaging materials
3. To explore the reasons for maintaining quality or deterioration, if any, due to different packaging materials

REVIEW OF LITERATURE

A conceptual frame work for the study based on the ideas and concepts gathered from review work of existing literature of both theoretical and empirical nature will facilitate planning the study in a systematic manner and a critical comprehensive review of literature is inevitable for any scientific investigation. As storage period increases, the seed deteriorates and loses its quality rapidly. Maintenance of viability and vigour of seed is very important and research on this aspect is of prime importance. A brief research work carried out on physiological and biochemical changes during long term storage of paddy and rice in different packaging materials stored under both ambient and cold storage has been presented in this chapter. Since limited reviews are available on these aspects and hence, the reviews of other related crops are also included.

2.1 STORAGE ENVIRONMENT

A controlled atmosphere is essential for safe and long term storage of seeds. Environmental conditions which are safe for storage from harvest to planting are not necessarily safe for longer periods. Hence, controlled storage is very essential especially in tropical and subtropical conditions to maintain high viability of seeds for longer periods.

2.1.1 Ambient Storage

Agarwal (1974) observed a reduction in shoot length and root length along with the reduction in germination per cent in maize seeds under both room temperature and cold storage after a period of 11 months.

Halder and Gupta (1980) observed that while sunflower seeds deteriorated completely within 90 days when seeds were stored at 28 ± 1 °C and 95 per cent relative humidity, but seeds were viable for 120 days when stored at 80 per cent relative humidity.

Fonesca *et al.* (1980) reported that bean seeds stored under ambient conditions (16-30 °C and 30% RH) deteriorated at faster rate and resulted in lower germination and seedling vigour index when compared to seeds stored in controlled conditions up to 27 months. Saibabu *et al.* (1983) observed drastic decline in germination of paddy seeds containing 13-15 per cent moisture in polythene bags between 10 and 12 months of storage. Further, they reported that the rain damaged seeds of rice (IET-5854) and maintained germination above certification standard for eight months, when stored in cloth bags under ambient conditions with 12 per cent initial seed moisture content.

Saxena *et al.* (1987) stored the seeds of onion, cabbage, radish, cauliflower, okra and peas in impervious and pervious container at room temperature for 24 months. They observed decrease in germination, root length; shoot length and vigour index with an increase in storage period and the decrease was greater in the seeds stored in cloth bags and least in polythene bags.

Nakagawa *et al.* (1991) reported that okra seed quality was better after storage period of 24 months under ambient conditions as compared to dry chamber storage. Similarly, Morena *et al.* (1994) recorded the maximum germination (74-98%) in pea seeds when stored for six months at 25 °C and 75 per cent relative humidity, while the seeds stored at 25 °C and 85 per cent relative humidity recorded 10-68 per cent germination after two months of storage.

Dayan (1997) found that temperature and moisture content of the seed are major factors in determining viability during storage. Seeds that can be stored in a state of low moisture content (1-8%) and at low temperature are called orthodox and their viability under certain storage conditions conform to some general rules *i.e.* for each 1 per cent decrease in seed moisture content, the storage life of the seed is doubled. For each 5.6 °C decrease in storage temperature, the storage life of the seed is doubled.

Kumari *et al.* (2001) reported that onion cultivars Hisar and N-53 were retained higher germinability over certification standards (77.0% and 87.5%) in ambient conditions in cloth bags up to eight and four months of storage, respectively. Dejene (2004) reported that sorghum seeds stored in warm temperature with high relative humidity, reduced seed viability due to increased degree of invasion by seed-borne or storage fungi.

2.1.2 Cold storage

Singh and Setia (1974) reported that germination of soybean seeds kept in the cold storage was much higher than those kept at room temperature. Seeds kept under room temperature lost viability completely at 12 months after storage.

Ellis *et al.* (1991) reported that when two batches of onion seeds one good quality (initial germination 85%) and another poor quality (initial germination 70%) were dried to a moisture content of 6.0 - 6.8 per cent (dry treatment) or 3.6-3.7 (ultra dry treatment) and stored at low (2.0 to 20 °C) temperature, showed that the low temperature storage maintained the original germination percentage more than 3 years, while 70 per cent germination declined over period of trial, with the ultra dry seeds.

Gao-ping ping *et al.* (1996) reported that stored seeds of five soybean varieties at - 4, 0, 4 °C and at room temperature for 8 years to determine their retention capacity of vigour. They found that the seeds stored at room temperature showed faster decline in vigour as compared to the seeds stored at lower temperature throughout the storage period. Similarly, pea seeds stored at 10 °C and 50 per cent relative humidity remained viable for five years but when stored at sub zero temperature (- 20 °C) remained viable for 33 years (James *et al.*, 1967).

2.2 CAUSES OF SEED DETERIORATION

Delouche *et al.* (1973) defined seed deterioration as summation of all physical, physiological and biochemical changes occurring in a seed which ultimately lead to its death. They also characterized seed deterioration as inexorable, irreversible, inevitable, minimal at the time of physiological maturity and variable among the seed kinds, varieties, between seed lots of same variety and among individual seeds.

Copeland (1988) highlighted the consequences of deteriorative changes in seed which include membrane degradation, accumulation of toxic metabolites, decreased enzymatic activity, lipid auto-oxidation, failure of repair mechanism, genetic degradation, reduced yield, finally loss of germination or death.

Many researchers agreed that the seed deterioration is a progressive process which has far reaching consequences. Generally, seed viability and vigour are maximum at the time of physiological maturity. After physiological maturity, seeds begin to deteriorate at varying rates depending on the conditions of storage environment. During seed deterioration including controlled deterioration, the root apical meristem was the first tissue to be damaged restricting longitudinal root growth (Argerich *et al.*, 1989).

Seed deterioration is loss of seed quality, viability and vigour due to effect of adverse environmental factors (Kapoor *et al.*, 2010). Deteriorative changes enhance when seed exposure to external challenges increases and decrease the ability of the seed to survive. It is an undesirable attribute of agriculture. Annual losses due to deterioration can be as much as 25 per cent of the harvested crop. It is one of the basic reasons for low productivity (Shelar *et al.*, 2008).

Deterioration is evident as a decrease in percentage germination, while those seeds that germinate produce weak seedlings. Losses in seed quality occur during field weathering, harvesting and storage (Farhadi *et al.*, 2012). Some of the major physiological and biochemical events during seed deterioration are presented below:

2.2.1 Biochemical manifestation of seed deterioration

Seed deterioration is associated with various cellular, metabolic and chemical alterations including chromosome aberrations and damage to the DNA, impairment of RNA and protein synthesis, changes in the enzymes and food reserves and loss of membrane integrity (Kibinza *et al.*, 2006).

2.2.2 Membrane degradation

Koostra and Harrington (1969) reported that decline in phospholipids owing to their oxidation may be the cause of leaky cell membranes. Damage to cellular membranes and other essential organelles by auto-oxidation are presumed as one of the possible reasons for seed senescence (Saha *et al.*, 1990).

Srivastava and Gill (1975) revealed that increase in electrical conductivity of seed leachates, increased the seed deterioration. Similarly, Krishnaveni and Ramasamy (1985) reported that the electrical conductivity and the leaching of free amino acids and sugars significantly increased with an increase in storage periods of maize seeds, which was ascribed to the membrane deterioration.

Vieira *et al.* (1999) reported that decline in seed germination, field emergence and seedling vigour was found to be negatively correlated with greater electrolyte leakage in soybean. Peroxidation of unsaturated fatty acids of biomembrane leads to leaching of electrolytes and other solutes in soybean. Membrane disruption is one of the primary reasons attributed to seed deterioration. As a result, seed cells are not capable to hold their normal physical condition and function. Causes of membrane disruption are enhancing the free fatty acid level and free radicals productivity by lipid peroxidation (Ghassemi-Golezani *et al.*, 2010).

Malik and Jyoti (2013) reported that during seed deterioration, membrane degradation increase electrolyte leakage. Decline in seed germination, field emergence and seedling vigour is associated with high level of electrolytes leakage. Alterations of membrane systems, such as the tonoplast, plasma lemma and endoplasmic reticulum, result in diminishing of normal cell function and energy production. Membrane deterioration and loss of permeability occur at an early stage during the seed deterioration.

2.2.3 Free radical damage

A free radical is an atom or group of atoms with an unpaired electron, which posses the ability of donating or receiving an atom. The hydroxyl ($-OH$) and super oxide (O^{-2}) are the two most important radicals believed to cause most damaging biological action. The free radical damage is an important aspect of seed deterioration and has a close relationship between the loss of vigour and viability of seeds (Basu *et al.*, 1975).

Hendry (1993) reviewed the role of oxygen and free radical generation on seed longevity and presented evidence that supported the role of oxygen in favoring the free radical hypothesis.

The free radicals are unstable and may react with and damage nearby molecules. Stored seed subjected to lipid peroxidation showed consistant attack by oxygen, forming hydro peroxides, other oxygenated fatty acids and free radicals, which are unstable and may react with and damage nearby molecules. The total amount of oxygenated fatty acid generated would be proportional to the age of seed (Wilson and McDonald, 1986).

2.2.4 Enzymes alterations

Francis and Coolbear (1988) reported that the accumulation of phospholipase activity in aged tomato seeds, acts on membrane phospholipids and release fatty acids, indicating the loss of membrane phospholipids and subsequent lipid peroxidation. Decreased peroxidase activity was observed due to natural ageing. During deterioration, marked changes in the content and activity of certain respiratory enzymes such as catalase, peroxidase, dehydrogenase, cytochrome oxidase and glutamic acid decarboxylase were noticed with decline in viability (Chauhan *et al.*, 1984). Association of loss of viability with enzymatic activity was reported in wheat (Bhattacharya and Mandi, 1985).

Malik and Jyoti (2013) reported the enzyme alterations, such as reduced activity of lipase, ribonuclease, acid phosphatase, protease, diastase, catalase, peroxidase and amylase, DNase and dehydrogenase enzymes, resulting in the production of reactive oxygen species and hydrogen peroxides from several metabolic reactions and could be destroyed by the activity of scavenger enzymes like catalase and peroxidases. Peroxidase activity decreases substantially with ageing due to which seeds become more sensitive to the effects of oxygen and free radicals in membrane unsaturated fatty acids and produce lipid peroxidation products such as monaldehyde and lipid conjugants.

2.2.5 Changes in chemical constituents

John (1983) reported that seed deterioration is due to decomposition of protein and lipids leading to decreased seed germination and seedling vigour or death of seeds. Seed viability has been related to chemical composition and storage food reserves. He classified protein rich seeds as good, starch rich seeds as medium and oilseeds as poor storers under ambient storage condition. In deteriorate seeds, significant decrease in protein, oil content and total sugars and increase in free fatty acids and reducing sugars has been noticed. Verma *et al.* (2003) showed that carbohydrates increased with decrease in protein content in deteriorated seeds.

2.3 EFFECT OF PACKAGING ON SEED QUALITY

Seed storage is an integral part of seed production programme. Seeds of many field crops are produced with greater care and cost. Hence, a good storage is essential to keep them alive and vigorous until required for subsequent sowing season. Seed is said to be in storage in various stages from harvest to sowing. Further, the left over seeds are to be stored without appreciable decline in quality in order to meet the further demand. Generally, seeds stored in moisture impervious sealed containers store better compared to moisture pervious containers under ambient storage as well as cold storage conditions.

The packaging materials used are decided by kind and quantity of seed to be packed, the type of package, duration of storage, storage temperature and relative humidity of the storage area, etc.

Nagarajan and karivaratharaju (1976) reported that the rate of deterioration in viability and increase in the moisture content of the seeds stored in moisture pervious containers were more than the seeds stored in moisture vapour proof containers. A significant negative correlation was observed between seed moisture content and the viability in sorghum, bajra and maize seeds. Similarly, Selvaraj and Ramaswamy (1978) observed the slow reduction in germinability of cotton seeds stored at room temperature in polythene bags.

Saibabu *et al.* (1983) found that seeds stored in moisture impervious containers (polythene bags) maintained viability longer than seeds stored in moisture pervious containers (cloth and jute bags). Storage studies in hybrid rice and their parental lines revealed that polythene bags proved better in maintaining viability and vigour compared to cloth bags (Yogalakshmi, 1995).

Kurdikeri *et al.* (1995) reported that the maize seeds stored in polythene bags were found to maintain viability for greater period (13 months) compared to cloth bags (7 months). The fluctuation in moisture content of seeds stored in polythene bags was less as compared to seeds stored in cloth bags.

Angamuthu (1996) observed that moisture pervious containers, viz., cloth bags, gunny bags, mud-pot maintained the seed germinability of 80 per cent in all the lines and hybrid seeds of rice for nine months, whereas, the moisture resistant containers, viz., polythene bags (300 and 700 gauge) and polylined gunny bags maintained the standard germinability for a period of 12 months without seed treatment. Similarly, Thungeswara (1996) also observed the superiority of polythene bags over cloth bags in storage of rice hybrids and their parental lines.

Ankaiah *et al.* (2006) reported that germination and seedling vigour were significantly higher in seeds stored in moisture impervious containers when compared to moisture pervious containers throughout the storage period. In cloth bags, viability in terms of germination was up to 8 months only. Seeds stored in polythene bags could maintain 70 per cent germination up to 18 months, while the seed stored in paper bags and poly pouch retained viability above Minimum Seed Certification Standard (MSCS) up to one year in sunflower.

2.3.1 Vacuum packaging

Vacuum packaging and gas flushing are techniques adopted for the purpose of prevention of food spoilage by oxidation. Elimination of oxygen from the pack therefore helps in extending the shelf life of the products. These methods are effectively utilized for packaging processed food products such as tea, coffee, cheese, snack foods, nuts, etc. (Narayanan and Dordi, 1998).

Nunez *et al.* (1986) reported that anaerobic environment of vacuum packaging prevents the growth of spoilage microorganism's especially aerobic ones which are responsible for off odor, slime and texture changes. Tao (1989) reviewed the literature and concluded that the benefit from vacuum storage is limited and variable. Hence, it should not be used for conservation by multi-crop gene banks.

Many properties of foods such as microbiological status, insect infestation and chemical degradation such as rancidity, pigment or nutrient loss and browning and physiological changes such as, respiration are influenced by oxygen level in the headspace of the packaging materials. Removal of oxygen from the headspace has long been a target and this has manifested in the development of technologies such as, vacuum packaging and inert gas flushing (Singhal and Kulkarni, 1998).

Vacuum packaging is removing air from the product pouch and hermetically sealing it. This increases storage or shelf life by inhibiting the growth of microorganisms and improves hygiene by reducing the danger of cross contamination. It also preserves flavour and protects against dehydration and weight loss (Anon., 2006a).

Oxidation of food ingredients like vitamins, pigments and aroma compounds is one of the most important causes of quality loss during food processing and is the main deteriorative reaction in microbiologically safe foods like dry and frozen products (Anderson and Lingnert, 1997). McDonald (1999) suggested that eliminating O₂ from the seed storage atmosphere might decrease the initiation of free radicals, which should extend seed longevity by reducing lipid peroxidation and generation of additional damaging compounds.

Rao and Sastry (2002) stored sorghum and bajra seeds of 6, 10 and 14 per cent moisture content in hermetically sealed aluminum foil envelopes containing air or vacuum at 35 °C and 50 °C. They found that there was a gradual loss in germination rate under all storage conditions. Seeds stored at higher temperature of 50°C and high moisture content (14%) deteriorated faster than with other treatments. Pearlmillet seeds survived longer than sorghum under similar conditions of storage. Seeds dried to 6 per cent moisture content retained viability longer than those stored at 10 and 14 per cent. Vacuum packing further enhanced seed longevity at 6 per cent moisture content but not at 10 or 14 per cent moisture content.

Guberac *et al.* (2003) stored seeds of four species (winter wheat, winter barley, spring oat and maize) in hermetic glass containers at an air temperature of 20 °C and relative humidity of 65 per cent. The germination level decreased for all cereals, on an average by 38 per cent, over the 5 years of storage.

Chiu *et al.* (2003) reported the effects of partial vacuum storage on longevity and free radical processing systems of primed sweet corn seeds and vacuum-packed it and stored at 25 °C up to 12 months. The longevity of 15 °C primed seeds showed higher viability and vigour than non-primed control seeds, when they were stored under non-vacuum conditions. The improved longevity was related to the decreased free radicals-mediated peroxidative responses.

Ellis and Hong (2007) studied the effect of hermetic or open storage on the sensitivity of timothy (*Phleum pratense* L.) and sesame (*Sesamum indicum* L.) longevity in relation to moisture content. They concluded that the deleterious effect of oxygen on seed longevity increases as seed moisture content decreases and confirmed that hermetic packaging is preferable for long term seed storage.

2.3.2 Influence of vacuum packaging on seed quality

Steinbuch (1980) studied the quality retention of unblanched frozen vegetables by vacuum packaging in asparagus, parsley and celery. Results indicated the favourable effect of vacuum packaging on quality retention, resulting in a long shelf life. Vacuum packing did contribute to a prolonged maintenance of original flavour of parsley leaves.

Rouziere (1986) stored three peanut varieties using high vacuum or nitrogen – compensated vacuum packaging for 18 months at 6 °C and at room temperature. He found no changes in physico-chemical properties under nitrogen compensated vacuum storage at room temperature.

Paakkonen *et al.* (1989) studied the effect of drying method, packaging and storage temperatures and time on the quality of dill (*Anethum graveolens* L.) and concluded that freeze dried dill was better preserved in vacuum packages at room temperature compared to glass jars and paper bags and was found to have higher intensity of odour and taste.

Severini *et al.* (2003) reported the auto oxidation of packed roasted almonds as affected by two packaging films and found that vacuum conditions were necessary for the successful preservation of roasted almonds, but the effectiveness of vacuum was apparent only if it is combined with a good oxygen barrier provided by the selected packaging film.

Dull and Kays (1988) studied the quality and mechanical stability of pecan kernel (*Carya illinonensis* (Koch.) under different packaging protocols and found that vacuum packaging maintained colour and greatly reduced the mechanical damage in pecan kernels. Loosely packed pecans were more susceptible to extensive fracturing of the kernel halves than vacuum packed pecans.

Achour *et al.* (2003) studied the effect of vacuum and modified atmosphere packaging on the storage of date palm and found decreased dehydration during storage under both the conditions. For

natural dates stored at less than 20°C, the application of partial vacuum packaging increased shelf life from 3.8 to 9 months compared to simple sealing.

2.3.3 Effects of vacuum Packaging on quality of other agricultural produce

Vacuum packaging of unbalanced frozen vegetables had a favourable effect, resulting in a longer shelf life of the produce. Vacuum packaging also contributed to a prolonged maintenance of original flavour of the leaves of herbs. Both the flavour and colour of the sliced celeriac was preserved by vacuum packing for one month (Steinbuch, 1980).

Sheikh *et al.* (1985) reported that vacuum and nitrogen gas replacement treatments in packaging of peanuts inhibited rancidity development. They also reported that the use of free oxygen absorbers produced anaerobic conditions for about 90 days and thus inhibited fungal growth and rancidity.

Storage trials conducted on shelled groundnut seeds by Rouziere (1986) revealed that no changes in physico-chemical properties occurred during high vacuum storage at any temperature or in technological quality of peanuts during nitrogen compensated vacuum storage at ambient temperature, over a period of 18 months.

Beirne and Alison (1987) also reported that enzymatic discolouration in potato strips could be reduced considerably by vacuum packaging with dipping in ascorbic acid based antioxidant solutions and storing at 5°C. Vacuum packaged strips had retained excellent colour for at least 14 days either without antioxidant or with 1 per cent or 5 per cent ascorbic acid.

Ada *et al.* (2003) studied the physical qualities of minimally processed potatoes (Desiree variety) stored for 7 days under vacuum packaging. It was reported that the main quality parameters were constant during storage and the shelf life of potatoes could be effectively extended to nearly one week under refrigerated storage by using vacuum packaging systems.

Sharma *et al.* (2006) monitored the quality changes of deep fat fried cashew kernels under vacuum packaging with respect to chemical parameters like peroxide value, free fatty acid content, thiobarbituric acid value, total carbonyls and fatty acid profile. Vacuum packaging of fried cashew kernels treated with antioxygenic salt extended the shelf life and acceptability up to one year, irrespective of frying medium under ambient conditions.

2.4 SEED MYCOFLORA

Seed pathologists strongly believe that seeds lose viability mainly due to invasion of fungi during storage which cause substantial decline in seed quality and quantity. However, their role in causing loss of seed viability was considered debatable until recently. Several deleterious effects on seed quality *viz.*, reduction in germination, discolouration, health hazards *etc.* have been reported (Barton, 1961 and Christensen, 1976).

Christensen and Kauffmann (1969) reported that even under limited moisture conditions where fungi and other microorganisms cannot grow, storage fungi adversely affect the seed by bringing down the seed viability, seedling vigour and also affect the chemical composition of seeds.

Under good vacuum condition, the oxygen level is reduced to less than 1 per cent and due to the barrier properties of the film used; entry of oxygen from outside is restricted. Commercial vacuum systems used on production lines do not reach absolute vacuum and there is always some residual oxygen present (0.3 – 3 per cent after sealing). Hence, the gaseous atmosphere of the vacuum package is likely to change during storage (owing to microbial and product metabolism and gas permeation) and therefore, the atmosphere becomes modified. The growth of aerobic microorganisms is supported by oxygen, thus removal of oxygen from the modified atmosphere has been shown to extend the microbiological shelf life (Sanjeev and Ramesh, 2006).

Saxena and Karan (1991) observed that gradual loss of protein and carbohydrate content of sesame and sunflower seeds due to *A. flavus* and *A. niger* during storage. Krishnamurthy and Raveesha (1996) identified 38 species of fungi in cultivars of soybean. Among them, *Aspergillus*, *Penicillium*, *Rhizopus* and *Nigricans* were most commonly occurring storage fungi which reduce seed germination and seedling vigour and cause a variety of symptoms on seedling.

Savitri *et al.* (1998) recorded 203 fungal colonies per 100 seeds in groundnut stored in cloth bags and storage fungi such as *Aspergillus flavus*; *A. niger*, *Rhizopus stolonizer*, *Rhizoctonia bataticola* and *Fusarium moniliforme* were found to be predominant in storage.

Krishnappa *et al.* (2003) reported that groundnut pods stored in gunny bags had recorded maximum fungal infection (18.3 per cent in JL-24 and 16.17 per cent in TMV-2 which caused reduction in germination and vigour index. Somda *et al.* (2008) reported that seed born pathogen in maize reduced the seed germination and also noticed the transmission of seed mycoflora from seed to seedlings. The metabolic activities of isolated fungi in the stored products may cause decay of agricultural produce thereby reducing their market and nutritional value (Amusa *et al.*, 2002).

The fungi that invade stored product are generally grouped into two categories *viz.*, field fungi which attack developing and matured seeds in the field and storage fungi which are predominantly species of *Aspergillus* and *Penicillium* which attack the stored products (Fagbohun *et al.*, 2010)

Najibullah and Muhammad (2011) studied the effect of seed mycoflora on maize seeds for a period of six months and revealed that there was decrease in association of field fungi, whereas, storage fungi increased during the storage period. This leads to reduction in germination, vigour index and also resulted in more abnormal seedlings and dead (rotted) seeds.

2.5 SENSORY EVALUATION

Sensory quality is a combination of different senses of perception coming into play in choosing and eating a food. Appearance, flavor, colour, texture, taste and mouth feel decide the acceptance of the food. Sensory analysis of food relies upon evaluation through the use of our senses (odour, taste, tactile, temperature, *etc.*). Only by applying exact scientific testing methods reproducible results can be obtained and analysed statistically. Scientific methods of sensory analysis of foods are becoming increasingly important in assessing the acceptability of food products (Jellinek and Horwood, 1985).

Quality is the ultimate criterion of the desirability of any food product. Food quality can be evaluated by sensory and objective methods. When the quality of a food product is assessed by means of human sensory organs, the evaluation is said to be sensory or subjective or organoleptic or psychometric. Every time food is eaten, a judgment is made (Srilakshmi, 1996).

2.6 SEED QUALITY PARAMETERS

2.6.1 Germination and seedling vigour index

Ader (1978) stored seeds of lettuce and carrot in different containers like paper bags, polythene bags and air tight glass jars and the experimental results showed that, there was no loss of germination in both the crop seeds, stored in airtight glass jars up to 7 years, but it was reduced in paper bags drastically followed by polythene bags. While, Radhakrishna (1982) reported that soybean seeds stored in airtight glass containers maintained 40 per cent germination during 4th month of storage, while in gunny or polyethylene bags maintained viability for only 2 months.

Siddalingappa (1991) observed better germinability of paddy seeds stored in polythene bags as compared to the seeds stored in cloth bags throughout the storage period. Angamuthu (1996) observed that moisture pervious containers *viz.*, cloth bags, gunny bags and mud-pot maintained the seed germinability of 80 per cent in all the lines and hybrids of rice for 9 months; whereas, the moisture resistant containers *viz.*, polythene bags (300 and 700 gauge) and polylined gunny bags maintained the minimum seed certification standards germinability for a period of 12 months without seed treatment.

Biradar (2001) recorded significantly higher seedling vigour and germination (1508 and 83.9%) in greengram seeds stored in polythene bags compared to those stored in cloth bags (1428 and 79.8%), respectively at the end of 12 months period.

Ankaiah *et al.* (2006) found that germination and seedling vigour were significantly higher in seeds stored in moisture impervious containers when compared to moisture pervious containers throughout the storage period. In cloth bags, viability in terms of germination was up to 8 months only. Seeds stored in polythene bags maintained 70 per cent germination up to 18 months, while the seeds stored in paper bags and polypouches retained viability above minimum seed certification standard (MSCS) up to one year in sunflower

Pham and Ramegowda (2007) observed that hybrid rice germination and seedling vigour was decreased more in cloth bags (83 to 62%) and (552 to 264) compared to polythene bags (84 to 66%) and (564 to 2970) after 10 months of storage.

Biradarpatil and Shekhargouda (2007) reported that hybrid rice seeds stored in polythene bags recorded higher germinability and seedling vigour (83.9%) and (2281 to 1363) throughout the storage period compared to cloth bags (79.8%) and (2280 to 1080) after 12 months of storage.

Ramanadane and Rettinassababady (2008) studied the evaluation of different packaging materials for safe storage of paddy seeds and found that germination per cent decreased more in cloth bags (98 to 69%) compared to HDPE (98 to 77%), poly lined cloth bags (98 to 83%) and superbags (98 to 87%), respectively after six months of storage.

Alam and Hasanuzzaman (2009) studied the performance of alternate storage devices on seed quality of boro rice and found that germination per cent of boro rice seeds was significantly higher (91%) to that of rexin cocoon (87%), polythene bags (80%), polythene with gunny bags (79.66%) and gunny bags (68%) compared to stored in organic cocoon. Seeds stored in an organic cocoon performed better in maintaining higher germination due to lower moisture content (12.1%), which was below the critical level (14%) and reduced oxygen level (4.9%).

Barua *et al.* (2009) studied that the effect of storage containers and storage environment at different storage period on the quality of chilli seed and found that the initial germination percentage of seeds in tin container, polythene and cloth bags seeds was 72.55 per cent, 76.76 per cent and 62.10 per cent respectively, but after 12 months of storage it declined to 62.25 per cent, 63.11 per cent and 55.54 per cent, respectively.

Raikar *et al.* (2011) reported that storability of scented rice seeds stored in polyethylene bags maintained higher seedling vigour index and seed viability as per seed certification standards for more than 20 months compared to seeds stored in cloth bags.

Asha (2012) reported that maize seeds stored in vacuum sealed bags recorded significantly higher germination (97.0%) and seedling vigour index (4283) followed by polythene bags (96.09%) and (4175). Minimum germination was observed in cloth bags (95.2%) and (4128) at 6th month of storage and 5th months of storage, respectively. Germination as per the minimum seed certification standards (90%) was maintained up to 14 months in vacuum packaging, 11 months in polythene bags and 9 months in cloth bags.

Monira *et al.* (2012) reported that germination rate of soybean seeds varied widely due to different moisture contents of containers. It was observed that germination rate was almost similar at initial stage and decreased with increase of storage period. After storage, the germination rate was better in seeds of tin (87.3%) and polythene bags (84.7%) compared to that of cloth bags (68.5%).

2.6.2 Seedling length and dry weight

Biradarpatil (1999) reported that rice seeds stored in polythene bags recorded higher shoot length (7.79 cm), root length (8.44 cm), seedling length (16.23 cm) and dry weight of seedlings (122.9 mg) while, these were 6.37 cm, 6.94 cm, 13.31 cm and 109.3 mg, respectively in cloth bags at the end of 12 months of storage period.

Tammanagouda (2002) revealed significantly higher root length (11.14 cm), shoot length (8.11 cm) and total seedling length (19.25 cm) in the green gram seeds stored in polythene bags as compared to seeds stored in cloth bags at the end of 10 months of storage period.

Pham and Ramegowda (2007) observed that seedling dry weight decreased (6.65 to 4.25 mg) in cloth bags compared to polythene bags (6.72 to 4.50 mg) after 10 months of storage in hybrid rice.

Biradarpatil and Shekhargouda (2007) reported that seeds stored in polythene bags recorded higher seedling dry weight (157.6 mg) throughout the storage period compared to cloth bags (156.9 mg) after 12 months of storage and observed that decrease in seedling dry weight was more in cloth bags (156.9 to 109.3 mg) compared to polythene bags (157.6 to 122.9 mg).

Monira *et al.* (2012) reported that in soybean, the initial root and shoot length of seeds stored in tin container, polythene and cloth bags were 15.04 and 13.3; 10.95 and 12.60 cm; and 8.24 cm and 11.15 cm, respectively; but decreased with increasing storage time. Decreasing rate was higher in seeds of cloth bags and also observed the initial root and shoot dry weight of seeds in tin container, polythene and cloth bags were 11.84, 10.56 and 9.59 mg, but it decreased with increasing storage time. The decreasing rate was higher in seeds of cloth bags compared to tin container and polythene bags. Asha (2012) studied the dry weight of maize seedlings from 4 months to till the end of storage period of 14 months and reported that after 4 months of storage, it was significantly higher (2.32 g)

with vacuum containers and minimum (2.25 g) with cloth bags. Seeds stored in vacuum sealed containers recorded significantly higher (1.88 g) seedling dry weight compared to polythene bags (1.79 g) and was minimum (1.63 g) in cloth bags at the end of the storage period.

2.6.3 Electrical conductivity

Storing seeds in polythene bags recorded significantly lower electrical conductivity especially during later stages of seed storage (10-12 months) indicating better seed quality with polythene bags as compared to cloth bags. Similar observations of increased electrical conductivity with an increase in storage period and more in cloth bags than in polythene bags were made in sorghum, maize and bajra by Nagarajan and Karivaratharaju (1976), Krishnaveni and Ramaswamy (1985) and Bharathi (1991) in maize.

Rice stored in cloth bags deteriorated more with higher electrical conductivity than those stored in paper, aluminium foil, polythene laminated bags (Sivasubramanian and Karivaratharaju, 1990). While, Biradarpatil (1999) found that rice seeds stored in polythene bags recorded lower electrical conductivity (293.6 $\mu\text{mhos/cm}$) and the higher electrical conductivity (305.8 $\mu\text{mhos/cm}$) in cloth bags at 12 months of storage period.

Thoithoi Singh *et al.* (2001) reported that rate of electrolyte leakage from seeds leachate is influenced by the type of paddy cultivars, associated fungal species and storage period. Among four rice cultivars, RCM-5 was more resistant to leakage of electrolytes which showed the lowest electrical conductivity values both in treated and untreated seeds throughout the storage period.

Tammanagouda (2002) observed that greengram seeds stored in polythene bags recorded lower electrical conductivity with increased germination and seedling length at the end of 10 months of storage. While, Ravi Hunje *et al.* (2007) reported significant differences in electrical conductivity of chilli seeds leachates due to containers throughout the storage period. Aluminium foil recorded lower electrical conductivity (0.813 dS m^{-1}) followed by polythene bags (0.876 dS m^{-1}) over cloth bags (0.885 dS m^{-1}) at the end of storage period.

Raikar *et al.* (2011) reported scented rice seeds stored in polyethylene bags maintained low electrical conductivity and high seed viability as per seed certification standards for more than 20 months compared to seeds stored in cloth bags.

Asha (2012) reported the electrical conductivity is significantly influenced by containers throughout the storage period. After 3rd month of storage in vacuum recorded significantly lower (0.232 dS m^{-1}) and higher in cloth bags (0.271 dS m^{-1}). The seeds stored in vacuum sealed container recorded lower (0.315 dS m^{-1}) electrical conductivity as compared to polythene bags (0.420 dS m^{-1}) and in cloth bags it was higher (0.857 dS m^{-1}) at the end of 14 months of storage.

2.6.4 Microbial Load

Ranjan *et al.* (1992) investigated fungal infection in four different storage structures viz; gunny bags, mora, kothi and iron bin. Infection of *Aspergillus flavus* was higher in gunny bags (36%) followed by kothi (29%), mora (21%) and iron bins (17%). According to Reed *et al.* (1992), there was 8 to 40 per cent increase in mold count in maize seeds with 15-18 per cent moisture stored in uninsulated drums at 25 °C up to two months.

Mohamed *et al.* (1996) studied the physico-chemical changes in chiku during storage at various temperatures and the effect of various techniques of modified atmospheric packaging at 5, 10, 15 °C and ambient temperature. It was observed that proportion of chiku spoiled by fungi increased with increasing temperature and duration of storage. The treatment which resulted in minimum pathogenic spoilage was vacuum packaging in low density polyethylene (LDPE), while control fruits had the most fungal spoilage. Fruits sealed in LDPE were found to have higher CO₂ which retarded fungal growth

Sidik (2000) studied on the quality changes of stored rice under vacuum conditions and revealed that rice was infected by various species of storage fungi at the beginning of the study. The percentage of fungal infection declined significantly after 2 months in the inside storage and 6 months in the outside storage. There was no fungal infection after 10 months of storage, which showed that the low oxygen level and low moisture content was unsuitable for fungal survival and also found that fungal infection was initially 100 per cent, which declined to 40 per cent inside after 6 months of storage and to 40 per cent outside after 8 months storage.

A study conducted by Malaker *et al.* (2008) revealed that among five storage structures, refrigerator appeared to be the best to store wheat seeds as compared to dole (bamboo made), earthen pitcher, tin container and polyethylene bags. The activity of storage fungi was the lowest in refrigerator as the temperature was 10 °C and moisture was not absorbed by the seeds from outside. Polyethylene bags and tin being air tight containers, no moisture was absorbed by seeds during high humid months and activity of the fungi was not high. As a result, seed germination was higher as compared to dole and earthen pot. In both years, containers effect was not significant and the storage duration increased the fungal infection.

2.7 BIOCHEMICAL PARAMETERS

2.7.1 Minerals content

Artik and Velioglu (1993) stated that iron content in pekmez was 100 mg/kg. Iron content in both conventional and vacuum methods were significantly affected by storage periods. It decreased sharply upto sixth months of storage, than a slow decrease thereafter.

Ustun and Tosun (1997) studied 11 pekmez samples and found that the level of copper varied between 2.9 - 9.4 mg/kg and iron content varied between 26.2-163 mg/kg. Storage period also significantly affected copper contents. Average copper contents of all treatments at the end of the 10th month of storage decreased to 21.9 per cent in comparison to the initial contents.

Kayısoğlu and Demirci (2006) studied the effects of storage time and condition on mineral contents of grape pekmez produced by vacuum and classical methods. They found that vacuum method having higher mineral content than classical method and reported that, zinc, copper, manganese and iron contents decreased in vacuum as well as classical methods after 10 months of storage period when compared to classical methods (at room condition and cold condition).

Echendu *et al.* (2009) reported that mineral contents (mg/100 g) viz., Zn (17.33), Cu (37.42) and Fe (0.70) in freshly prepared cocoyam chips, but it decreased to 14.96, 33.85 and 0.65, respectively when stored for six months. Similarly, Alinnor and Akalezi (2010) also reported the decrease in Zn, Cu and Fe of cocoyam and white yam respectively stored for six months.

Fagbohun *et al.* (2011) revealed that there was a decrease mineral composition of sun dried shelled melon seeds (*Citrullus vulgaris*) during long term storage (zinc from 0.75 to 0.63, iron from 1.11 to 0.63 and copper from 0.26 to 0.19, respectively). Similarly, Fagbohun and Faleye (2012) studied the nutritional changes during storage in groundnut seeds and found that all mineral contents (mg/100 g) decreased with increase in storage period.

Lawal and Fagbohun (2012) reported that mineral content (mg/100mg) in the millet seeds decreased with increase in storage period viz; Zn (24.55 to 20.54), Fe (0.39 to 0.23), Mn (1.44 to 0.61), respectively at the end of 6 months storage period.

Fagbohun and Faleye (2012) studied the effect of storage on chemical composition of okra (*Abelmoschus esculentus*) and found that all mineral contents (mg/100 g) were decreased with an advancement in storage period viz., iron (from 0.68 to 0.50), zinc (from 38.10 to 31.82), manganese (from 1.75 to 0.75), respectively, The nutritional composition of okra was depleted during storage. Therefore, storage should be done under controlled environment that will not favour the growth of spoilage microorganisms.

2.7.2 Hydrolytic enzymes (amylase, lipase, protease and peroxidase)

Kruger and Tipple (1980) reported that falling number is inversely proportional to α -amylase activity. It has considerable significance, since there is a direct relationship between enzyme activity and finished product attributes (bread crumb quality, loaf volume *etc.*). Pre harvest sprouting or sprouting during storage, which results due to high temperature and humidity, increases the level of α - amylase enzyme activity.

Upon seed germination, storage proteins are degraded by protease enzymes to provide nutrients for embryo/seedling growth (Bing *et al.*, 2003). Lipases are lipolytic enzymes catalyze the hydrolysis of fats as well as esters of fatty acids with alcohol's (Sarada and Desnuelle, 1957).

Beck and Ziegler (1989) reported that α - and β -amylases are the major amyolytic enzymes found during seed germination and are involved in the degradation of endosperm starch. Starch in the endosperm of cereals is the most abundant reserve synthesized during seed development. Degradation of starch into soluble sugars is important to support seedling growth during seed

germination. Starch can be degraded either by hydrolysis with amylases or phospholysis with starch phosphorylase. In germinating cereal kernels, hydrolysis but not phospholysis is the major process to break down starch molecules.

Dhaliwal *et al.* (1991) reported that α -amylase and β -amylase activities of rough rice samples decreased significantly during storage. Similarly, both alpha and beta- amylase activities decreased during storage of milled rice (Barber, 1969). Dhaliwal *et al.* (1991) found that proteolytic enzyme activity increased during storage of milled rice. The mean values for proteolytic activity for samples stored one month was 97.5 mg/100 g, which value increased to 189 mg/100 g after 12 months of storage. Further they observed an increase of lipase enzyme activity during storage; while lipase activity of bran from paddy stored for one year was higher than that of the freshly harvested crop.

Azulay (1997) reported that different enzymes and minerals play a significant role in different ways at different times of seed germination. Germinated seed and grain showed an increase in minerals and enzymes from 25 to 40 per cent. Protease activity during germination was studied in mungbean (Chrispeels and Boutler, 1981) and legume seeds (Lichenfeld *et al.*, 1981). Similarly, activity of amylase was studied in legume seeds by Koshiba and Minamikawa (1983).

Rehman and Shah (1999) reported that temperature and humidity of the environment increase very rapidly during rainy season, which coincides with two months after harvesting of wheat, during which biochemical changes occur in grains by the action of enzymes such as lipases, proteases and amylases on lipids, proteins and starches, respectively, thus deteriorating the end use quality of wheat. A significant decrease in moisture content, amylase activity, pH and increase in titerable acidity was observed during storage of wheat at 45 °C. However, no significant biochemical changes occurred during storage at 10 °C. Storage of wheat grains in tin containers at high temperature and moisture contents showed high increase in fat, acidity than those stored in cotton and jute bags, thus lowering of the baking quality scores of wheat (Chaudhry *et al.*, 1987).

Matsukura *et al.* (2000) found that peroxidase activities declined rapidly during storage of rice. As it can easily be measured, it is used as good indice of quality deterioration in rice grains during storage.

Kumar and Sreenarayanam (2000) showed that the reduction of carbohydrates, proteins, rehydration ratio and increase in moisture content was comparatively higher in ordinary heat sealed storage against vacuum packaging which was attributed to the lower activity of amylases and proteinase enzyme during long term storage.

Chaitanya *et al.* (2000) studied the change in total protein and protease activity in dehydrating recalcitrant sal (*Shorea robusta*) seeds and reported gradual decline in total protein content due to corresponding increase in protease activity. Almost 43.7 per cent and 52.6 per cent loss in total protein content was observed on 3 days after harvesting in embryonic axis and cotyledon, respectively of seeds showing 100 per cent viability. No protease activity was detected in the embryonic axis and cotyledon of freshly harvested viable seeds (0 days after harvest). The protease activity was detected after 12 hrs of storage and increased sharply with peak levels on 6 days (0.71 ± 0.04 /min/mg protein) and 4 days after harvest (0.16 ± 0.01 /min/mg protein) in embryonic axis and cotyledon, respectively. Later on the enzyme activity declined sharply in both the tissues.

Scialabba *et al.* (2002) reported that peroxidase activity decreased in aged seeds as compared to fresh seeds in radish. According to Pallavi *et al.* (2003) there was a sharp decline in peroxidase activity during ageing in sunflower. While, Peroxidase and catalase activities were found higher in younger seeds of *Chenopodium rubrum* (Mitrovic *et al.*, 2005).

Sana *et al.* (2009) carried out a study on enzyme activities and mobilization of nutrients in *Brassica spp.* and wheat (*Triticum aestivum* L.) seeds during germination and reported that the activities of α - amylase, protease and lipase varied from 8.02- 48.69, 20.96 - 45.45 and 2.72-12.76 units/ml, respectively. α -amylase activity increased considerably during germination.

Chauhan *et al.* (2011) found that in case of natural aged seed, peroxidase activities decreased as the natural ageing progressed in all the six varieties of wheat. The rate of decrease of both the enzymes activity was higher after 18 months of storage. In cereal seeds, the development of amylase activity constitutes an important event in germination. A gradual decline in amylase activity was reported in natural aged seed lot in all the six varieties as time of ageing increased. Similar observation was reported by Agarwal and Kharlukhi (1987) in natural aged gram, chickpea and wheat seeds. Mostarin *et al.* (2012) found that all the seed quality parameters in bush bean higher in cold storage followed by ambient conditions. But there was a significant effect of such temperature

changes on α -amylase and proteases enzymes activity during the storage. The higher amylase enzyme activity (1.42) was observed when seeds were stored at low temperature (5 °C) than that of seeds stored at room temperature (1.39).

2.8 PROXIMATE COMPOSITION

2.8.1 Moisture content

Jalote and Vaish (1976) stored IR-8 paddy seeds under ambient conditions with 10, 12, 14 and 16 per cent seed moisture in gunny and polythene bags and observed that storage in gunny bags was better for the seeds of higher moisture content. Whereas, the seeds with 10 per cent moisture, stored in polythene bags was found to be better storer than gunny bags. Similarly, Asokan *et al.* (1980) tested the storability of rice seeds in polythene bags, which were found to be superior over cloth bags and gunny bags.

Saibabu *et al.* (1983) reported that viability of paddy seed was maintained for longer periods when stored with initial seed moisture of 11 per cent in moisture proof containers like polyethylene bags (600 gauge) and metal containers, under ambient conditions.

Rahman and Rahman (1997) studied the effect of storage containers environment at different storage periods on the quality of soybean seed and found that the highest germination and lowest prevalence of fungi was recorded in the seeds stored in tin followed by polythene bags and cloth bags. A positive correlation between increases in population of storage fungi and loss in germination was obtained.

The fluctuation in seed moisture content was noticed in seeds stored either in cloth or polythene bags in all the months of storage. Seeds stored in cloth bags recorded significantly higher seed moisture content than in polythene bags (Uppar, 1998). Similarly, fluctuation of moisture content in seeds stored in cloth or polythene bags was reported by Teng (1981) in maize seeds.

Sidik (2000) studied the moisture content of milled rice, which declined throughout the observation period of 16 months. The initial moisture content of the rice was 14.20 per cent and after 16 months of storage, the moisture content was 12.87 per cent for rice stored inside and 11.95 per cent for rice stored outside under vacuum conditions.

According to Rehman (2006), no significant changes in the nutritional quality were observed during storage of cereal grains at temperature less than 20 °C and moisture of stored product up to 14 per cent.

Pham and Ramegowda (2007) reported that seed moisture content increased in hybrid rice after 10 months of storage from 13 to 14.3 and 12.51 to 13.7 per cent in cloth bags and polythene bags, respectively.

Ramanadane and Rettinassababady (2008) revealed that the seed moisture content increased with an advancement of storage period in cloth bags (9.5 to 13.5%) compared to HDPE bags (9.5 to 13.3%) and super grain bags (9.5 to 11.9%). However, the rate of increase was significantly higher in cloth bags followed by HDPE bags than in polylined cloth bags and super bags. Masum *et al.* (2010) also found that tin and polythene containers were less permeable to moisture transmission compared to gunny bags and the tin containers retained higher seed quality attributes throughout the storage period.

Khalequzzaman *et al.* (2012) reported that initial moisture content was 13.1 per cent for all containers before storage. Storage container showed significant effect on moisture content which increased with an increase in storage period. Seeds stored in gunny bags gave the highest moisture content (15.0, 17.1, 20.33 and 24.25%) compared to tin container (13.5, 14.33, 15.99 and 16.59%) at 15, 30, 45 and 60 days after storage, respectively.

Asha (2012) found that the moisture content differed significantly from fourth month to the end of storage period due to containers. The moisture content was significantly lowest (8.29%) in vacuum sealed container followed by polythene bags (8.26%) and highest in cloth bags (8.35%) after second month of storage in maize seeds. Similar trend was followed up to fourteen months of storage.

Monira *et al.* (2012) reported higher moisture enhances seed deterioration, which ultimately reduces the planting value of soybean seeds in the field. The initial moisture content of different containers was similar (around 12%), but it increased with an increase of storage time and the rate of increased was higher in seeds of cloth bags.

2.8.2 Crude protein and soluble protein content

Esh *et al.* (1962) reported a decrease in protein content during storage of food grains. Similarly, significant decrease in protein and free amino nitrogen content of rice and jowar during 12 months of storage were observed by Pushpamma and Reddy (1979).

Hira *et al.* (1988) reported that crude protein content of wheat stored in the different rural storage structure increased after five months of storage and decreased thereafter. Chrastil (1990) reported that the number of disulfide bonds and the average molecular weight of oryzenin, which is a major protein in rice, increased during storage of rice grain. The interaction between oryzenin and starch decreased during storage.

Dhaliwal *et al.* (1991) observed that protein and soluble protein content of milled rice decreased during storage of paddy. Similarly, decrease in protein content in rice during storage has also been reported by Beloglazona *et al.* (1977).

According to Pomeranz (1992), protein remains unchanged during long term storage, but it may increase in mold damaged samples due to respiratory loss of carbohydrate.

Gujral and Kumar (2003) studied the ageing on physiochemical and textural characteristics of brown and milled rice and found a decrease in soluble protein during ageing, which may be due to denaturation of proteins, elevated super oxide activity and lack of ATP. While, Zhou *et al.* (2001) reported that the protein content did not change during storage, although its general solubility was reduced with a decrease in the albumin during storage.

Nasir *et al.* (2003) studied on the effect of moisture on the shelf life of wheat flour and observed that crude protein content decreased (12.21-12.01%) with 60 days storage period. Among the treatments, the changes were more in treatments having higher moisture content because higher moisture content favoured proteolytic activity. Similar results have been obtained by Leelavathi *et al.* (1984) and Upadhyay (1994).

Sahib (2006) showed that the kind of packaging material and storage duration had no significant effect on crude protein. Similarly, no conclusive change in protein content was observed by Hruskova *et al.* (2004).

Lawal and Fagbohun (2012) studied the nutritive composition and mycoflora of sundried millet seeds (*Panicum miliacum*) during storage and revealed that freshly harvested seeds had crude protein of 11.52 per cent and after six months of storage, the crude protein decreased to 10.86 per cent.

Fagbohun and Faleye (2012) studied the effect of storage on chemical composition and mycoflora of okra (*Abelmoschus esculentus*) and found that crude protein decreased from 14.54 g/100 g to 12.68 g/100 g, after six months of storage.

Lawal (2011) studied the effect of storage on the nutrient composition and the mycobiota of sundried watermelon seeds and found that the freshly shelled watermelon seed had crude protein of 43.61 per cent and after six months of storage, crude protein decreased to 42.17 per cent.

2.8.3 Fat content

Nasir *et al.* (2003) found that crude fat of whole-wheat flour during the storage period of 60 days was significantly affected due to storage. The decrease may be attributed to the lipolytic activity of enzymes *i.e.* lipase and lipoxidase as reported earlier (Haridas *et al.*, 1983 and Leelavathi *et al.*, 1984).

Branimir *et al.* (2007) studied changes in seed oil content in different genotypes of maize, soybean and sunflower from 2002 to 2006, in two types of storage conditions which differed in air temperature and humidity: 25 °C / 75 per cent and 12 °C / 60 per cent, respectively; affected by storage longevity, in average seed oil content decreased by 0.82 per cent in maize, 2.19 per cent in soybean and 8.53 per cent in sunflower. Storage longevity was negatively associated with oil content. At storage conditions at 12 °C / 60 per cent, decrease of seed oil content was less by 0.55 per cent (maize), .30 per cent (soybean) and 1.75 per cent (sunflower) than in storage conditions at 25 °C.

Suriyong (2007) reported that the ageing process naturally affects the quality of seeds during storage at various conditions, particularly the oil content which is sensitive to deterioration as a result of the oxidation process (a reaction between unsaturated fatty acids and oxygen). The longer the storage time the higher the oxygen availability and vice versa. This might be a reason why the percentage of oil of stored seeds tends to reduce during storage.

Jafri (2010) reported that crude fat content of wheat grain decreased during storage. Highest value (2.30%) was observed in Margalla-99 at starting stage of storage which decreased in all the durations. Lowest value (1.73%) was noted in Chakwal-97 after 12 months storage which did not differ significantly different from that of its value at initial stage of storage.

Lawal and Fagbohun (2012) studied nutritive composition and mycoflora of sundried millet seeds (*Panicum miliacum*) during storage. The result of the proximate analysis (%) revealed that the freshly harvested millet seeds decreased fat content from 4.55 to 3.55 after six months of storage. They also studied the effect of storage on nutrient composition and mycoflora of sundried soybean seeds and revealed that the fresh soybean had fat content of 19.15 per cent and it decreased to 18.37 per cent after six months of storage.

Fagbohun and Faleye (2012) studied the effect of storage on chemical composition and mycoflora of okra (*Abelmoschus esculentus*) and found that fat content decreased from 9.75 g/100 g to 6.49 g/100 g after six months of storage. The proximate analysis (g/100 g) in sundried groundnut after six months of storage period revealed that fat content decreased from 50.38 to 47.69 (Fagbohun and Faleye, 2012).

Lawal (2011) studied the effect of storage on the nutrient composition and the mycobiota of sundried watermelon seeds and observed that crude fat content decreased from 38.98 to 35.44 per cent after six months of storage. Fagbohun *et al.* (2011) studied on the chemical composition and the mycoflora of shelled melon seeds and revealed that the fat content decreased from 45.95 per cent in the freshly shelled seeds to 39.49 per cent in the stored seeds.

Kandil *et al.* (2013) studied the effect of seed storage periods, conditions and materials on the seed quality of some soybean cultivars. They found that oil content and moisture per cent decreased as storage periods increased. Storage for 12 months recorded lowest oil and moisture per cent. It could be concluded that increase in storage period from 6 and 12 months decreased oil per cent by 12.99 and 17.58 per cent, respectively as compared with before storage treatment. Increasing storage periods from 3, 6, 9 and 12 months decreased oil per cent by 0.42, 1.38, 0.95 and 2.45 per cent, respectively compared with before storage treatment.

2.8.3 Ash content

Ash content of jowar and bajra were not much influenced by storability of food grains and milled product under normal condition during 7 months of storage (Agarwal *et al.*, 1990).

Lawal and Fagbohun (2012) studied the nutritive composition and mycoflora of sundried millet seeds (*Panicum miliacum*) during storage and they revealed the freshly harvested millet seed had ash content of 2.19 per cent and after six months of storage, the ash content was increased to 2.87 per cent. While, Fagbohun and Faleye (2012) studied on the effect of storage on chemical composition and mycoflora of okra (*Abelmoschus esculentus*) and found that ash content decreased from 8.06 g/100 g to 7.56 g/100 g after six months of storage.

Fagbohun and Faleye (2012) studied the nutritional and mycoflora changes during storage of groundnut and found that ash content decreased (g/100 g) from 2.78 g/100 g to 2.64 g/100 g after six months of storage. Lawal *et al.* (2012) studied the effect of storage on the nutrient composition and the mycobiota of sundried watermelon seeds and found that freshly shelled seeds had ash content of 3.23 per cent which decreased to 2.92 per cent, after six months of storage.

2.8.4 Carbohydrates

Fagbohun *et al.* (2011) studied the chemical composition and the mycoflora of shelled melon seeds and revealed that the carbohydrate content increased to 0.56 per cent in the freshly shelled melon seeds to 1.56 per cent in the stored seeds. They also reported that the effect of storage on nutrient composition and mycoflora of sundried soybean seeds and which revealed that the fresh soybean contains 22.33 per cent of carbohydrate after six months of storage, the per cent carbohydrate contents decreased to 19.18 per cent. Similar observations were reported earlier by Fagbohun *et al.* (2010) in stored sundried plantain chips.

Lawal *et al.* (2012) studied the nutritive value and mycoflora of sun dried cocoyam chips during six months of storage and revealed that the carbohydrate content increased from 68.32 per cent in freshly prepared samples to 69.52 per cent in stored sample.

Fagbohun and Faleye (2012) studied the effect of storage on chemical composition and mycoflora of okra (*Abelmoschus esculentus*) and found that carbohydrate content increased from 21.17 g/100 g to 22.99 g/100 g after six months of storage.

2.9 SENSORY EVALUATION (Appearance, colour, flavor, taste, texture and overall acceptability)

Barber (1972) studied the milled rice changes during ageing and found that flavor of cooked rice changes even stored under air tight containers and well polished rice retained its flavor longer period than polished rice.

Chrastil (1990) studied the chemical and physio- chemical changes of rice during storage and reported that as rice ages; cooked rice texture becomes fluffier and harder. Similar observations have been reported by Villareal *et al.* (1976), Indhudhara Swamy *et al.* (1978) and Chrastil (1992).

Daniel (1998) studied the effect of long grain rough rice storage history on end use quality and reported that taste is an expression of intrinsic characteristic of the rice as influenced by the interaction of seed physiological process with the ambient environment. Accordingly taste is very sensitive to the storage conditions such as temperature and the associated compilation effects of other metabolic process.

Meuellenet *et al.*, (1999) reported that the storage duration significantly affects the texture and flavour. As the storage period increases in rice becomes less sticky and harder and granular in nature. It suggests that stored rice is more acceptable than fresh rice.

Sidik (2000) reported that aroma, colour and appearance for rough rice and aroma, colour for cooked rice decreased with an increased storage period of 16 months *i.e.* from 4.75 to 2.90, 4.75 to 3.60, 4.97 to 4.43 rated and from 4.82 to 3.59, 5.07 to 4.11 (organoleptic qualities were rated on scale of 1-7, the higher the score the better).



Vacuum packed bag (C₁)



Polythene bag (C₂)



Cloth bag (C₃)



Gunny bag (C₄)

Plate 1a: Storage of paddy using different packaging materials at room temperature

Plate 1a: Storage of paddy using different packaging materials at room temperature

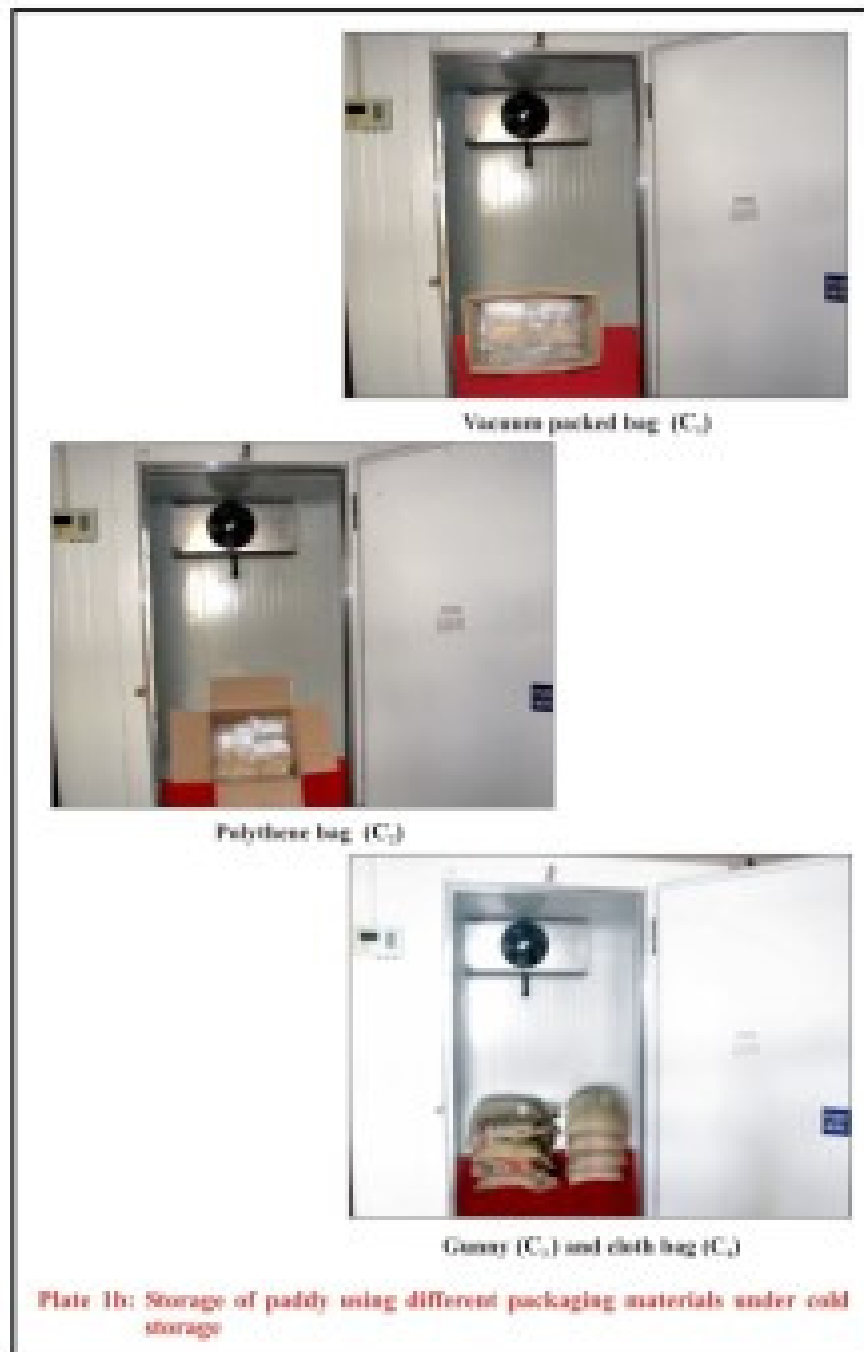


Plate 1b: Storage of paddy using different packaging materials under cold storage



Plate 1c: Different packaging materials for paddy and storage treatments



Plate 1d: Storage of rice grains using different packaging materials at room temperature



Plate 1e: Storage of rice grains using different packaging materials under cold storage



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Plate 1f: Different packaging materials for rice and storage treatments

3.2 VACUUM PACKAGING OF DIFFERENT SEEDS

The machine used for vacuum packaging of different seeds was OLPACK 501/V manufactured by INTERPRISE–BRUSSELS S.A., BRUXTAINER DIVISION, Belgium (Plate 2). The general description of the machine and the details regarding the setting up of machine, its operation and the procedure involved in vacuum packaging are enumerated as under.

3.2.1 General description of vacuum packaging machine

The OLPACK machine is a vertical vacuum packaging system designed and developed for vacuum packing of solid, liquid and semi-liquid food stuffs. The bags are filled with the product by means of a “bags shaping” guide to be thus manually placed inside the machine, which creates vacuum by means of a special pump. The bags is thus sealed by means of a thermal sealing system, featuring a sealing bar for double sealing. During the cycle, it is possible to inject inert gas inside the bags, by means of special gas nozzles. The entire packing and thermal sealing cycle is controlled by two independent control software systems with the relative control panels.

The machine is basically composed of the following.

- Frame
- Vacuum chamber bell
- Cycle controls
- Heat regulator for the pulse type sealing system
- Vacuum pump
- Heated sealing bar
- Compressed air system
- Bag stretching bar
- Red mushroom on a yellow background
- 2-position power switch
- Red indicator light

The machine can also accommodate some additional components, *viz.*,

- In feed roller way
- Roller way with guides inside the vacuum chamber bell
- Different types of bags shapers
- Different types of bags stretching bars

3.2.2 Setting up of the machine

- The leveler was kept on top of the machine, whenever it was found to be unlevelled; the leg of the machine was turned with the help of spanner bolt until the machine was leveled. The conveyor of the leg of the machine was also leveled, by keeping the leveler on a flat surface on top of the conveyor. Similarly, the conveyor outside the machine and the sealing bar was also leveled.
- The air tube (blue colour) was connected to the machine at a vent marked “AIR”.
- The compressor was switched on and the corresponding readings on the gauge (black) hanging on window were observed (It should exactly be 75 lb/sq.ft. (5 bars). If it is less than 5 bars, compressor should work more to obtain more pressure. If it 4 bars (low) or 6 bars (high), the compressor would automatically be switched off).
- When the compressor was ready, the machine was plugged.



Plate 2: Bruxtainer vacuum packaging machine with the mould used for vacuum packaging

3.3 GENERAL DESCRIPTION

3.3.1 Location and climatic conditions

Dharwad lies between 15°21' in North latitude and 76°07' East longitude at an altitude of 678 m above the mean sea level. The mean meteorological data from February 2011 to August 2013 (18 months) were collected from the Meteorological Observatory of Main Agricultural Research Station, UAS, Dharwad and presented in Appendix I and II. The average minimum and maximum temperatures during storage period ranged from 14.4°C to 36.9°C with a mean annual temperature of 25.2°C. The maximum temperature was noticed during the month of April (36.9°C) and minimum temperature was noticed during the month of December (14.4°C). The mean relative humidity during storage period ranged from 43 to 89 per cent.

3.4 OBSERVATIONS RECORDED

The required quantity of seeds was drawn at bimonthly interval from each treatment under both ambient as well as cold storage conditions for determining different quality parameters. Observations on the following parameters were recorded.

3.4.1 Seed quality parameters

3.4.1.1 Germination (%)

Germination test was conducted as per the ISTA procedure (Anon., 1996) using between paper methods. Three replicates of 100 seeds each were germinated in a germinator maintained at 25 ± 2 °C and 95 ± 1 per cent relative humidity. The number of normal seedlings were counted at the end of 14th day and expressed in per cent.

3.4.1.2 Root length (cm)

At the time of germination count, 10 normal seedlings were selected at random from each replication and used for measuring the root length. Root length was measured from the point of attachment of seed to the tip of primary root. The mean values were calculated and expressed in cm.

3.4.1.3 Shoot length (cm)

The same 10 normal seedlings used for the measuring root length were used for measuring shoot length. The shoot length was measured from the point of attachment of seed to tip of the leaf and the mean values were expressed in cm.

3.4.1.4 Total seedling length (cm)

Total seedling length is the summation of shoot length and root length expressed in cm.

3.4.1.5 Seedling dry weight (mg)

The same 10 normal seedlings used for measuring root and shoot length were put in butter paper packets and dried in hot air oven maintained at 80 ± 1 °C for 24 hours. After drying, seedlings were kept in desiccator for cooling, then weighed and expressed in milligrams (Anon., 1996).

3.4.1.6 Seedling vigour index

Vigour index values were computed using the following formula and the mean values were expressed in whole number (Abdul-Baki and Anderson, 1973).

$$\text{Seedling Vigour Index} = \text{Germination (\%)} \times \text{Seedling length (cm)}$$

3.4.1.7 Mobilization efficiency (%)

Mobilization efficiency is defined as mobilization and utilization of food reserves during seed germination and expressed in per cent. It was calculated by the following formula (Srivastava and Sareen, 1974).

$$\text{Mobilization efficiency (\%)} = \frac{\text{Dry weight of seedlings}}{\text{Dry weight of seeds}} \times 100$$

3.4.1.8 Mean daily germination (MDG)

It is the average number of seeds germinated per day of the test period.

$$\text{Mean daily germination} = \frac{\text{Final germination}}{\text{Total number of days of test}}$$

3.4.1.9 Electrical conductivity of seed leachate (dS m^{-1})

Three replicates of 5.0 g seeds from each treatment were drawn randomly, then treated with 1.0 per cent mercuric chloride for five minutes and washed well with distilled water to remove the adhering chemicals and then soaked in 25 ml distilled water for 24 hours at room temperature. After soaking, the leachate was decanted to another container and the volume was made up to 25 ml with distilled water.

The electrical conductivity of the seed leachate was measured in a digital conductivity meter and expressed as dS m^{-1} (Presley, 1958).

3.4.1.10 Fungal load

The microflora on the surface of paddy seeds was enumerated by standard serial dilution plate count method by transferring 10 g of seeds to 90 ml water blank and then serially diluting it up to 10^{-5} . One ml aliquot from each of these dilutions was transferred aseptically to sterile petriplates and covered with Martin's Rose Bengal Agar medium (Martin, 1950). There were three replications for each dilution. Petriplates were incubated at $30 \pm 1^\circ\text{C}$ and colony count of fungi was recorded after 3 days of incubation. The average of the data from the replications under appropriate dilutions were calculated and expressed as population of external microflora per gram of paddy seeds. The observations on population count were subjected to logarithmic transformation for statistical analysis.

3.4.2 Biochemical parameters

3.4.2.1 Estimation of mineral content

Copper, zinc, iron and manganese contents in seed samples were estimated using Atomic Absorption Spectrophotometer (AAS-4141, Electronic Corporation of India Ltd.).

Digestion of seed samples

Seed samples were dried at $65 \pm 1^\circ\text{C}$, ground thoroughly in Wiley mill and were used for analysis of minerals content. A representative sample (0.5 g) was taken into a 100 ml conical flask for pre-digestion and soaked overnight with 10 ml of concentrated HNO_3 and finally digested next day in a tri-acid mixture $\text{HNO}_3 : \text{H}_2\text{SO}_4 : \text{HClO}_4$ in the ratio of 10 : 1 : 4. The contents were gently heated on a hot plate using sand bath until the volume was reduced to 4.0 ml or even less till brown fumes cease leaving and only snow white residue was left in the conical flask. The residue was cooled, to which 20 ml of 6N HCl was added to each sample, then filtered through Whatman No. 42 filter paper and diluted with distilled water to make up the volume to 100 ml. and used for analysing Cu, Zn, Fe and Mn. The concentration of micronutrients in the seed samples were determined from the standard curve of known concentration and were expressed in mg / kg or ppm.

3.4.2.2 Determination of α -amylase activity

Extraction of enzyme source

One g of sample was taken into a beaker, to which 5-10 volume of ice cold 10 mM calcium chloride solution was added by grinding with mortar and pestle and kept for 3 hours at room temperature. Then the sample mixture was centrifuged at 54000 g at 4°C for 20 minutes and supernatant was collected, which was used as enzyme source.

Reagents

- Sodium acetate buffer (0.1 M ; pH 4.7)

Solution A: 0.2 M solution of acetic acid (11.55 ml of acetic acid was dissolved in 1000 ml distilled water).

Solution B: 0.2 M solution of sodium acetate (16.4 g of sodium acetate was dissolved in 1000 ml distilled water).

- Final volume was made upto 100 ml with 25.5 ml of solution A and 24.5 ml of solution B was mixed just before use.

Starch solution (1%): One gram of starch powder was dissolved in 100 ml of 0.1 M sodium acetate buffer (pH 4.7).

Dinitrosalicylic acid reagent: 1.0 g dinitrosalicylic acid was dissolved by stirring 200 mg crystalline phenol and 50 mg sodium sulphite in 100 ml of 1 per cent NaOH and stored at 4°C. 40 per cent Rochelle salt solution: 40 g of potassium sodium tartarate was dissolved in 100 ml of distilled water.

Maltose Standard curve

50 mg maltose was dissolved in 50 ml of distilled water in a standard flask to get a standard maltose solution and stored in a refrigerator. 1.0 ml of Standard maltose solution was taken in a test tube and made up the volume to 2.0 ml with distilled water. Then 1.0 ml of dinitrosalicylic acid reagent was added and it was heated on boiling water bath for 5 minutes. The tubes were cooled under running tap water and to which 10 ml of distilled water was added. The absorbance of sample was measured at 540 nm in a UV visible spectrophotometer (UVS-2700 Labomed, UK).

Procedure

Starch standard solution (1.0 ml) was pipetted out into a test tube to which 1.0 ml of properly diluted enzyme source was added. Then it was incubated at 27 °C for 15 min and the reaction was stopped by adding 2.0 ml of dinitrosalicylic acid reagent. The solution was heated on a boiling water bath for 5 min and 1.0 ml potassium sodium tartarate solution was added, while the tubes were warm. Then cooled under running tap water and made up the volume to 10 ml with distilled water. The absorbances of samples were measured at 540 nm using UV visible spectrophotometer (UVS-2700 Labomed, UK). A standard graph with 0-100 µg maltose was prepared. The amylase enzyme activity in the samples was calculated using standard graph developed with maltose and expressed as mg maltose released per minute (Bernfeld, 1955).

3.4.2.3 Determination of lipase enzyme activity

Reagents

Substrate solution

For preparation of substrate solution, 2.0 ml of castor oil was taken into conical flask, which was neutralized to pH 7.0 and stirred well with 25 ml of distilled water in presence of 100 mg of bile salts (sodium taurocholate) till an emulsion was formed. Then 2.0 g of gum acacia powder was added to hasten emulsification.

Phosphate buffer (0.1 M, pH 7.0)

Solution A: 0.2 M solution of monobasic sodium phosphate (27.8 g of monobasic sodium phosphate was dissolved in water and made up the volume to 1000 ml of distilled water).

Solution B: 0.2 M solution of dibasic sodium phosphate (53.65 g of dibasic sodium phosphate was dissolved in water and made up the volume to 1000 ml of distilled water)

- Final volume was made upto 200 ml with 39.0 ml of solution A and 61.0 ml of solution B, mixed just before use.

For preparation of 0.1 N of NaOH: 4.0 g of NaOH was dissolved in distilled water and made up the volume to 1000 ml.

- Ether, ethanol and phenolphthalein indicator were also used as reagents.

Preparation of enzyme Source

1.0 g of water soaked seeds were taken and ground in a mortar and pestle. Grinding was continued by adding distilled water in a proportion of 5 ml every time. The suspension was then homogenized and centrifuged at 15000 rpm at 4 ° C for 10 minutes. Three layers were formed, of which, the upper creamy layer was carefully separated and used as enzyme source.

Procedure

Exactly 25 ml of 0.1 M phosphate buffer (pH 7.0) was taken into a conical flask, containing 5.0 ml of substrate solution, to which 2.0 ml of enzyme solution was added. The reaction mixture was incubated at 37 °C for one hour. After exactly one hour, 5.0 ml each of ethanol and ether were added to stop the reaction. Finally one drop of phenolphthalein indicator was added to the mixture and titrated was carried out against 0.1N NaOH till pink colour was obtained. Similarly, a blank titration

was done against 0.1N NaOH by adding equal volume of distilled water in place of enzyme source. The enzyme activity was calculated by the following formula and expressed as milli equivalent free fatty acid /min (Jayaraman, 1981).

$$\text{Volume of alkali consumed} \times \text{Strength of alkali} \\ = \frac{\text{Wt. of sample in (g)} \times \text{Time in min}}{\text{-----}}$$

3.4.2.4 Determination of protease enzyme activity

Reagents

Sodium acetate buffer (0.1 M, pH 3.8)

Solution A: 11.55 ml of 0.2M acetic acid was dissolved in water and made up the volume to 1000 ml of distilled water.

Solution B: 16.4 g of 0.2M sodium acetate was dissolved in water and made up the volume to 1000 ml of distilled water

- Final volume was made up to 100 ml, consisting a mixture of 44 ml of solution A and 6.0 ml of solution B.

Haemoglobin substrate (1.0%): One g of haemoglobin was dissolved in 100 ml of 50 mM sodium acetate buffer (pH 3.8)

5 per cent Tri-chloro-acetic acid: 5.0 g of Tri-chloro- acetic acid was dissolved in 100 ml of distilled water.

Extraction of enzyme source

Water soaked 1.0 gm of seed samples were taken in a pre-chilled mortar and pestle and ground to a fine paste with 5.0 ml of 0.1 M sodium acetate buffer (pH 3.8). The homogenate was centrifuged at 15,000 rpm for 15 minutes at 4 °C and the supernatant was used as enzyme source.

Procedure

One ml of haemoglobin substrate solution and 1.0 ml of enzyme extract were pipetted out into test tubes and mixed thoroughly, then incubated at 37 °C for one hour. After incubation, the mixed solution was centrifuged at 10,000 rpm for 10 minutes at 4 °C and the supernatant was collected and used as enzyme source. The absorbance was measured at 280 nm in a UV visible spectrophotometer (UVS-2700 Labomed, UK).

The protease enzyme activity in the samples was calculated by using following formula and expressed as mg amino acid released per hour per ml of the sample (Pouille and Jones, 1988).

$$= A_{280} \times \text{Volume of enzyme extract (1.0 ml)}$$

3.4.2.5 Estimation of peroxidase activity

Peroxidase activity was estimated following the method of Mahadevan and Sridhar (1986) with some modifications.

Reagents

Phosphate buffer (0.1 M, pH 7.0)

Solution A: 0.2 M solution of monobasic sodium phosphate (27.8 g of monobasic sodium phosphate was dissolved in water and made up the volume with 1000 ml of distilled water).

Solution B: 0.2 M solution of dibasic sodium phosphate (53.65 g of dibasic sodium phosphate was dissolved in water and made up the volume with 1000 ml of distilled water).

- Final volume was made upto 200 ml with 39 ml of solution A and 61.0 ml of solution B and 100 ml of distilled water just before use.

Guaicol solution (20 mM): Dissolved 240 mg of guaicol in a distilled water and made up the volume to 100 ml.

Hydrogen peroxide solution (12.3 mM): Dissolved 0.14 ml of 30 per cent hydrogen peroxide in 100 ml with distilled water.

Preparation of enzyme source

One g of seed sample was homogenized in with 5 ml of 0.1M phosphate buffer (pH 7.0) and the homogenate was centrifuged at 15000 g for 10 min and the supernatant obtained was used as enzyme source. All the steps in the preparation of the enzyme extract were carried out at 4 °C. The aliquot of the extract was used to determine its protein content.

Measurement of peroxidase activity

Three ml of buffer solution, 0.05 ml guaiacol solution, 0.1 ml enzyme extract and 0.03 ml hydrogen peroxide solution were pipetted out into a cuvette. The absorbance was adjusted to zero at 436 nm in a UV-Vis spectrophotometer. The change in absorbance was noted at an interval of 20 seconds after adding 0.5 ml of 2.0 per cent hydrogen peroxide. The enzyme activity was expressed as change in absorbance (ΔOD) per gram protein per minute.

3.4.2.6 Estimation of soluble protein

Soluble proteins in paddy and rice flour samples were estimated by the method of Lowry *et al.* (1951).

Sample extraction

A representative sample (1.0 g) was weighed and ground well with a pestle and mortar in 10 ml of 0.1 M phosphate buffer (pH 7.0). The homogenate was centrifuged at 10000 rpm for 10 min and the supernatant was collected and used for the estimation of soluble protein.

Reagents

Phosphate buffer (0.1 M, pH 7.0)

Solution A: 0.2 M solution of monobasic sodium phosphate (2.78 g of monobasic sodium phosphate was dissolved in water and made up the volume with 100 ml of distilled water).

Solution B: 0.2 M solution of dibasic sodium phosphate (5.36 g of dibasic sodium phosphate was dissolved in water and made up the volume with 100 ml of distilled water)

- Final volume was made upto 200 ml with 39 ml of solution A and 61.0 ml of solution B and 100 ml of distilled water just before use.

Alkaline copper reagent

Solution A: 2.0 g of sodium carbonate was dissolved in 80 ml of 0.1 N NaOH and the volume was made up to 100 ml.

Solution B: 0.5 g of copper sulphate was dissolved in 1.0 g of potassium sodium tartarate in a small volume of distilled water.

- Final volume was prepared to 100 ml by mixing 98.0 ml of solution A and 2.0 ml of solution B just before use.

Stock protein standard solution

50 mg of bovine serum albumin was weighed and dissolved in distilled water and made up the volume to 50 ml in a volumetric flask. This solution contained 1.0 mg of protein per ml.

Working standard solution

10 ml of stock solution was diluted with 100 ml with distilled water in a volumetric flask. This solution contained 100 μ g of protein per ml.

Folin-Ciocalteu reagent

Used the readymade mixture with appropriate dilution in the 1:1 ratio of FCR: distilled water (10 ml of folin-ciocalteu reagent was dissolved in 10 ml of distilled water).

Procedure

0.1 and 0.2 ml of sample aliquot was pipetted out in a test tube. Similarly, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of working standard solutions were pipetted out into different test tubes. The volume was made up to 1.0 ml with distilled water. Blank was maintained using 1.0 ml of distilled water in a separate test tube. 5.0 ml of alkaline copper reagent was added to each tube including blank. Mixed

well and allowed to stand for 10 minutes, after which, 0.5 ml of folin-ciocalteau reagent was added to each test tube. Mixed well and incubated at room temperature in the dark for 30 min to get blue colour. Finally, the volume was made up to 10 ml with distilled water and the absorbance was measured at 660 nm in UV-Vis spectrophotometer. The soluble protein was estimated using a standard curve developed with bovine serum albumin (BSA).

3.4.3 Proximate composition

3.4.3.1 Moisture content

The per cent moisture, per cent solids and per cent regain were obtained by using MB 45 Halogen Moisture Analyzer from Ohaus, USA. The halogen moisture analyzer works on the basis of thermo gravimetric principle *i.e.*, the moisture is determined from the weight loss of a sample by heating. It has a built in precision balance and a halogen dryer unit that ensures fast heating of the sample and thus guarantees the rapid availability of the measurement results. The samples were dried at 125 °C, which took approximately 5 min for the minimum size (2.0-3.0 g) of the sample until all the moisture was evaporated automatically. When the moisture is evaporated, only the solids are left out and it directly gives both per cent moisture and per cent solids. The per cent water content in the dehydrated sample was recorded as per cent regain. It indicates the capacity of the dehydrated sample to absorb moisture. More the absorption, more will be the per cent regain.

3.4.3.2 Estimation of crude protein

Protein content in the seed samples was analyzed by indirect method. First, the nitrogen present in the samples was determined using micro Kjeldahl method (Jackson, 1967) and crude protein was calculated by multiplying the nitrogen content with a factor of 5.95.

Reagents

Concentrated H₂SO₄ containing salicylic acid: Dissolved 1.0 g of salicylic acid in 30 ml of concentrated H₂SO₄.

Digestion mixture: prepared by mixing 25 g of K₂SO₄, 5.0 g of CuSO₄ and 0.5 g of metallic selenium powder in a mortar and pestle.

NaOH (40%): 400 g of NaOH was dissolved in 50 ml of distilled water and made up the volume to 1000 ml with distilled water.

Mixed indicator: 0.1 g of bromocresol green and 0.07 g of methyl red were dissolved in 100 ml of 95 per cent ethanol.

Boric acid solution (2.0%): 20 g of boric acid was dissolved in distilled water and added 20 ml of bromocresol green + methyl red mixed indicator and made up the volume to 1000 ml with distilled water.

Procedure

Paddy as well as rice oven dried and finely ground samples were used for the estimation of crude protein. For the estimation of nitrogen, 1.0 g of powdered sample was digested with 10 ml of concentrated sulphuric acid in presence of 0.2 g of digestion mixture (CuSO₄ + K₂SO₄ + Selenium powder) in a 100 ml conical flask and kept it for overnight. Next day, contents were gently heated on hot plate using sand bath in digestion chamber till contents turned blue colour. The digested samples were distilled with excess 10 ml of 40 per cent sodium hydroxide (NaOH) and the ammonia released was trapped in 20 ml of 2.0 per cent of boric acid and titrated against 0.1N H₂SO₄ to get total nitrogen content in the samples. The amount of nitrogen present in a given sample was calculated by the following formula and expressed in per cent.

$$\text{Per cent Nitrogen} = (T-B) \times 14 \times N \text{ Acid} \times 100 / \text{wt. of samples}$$

$$\text{Crude protein (\%)} = 5.95 \times \text{per cent Nitrogen}$$

3.4.3.3 Estimation of fat content

Fat content in seeds was estimated by the method of Randall (1974) with some modifications.

Procedure

Two gram oven dried paddy as well as rice flour samples were wrapped in filter paper and then placed in main extraction chamber of Soxhlet apparatus and fat was extracted by refluxing with

60 to 80 °C petroleum ether for 4-5 hours at 60 °C. Thereafter, the samples were removed from the apparatus and kept between the blotting paper to remove excess petroleum ether. Then the samples were oven dried for 30 minutes and the final dry weight was recorded. The fat content of samples was calculated using the following formula and expressed in per cent.

$$\text{Fat (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 = Initial weight of seed (oven dried powder)

W_2 = Final weight of seed

3.4.3.4 Estimation of ash content

Three grams of paddy as well as rice flour were taken in a crucible and heated on oxidizing flame till smoke subsided. The crucible was transferred to muffle furnace at 550 °C for 5 hours. The samples were cooled in a desiccator and weighed. The difference in the weight was considered as weight of ash. The ash in the sample was calculated and expressed in per cent (Gupta *et al.*, 1988).

$$\text{Ash (\%)} = \frac{\text{Wt. of the ash (g)}}{\text{Wt. of the sample (g)}} \times 100$$

3.4.3.1 Determination of carbohydrate content

Total per cent of carbohydrate content in the rice samples were determined by the difference method as reported by Onyeike *et al.* (1995). This method involved adding the total values of crude protein, fat, moisture and ash constituents of the sample and subtracting it from 100.

Carbohydrate (%) = 100 – (per cent moisture + per cent crude protein+ per cent fat+ per cent ash)

3.4.4 Sensory evaluation

50 g of rice samples were used for sensory evaluation in cooked form to a panel of semi-trained judges who evaluated parameters appearance, color, flavour, texture, taste and overall acceptability of cooked rice. Following nine point hedonic scale was used to evaluate the samples (Amerine *et al.*, 1965).

Organoleptic score rating

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

3.5 STATISTICAL ANALYSIS

The experimental data were analysed statistically by following the Analysis of Variance Techniques using suitable design outlined by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' tests was P = 0.01. Critical differences (CD) were calculated wherever 'F' test was significant.

EXPERIMENTAL RESULTS

Laboratory experiments were conducted to study physiological and biochemical changes during the long term storage of paddy and rice under different packaging materials at the Department of Crop Physiology, University of Agricultural Sciences, Dharwad. Observations were recorded for various seed quality, physiological and biochemical parameters at two months interval for a period from February, 2011 to August 2013. The results obtained during the course of investigation during 18 months of storage are presented in this chapter.

EXPERIMENT-I: PADDY

4.1 SEED QUALITY PARAMETERS

4.1.1 Germination (%)

The data on germination per cent as influenced by storage containers and storage conditions measured up to 18 months presented in Table 1 and Plate 3a to 3d revealed significant differences between treatments from 6 months of storage and up to 18 months of storage. Up to 4 months of storage no significant differences between storage containers, storage conditions and their interactions were observed. Among the storage containers, the germination per cent was maximum in vacuum packaged bags (C_1) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to other treatments. Significantly lower germination per cent was observed in gunny bags (C_4), which was significantly lower compared to all other treatments. However, no significant differences were observed at this stage.

At 12 month, maximum germination was observed in vacuum packed bags stored under cold storage (S_2C_1) followed by vacuum packed bags stored under ambient storage (S_1C_1). However, both did not differ significantly among themselves. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) were at par with each other. Significantly lower germination per cent (76.4) was observed in gunny bags stored under ambient storage (C_4S_1), which was significantly

lower compared to all other treatments. A similar trend was continued at 10, 12, 14, 16 and 18 months. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher germination per cent over all other containers under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1). It was further observed that, cold storage (S_2) recorded significantly higher germination per cent in both polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) compared to ambient storage (S_1). Significantly lower germination per cent was observed in gunny bags stored under ambient storage (C_4S_1), which was significantly lower compared to all other treatments except cloth bags stored under ambient storage (C_3S_1). Similarly, cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves.

4.1.2 Root length (cm)

The observations on root length indicated significant differences between treatments from 4 months of storage and continued up to 18 months of storage (Table 2 and Plates 4a to 4d). Up to 2 months of storage, no significant differences between storage containers, storage conditions and their interaction was observed. In general, the reduction in root length was observed with advancement in storage period. The decline in root length was minimum in vacuum packaged bags (C_1) as compared to polythene bags (C_2) followed by cloth bags (C_3) throughout the storage period under both ambient storage (S_1) and cold storage (S_2). The root length in vacuum packaged bags (C_1) did not differ significantly among themselves under ambient storage (S_1) and cold storage (S_2). But, significant differences were observed in gunny bags (C_4) and cloth bags (C_3) up to 18 months. Among the storage containers, root length was maximum in vacuum packaged bags (C_1), which was significantly higher over all other treatments. Significantly lower root length was observed in gunny bags (C_4), which was significantly lower compared to all other treatments throughout the storage period. However, no significant differences were observed at this stage.

Table 1. Influence of packaging and storage conditions on germination (%) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	96.6	96.8	96.7	96.3	96.6	96.5	95.8	96.6	96.2	95.5	96.3	95.9	94.8	96.1	95.5
C ₂	96.7	96.6	96.6	96.2	96.4	96.3	95.3	95.6	95.5	94.6	94.8	94.7	92.8	93.5	93.1
C ₃	96.1	96.3	96.2	95.3	95.6	95.4	95.0	95.5	95.2	94.2	94.4	94.3	92.6	93.5	93.1
C ₄	96.4	95.9	96.2	94.8	95.4	95.1	94.0	95.2	94.6	90.3	94.3	92.3	87.8	93.1	90.4
Mean	96.5	96.4		95.6	96.0		95.0	95.7		93.6	94.9		92.0	94.0	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.17	NS		0.46	NS		0.45	NS		0.39	1.19		0.43	1.32	
C	0.26	NS		0.65	NS		0.63	NS		0.56	1.69		0.61	1.86	
S × C	0.35	NS		0.92	NS		0.89	NS		0.79	NS		0.87	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	94.5	95.6	95.1	94.3	95.4	94.8	94.0	94.5	94.2	93.6	94.1	93.8	93.2	93.7	93.5
C ₂	90.2	92.4	91.3	89.7	91.6	90.7	87.8	90.0	88.9	86.5	87.2	86.9	82.2	85.5	83.9
C ₃	89.2	90.5	89.9	84.5	85.3	84.9	75.2	81.5	78.3	70.2	75.5	72.8	64.8	71.0	67.9
C ₄	84.2	90.2	87.2	76.4	85.0	80.7	71.6	80.1	75.8	67.1	75.3	71.2	63.5	70.1	66.8
Mean	89.5	92.2		86.2	89.3		82.1	86.5		79.3	83.0		75.9	80.1	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.44	1.33		0.53	1.62		0.60	1.82		0.61	1.85		0.65	1.98	
C	0.62	1.88		0.75	2.29		0.85	2.58		0.86	2.61		0.92	2.80	
S × C	0.88	NS		1.07	3.23		1.20	3.65		1.22	3.70		1.31	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

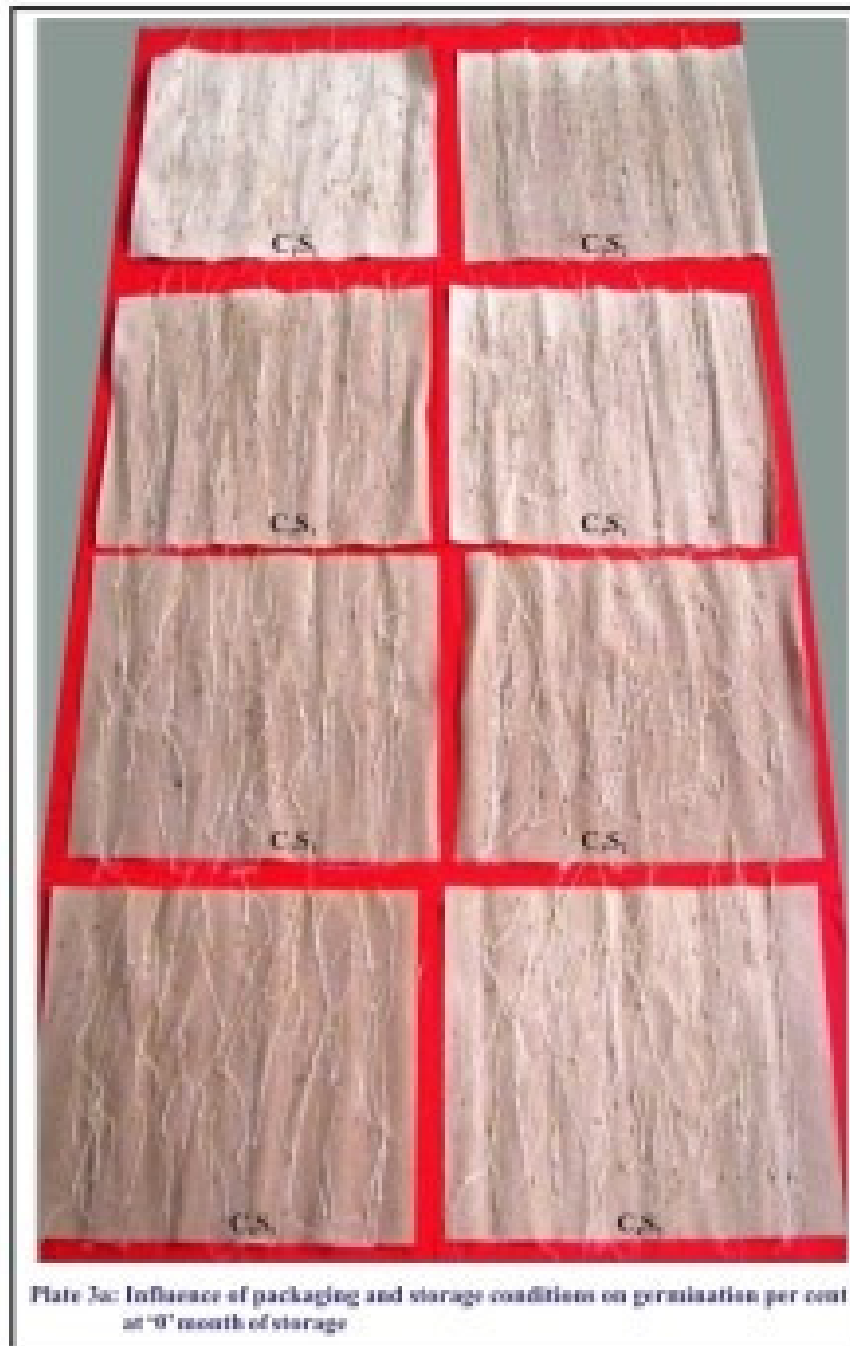


Plate 3a: Influence of packaging and storage conditions on germination per cent at '0' month of storage

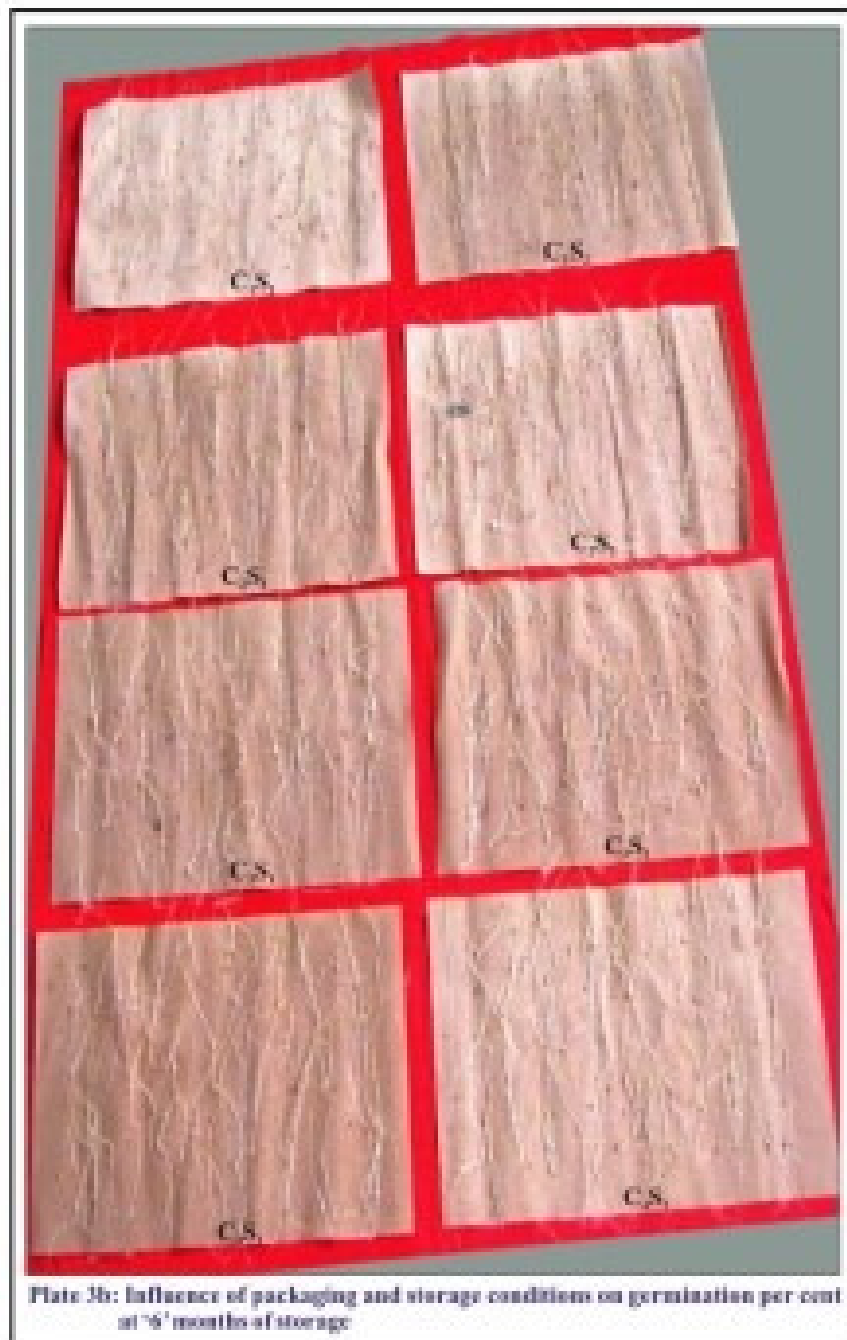


Plate 3b: Influence of packaging and storage conditions on germination per cent at '6' months of storage

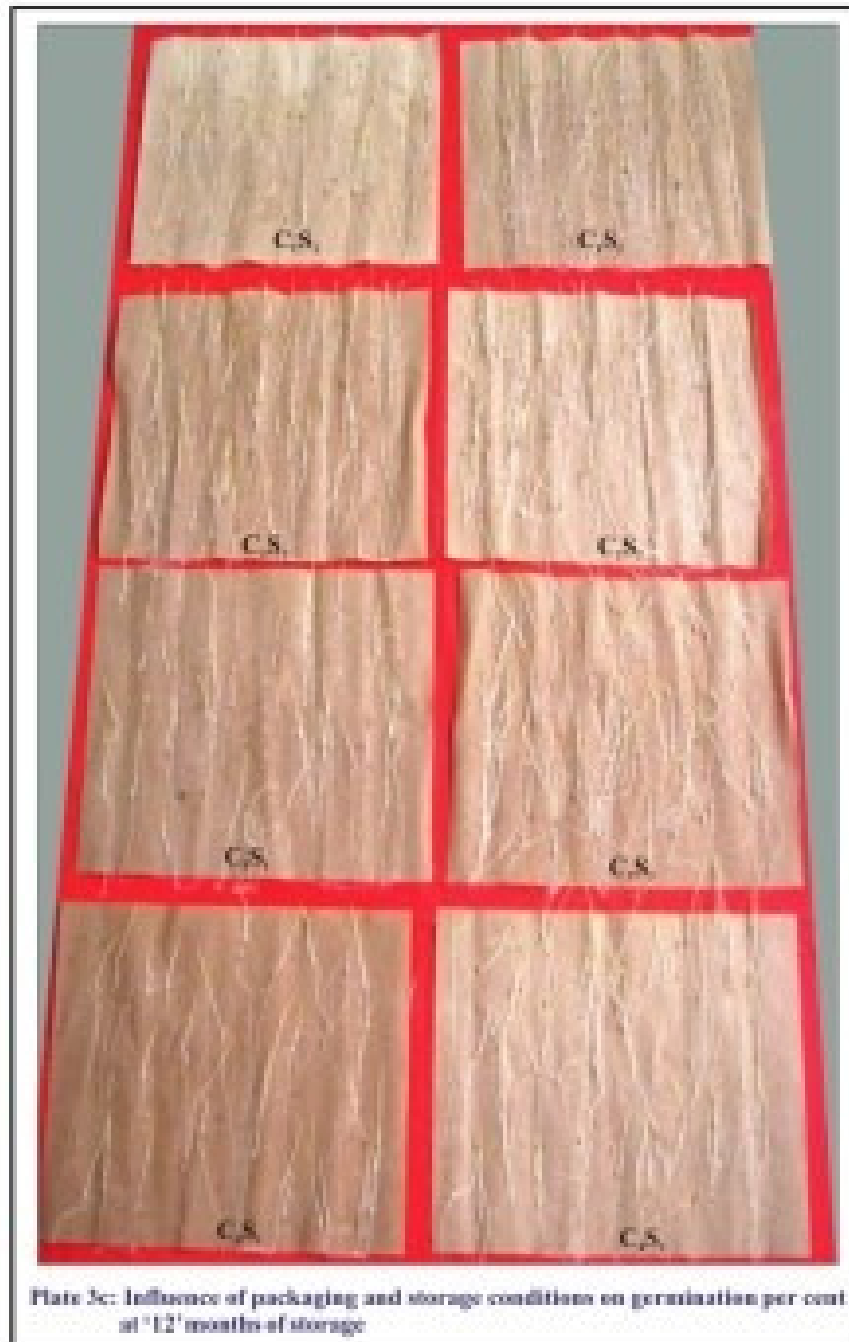


Plate 3c: Influence of packaging and storage conditions on germination per cent at '12' months of storage

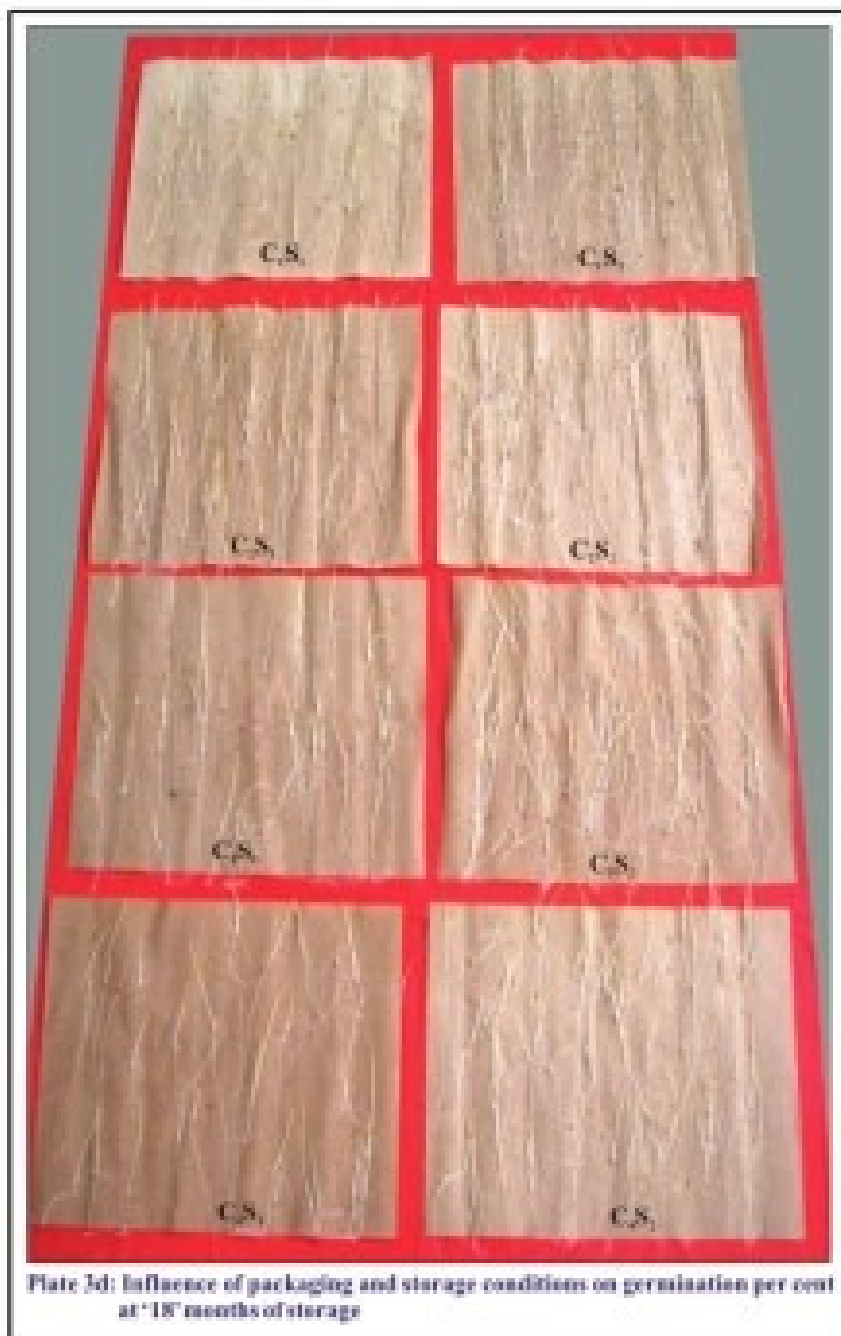


Plate 3d: Influence of packaging and storage conditions on germination per cent at '18' months of storage

At 10th month of storage, maximum root length (13.60 cm) was observed in vacuum packed bags stored under cold storage (S_2C_1) followed by vacuum packed bags stored under ambient storage (S_1C_1) (13.53 cm), However, both did not differ significantly among themselves. Significantly lower root length (13.07 cm) was observed in gunny bags stored under ambient storage (C_4S_1), which was significantly lower compared to all other treatments throughout the storage period. A similar trend continued from 12 months of storage and upto 18 months of storage. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) were on par with each other. During 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher root length (12.83 cm) over all other containers under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1). It was further observed that cold storage (S_2) recorded significantly higher root length compared to ambient storage (S_1) among all the containers throughout the storage period. Significantly lower root length (10.21 cm) was observed in gunny bags stored under ambient storage (C_4S_1), which was significantly lower compared to all other treatments. Similarly, cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves. It was further observed from the results that vacuum packaged bags (C_1) maintained the higher root length over polythene bags (C_2) followed by cloth bags (C_3) at all the stages of storage period.

4.1.3 Shoot length (cm)

The results of shoot length as influenced by storage containers and storage conditions presented in Table 3 and Plates 4a to 4d indicated significant differences between the treatments at all the stages of storage period, except at 2 months of storage. A gradual decrease in shoot length was observed with a progress in storage period. Among the containers, decline in shoot length was minimum in vacuum packaged bags (C_1) compared to polythene bags (C_2) followed by cloth bags (C_3) throughout the storage period under both ambient storage (S_1) and cold storage (S_2). Significantly lower shoot length was observed in gunny bags (C_4), which was significantly lower compared to all other treatments. However, no significant differences were observed among themselves. The maximum shoot length was observed in vacuum packaged bags (C_1) under both ambient storage (S_1) and cold storage (S_2), which was significantly

higher compared to other treatments. But, no significant differences were observed among interactions of storage conditions and storage containers ($S \times C$) throughout the storage period.

At 6th months of storage, higher shoot length (8.83 cm) was observed in vacuum packed bags stored under cold storage (S_2C_1) followed by vacuum packed bags stored under ambient storage (S_1C_1) (8.81), However, both did not differ significantly among themselves. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) were at par with each other. Significantly lower values of shoot length (8.34 cm) was noticed in gunny bags stored under ambient storage (C_4S_1), which was significantly lower compared to all other treatments. A similar trend continued at 8, 10, 12, 14, 16 and 18 months of storage. During 18 months of storage, significantly higher shoot length (8.03 cm) was observed in vacuum packaged bags (C_1) and lower shoot length was in gunny bags (C_4) (6.48 cm) compared to other containers under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1). It was further noticed that, significantly higher shoot length was recorded in cold storage (S_2) compared to ambient storage (S_1). Significantly lower shoot length was observed in gunny bags stored under ambient storage (C_4S_1), which was significantly lower compared to all other treatments, except cloth bags stored under ambient storage (C_3S_1). Similarly, cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves.

4.1.4 Total seedling length (cm)

The data on total seedling length indicated significant differences due to storage (Table 4). Up to 2 months of storage, no significant differences between storage containers, storage conditions and their interaction was observed. But, at 4 and 6 months of storage significant differences were found only between treatments, not in storage conditions and their interaction ($S \times C$). Among the storage containers, vacuum packaged bags (C_1) had significantly higher values for seedling length under both

Table 2. Influence of packaging and storage conditions on root length (cm) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	14.04	14.09	14.06	13.98	14.07	14.02	13.83	13.94	13.89	13.68	13.85	13.77	13.57	13.72	13.64
C ₂	14.10	14.07	14.09	13.94	13.93	13.94	13.76	13.84	13.80	13.63	13.67	13.65	13.41	13.50	13.45
C ₃	14.08	14.15	14.12	13.57	13.82	13.69	13.45	13.70	13.57	13.33	13.51	13.42	13.17	13.30	13.23
C ₄	13.98	14.03	14.01	13.53	13.63	13.58	13.32	13.58	13.45	13.07	13.39	13.23	12.68	13.22	12.95
Mean	14.05	14.08		13.75	13.86		13.59	13.76		13.43	13.61		13.21	13.44	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.03	NS		0.09	NS		0.08	NS		0.06	0.17		0.04	0.13	
C	0.06	NS		0.12	NS		0.11	0.33		0.08	0.24		0.06	0.18	
S × C	0.08	NS		0.18	NS		0.16	NS		0.11	NS		0.08	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	13.53	13.60	13.57	13.38	13.47	13.43	13.31	13.43	13.37	12.83	13.19	13.01	12.72	12.83	12.78
C ₂	13.35	13.43	13.39	13.21	13.27	13.24	13.07	13.22	13.14	12.62	12.73	12.68	12.50	12.58	12.54
C ₃	13.10	13.23	13.17	12.67	13.11	12.89	12.53	12.85	12.69	12.34	12.61	12.47	11.81	12.03	11.92
C ₄	12.59	13.15	12.87	11.83	12.70	12.27	11.42	12.57	11.99	11.07	12.43	11.75	10.21	11.51	10.86
Mean	13.14	13.35		12.77	13.14		12.58	13.02		12.22	12.74		11.81	12.24	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.04	0.12		0.06	0.19		0.06	0.18		0.06	0.18		0.06	0.19	
C	0.06	0.18		0.09	0.27		0.08	0.26		0.08	0.25		0.09	0.27	
S × C	0.08	0.26		0.12	0.37		0.12	0.37		0.12	0.35		0.12	0.38	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

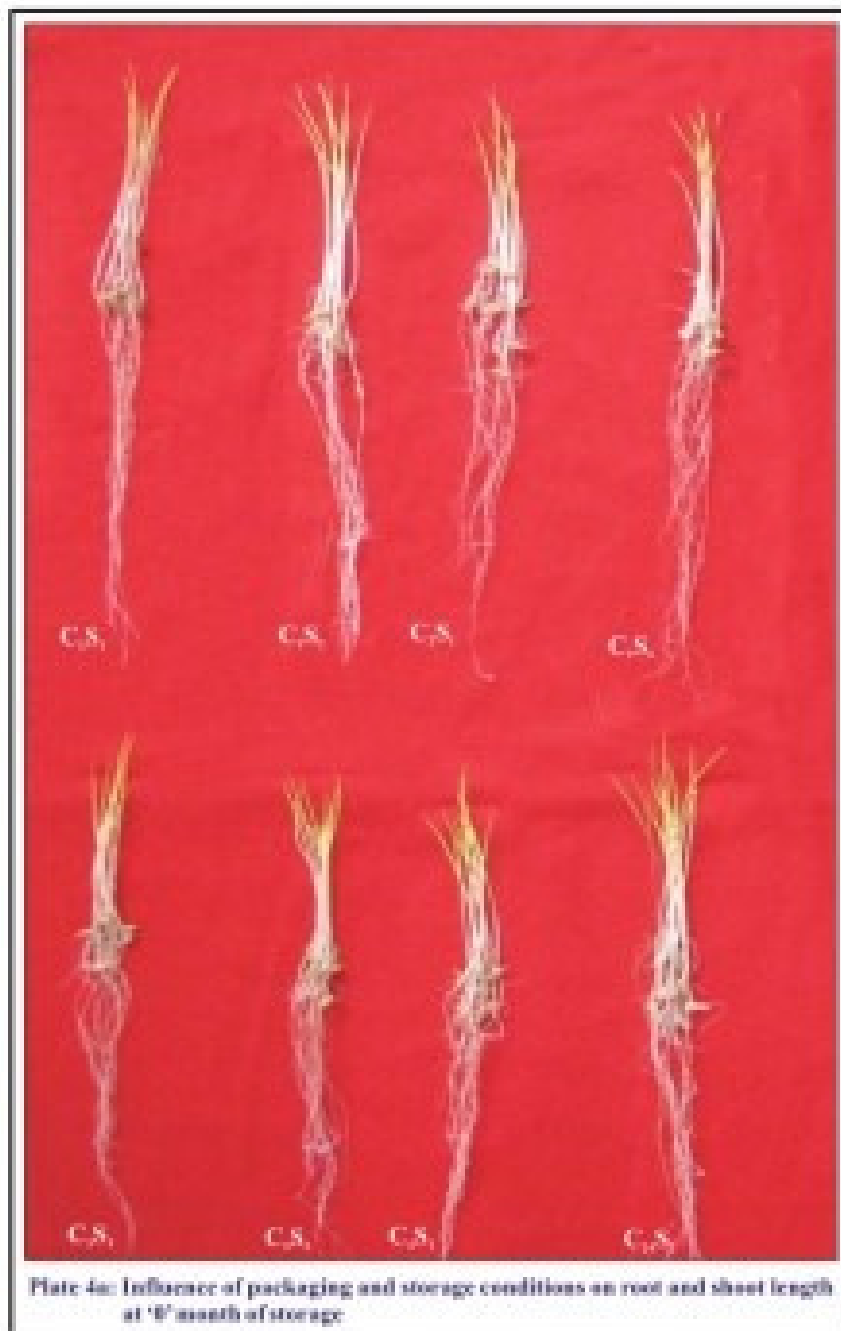


Plate 4a: Influence of packaging and storage conditions on root and shoot length at '0' month of storage



Plate 4b: Influence of packaging and storage conditions on root and shoot length at '6' months of storage

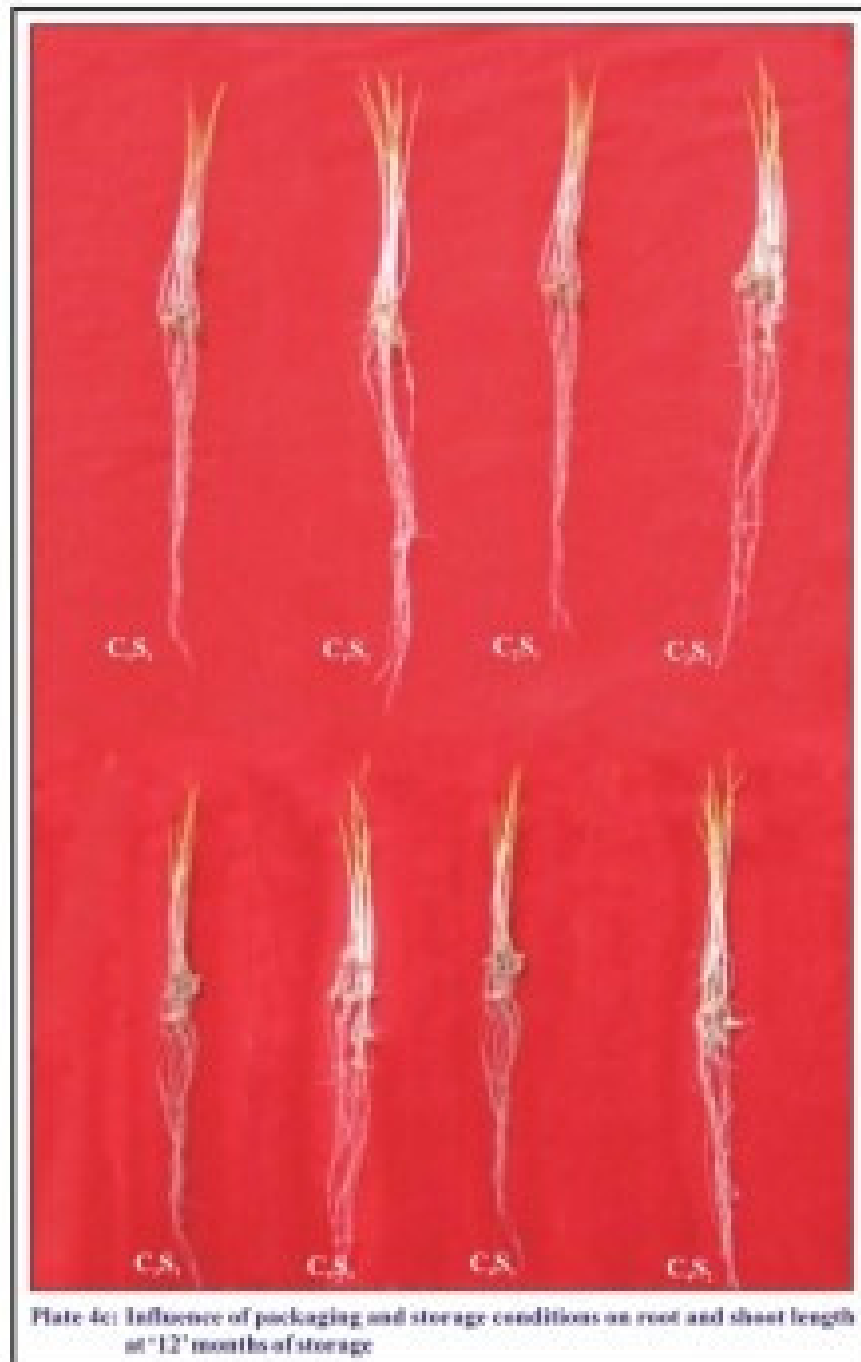


Plate 4c: Influence of packaging and storage conditions on root and shoot length at '12' months of storage

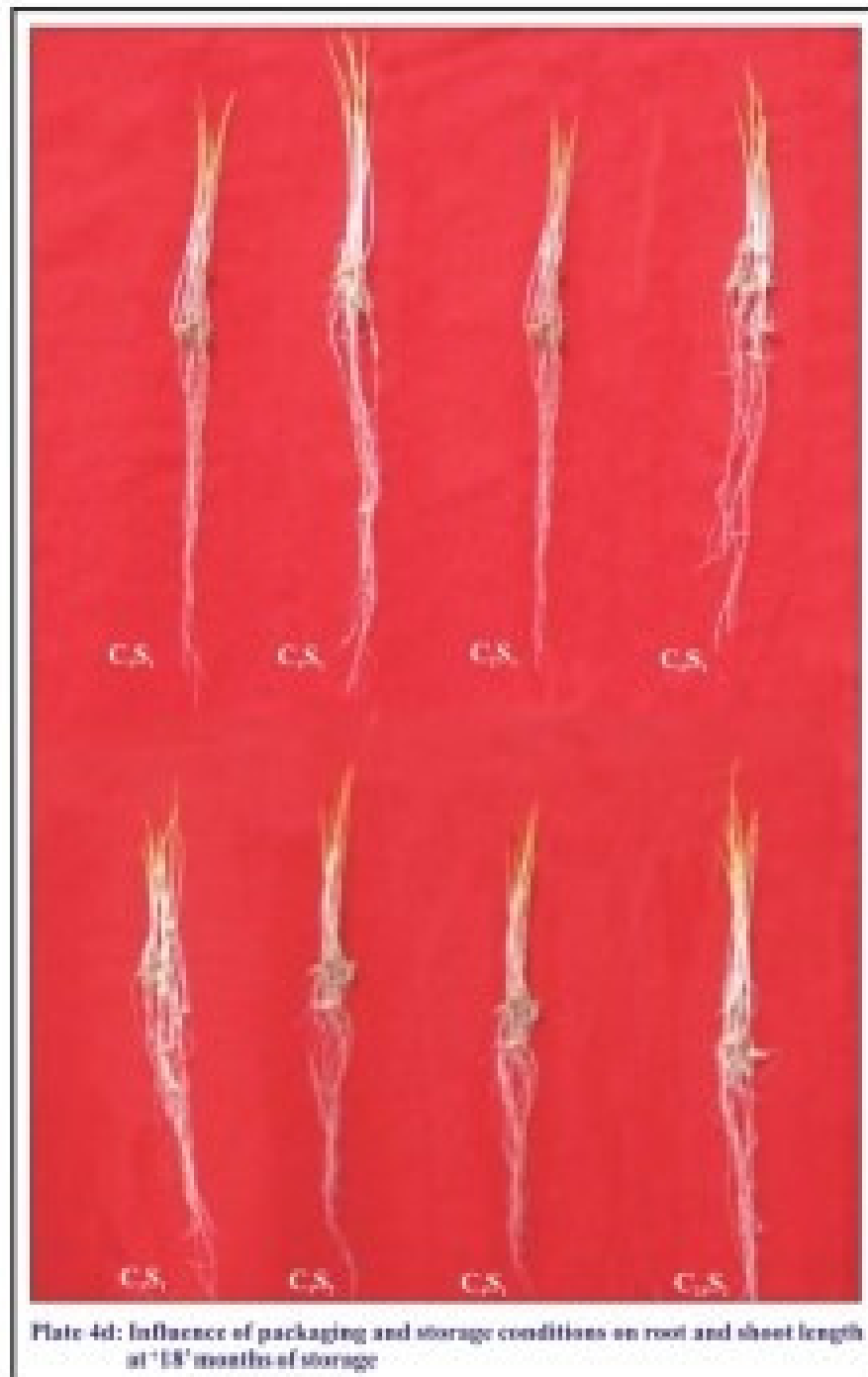


Plate 4d: Influence of packaging and storage conditions on root and shoot length at '18' months of storage

Table 3. Influence of packaging and storage conditions on shoot length (cm) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	9.10	9.05	9.08	8.97	9.03	9.00	8.93	9.01	8.97	8.81	8.83	8.82	8.65	8.67	8.66
C ₂	9.06	9.00	9.03	8.77	8.95	8.86	8.63	8.91	8.77	8.47	8.73	8.60	8.23	8.53	8.38
C ₃	9.08	9.02	9.05	8.74	8.90	8.82	8.53	8.67	8.60	8.37	8.63	8.50	8.20	8.37	8.28
C ₄	8.96	9.06	9.01	8.67	8.80	8.73	8.42	8.73	8.58	8.34	8.50	8.42	8.20	8.27	8.23
Mean	9.05	9.03		8.79	8.92		8.63	8.83		8.50	8.68		8.32	8.46	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.02	NS		0.05	NS		0.05	0.14		0.04	0.14		0.04	0.12	
C	0.04	NS		0.07	NS		0.06	0.20		0.06	0.19		0.06	0.17	
S × C	0.07	NS		0.09	NS		0.09	NS		0.09	NS		0.08	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.57	8.53	8.55	8.40	8.47	8.43	8.30	8.37	8.33	8.17	8.23	8.20	7.90	8.03	7.97
C ₂	8.07	8.40	8.23	7.93	8.20	8.07	7.83	8.10	7.97	7.70	7.97	7.83	7.40	7.73	7.57
C ₃	7.93	8.22	8.08	7.67	8.00	7.83	7.41	7.70	7.56	7.22	7.33	7.28	6.69	7.04	6.86
C ₄	7.93	8.10	8.02	7.48	7.77	7.62	7.13	7.47	7.30	6.76	7.23	7.00	6.48	6.82	6.65
Mean	8.13	8.31		7.87	8.11		7.67	7.91		7.46	7.69		7.12	7.41	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.05	0.15		0.05	0.16		0.06	0.17		0.06	0.19		0.07	0.21	
C	0.07	0.21		0.08	0.24		0.08	0.24		0.09	0.26		0.10	0.30	
S × C	0.10	NS		0.11	NS		0.11	NS		0.12	NS		0.14	NS	

Storage conditions (S)
S₁= Ambient storage
S₂= Cold storage

Storage containers (C)
C₁= Vacuum packed bags
C₂= Polythene bags

C₃= Cloth bags
C₄= Gunny bags

Table 4. Influence of packaging and storage conditions on total seedling length (cm) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	23.14	23.14	23.14	22.94	23.10	23.02	22.77	22.95	22.86	22.49	22.68	22.59	22.22	22.39	22.30
C ₂	23.16	23.07	23.12	22.71	22.88	22.80	22.39	22.75	22.57	22.10	22.40	22.25	21.64	22.03	21.84
C ₃	23.16	23.17	23.17	22.31	22.72	22.51	21.98	22.37	22.17	21.70	22.15	21.92	21.37	21.67	21.52
C ₄	22.94	23.09	23.02	22.20	22.43	22.32	21.73	22.31	22.02	21.41	21.89	21.65	20.88	21.49	21.19
Mean	23.10	23.12		22.54	22.78		22.22	22.59		21.92	22.28		21.53	21.89	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.05	NS		0.14	NS		0.13	NS		0.12	NS		0.11	0.34	
C	0.07	NS		0.19	NS		0.18	0.56		0.17	0.53		0.16	0.49	
S × C	0.11	NS		0.27	NS		0.26	NS		0.24	NS		0.23	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	22.10	22.13	22.12	21.78	21.93	21.86	21.61	21.80	21.70	21.00	21.43	21.21	20.62	20.87	20.74
C ₂	21.42	21.83	21.63	21.14	21.47	21.30	20.90	21.32	21.11	20.32	20.70	20.51	19.90	20.31	20.11
C ₃	21.03	21.45	21.24	20.33	21.11	20.72	19.94	20.55	20.25	19.56	19.94	19.75	18.49	19.07	18.78
C ₄	20.52	21.25	20.89	19.31	19.47	19.39	18.55	20.03	19.29	17.82	19.67	18.75	16.69	18.32	17.51
Mean	21.27	21.67		20.64	21.00		20.25	20.93		19.68	20.43		18.93	19.64	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.11	0.34		0.11	0.33		0.10	0.30		0.10	0.29		0.09	0.28	
C	0.16	0.48		0.15	0.47		0.14	0.43		0.14	0.42		0.13	0.40	
S × C	0.22	NS		0.22	NS		0.20	0.60		0.19	0.58		0.19	0.57	

Storage conditions (S)
S₁= Ambient storage
S₂= Cold storage

Storage containers (C)
C₁= Vacuum packed bags
C₂= Polythene bags

C₃= Cloth bags
C₄= Gunny bags

ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to other treatments. While gunny bags (C_4) recorded significantly lower values for seedling length under both ambient storage (S_1) and cold storage (S_2), which was significantly lower compared to all other treatments.

At 8th months of storage, among the interactions, vacuum packed bags stored under cold storage (C_1S_2) recorded higher values (22.39 cm) followed by vacuum packed bags stored under ambient condition (C_1S_1) (22.22 cm); while the lower values were found in gunny bags stored under ambient storage (C_4S_1) (20.88 cm) followed by cloth bags stored under ambient storage (C_3S_1) (21.37 cm). A similar trend continued at 10, 12, 14, 16 and 18 months of storage. At 18 months of storage, seedling length was significantly higher in vacuum packaged bags (C_1) (20.87 cm) and lower values were in gunny bags (C_4) (16.69 cm) over all other treatments under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1), but significant differences were observed between ambient storage (S_1) and cold storage (S_2) under gunny bags (C_4). Among the interactions, significantly lower values of total seedling length was observed in gunny bags stored under ambient storage (C_4S_1) (16.69 cm), which was significantly lower compared to all other treatments, except cloth bags stored under ambient storage (C_3S_1). Similarly, cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves. Among storage conditions, cold storage (S_2) recorded significantly higher seedling length compared to ambient storage (S_1) at all the stages of storage. It was clear from result, irrespective of storage conditions; vacuum packaged bags (C_1) had significantly higher values over all other treatments throughout the storage period.

4.1.5 Seedling dry weight (mg)

The data on seedling dry weight indicated significant differences due to storage period (Table 5). Among the storage conditions, cold storage (S_2) recorded significant differences higher seedling dry weight compared to ambient storage (S_1) at all the stages of storage period. Among the storage containers, vacuum packaged bags (C_1) recorded significantly higher seedling dry weight compared to polythene bags (C_2).

But, significantly lower seedling dry weight was observed in gunny bags (C_4) followed by cloth bags (C_3), which was significantly lower compared to all other containers. As the storage period advanced, the values of seedling dry weight showed declining trend among all the treatments throughout the storage period.

During 8th month, significant differences were noticed due to interaction of storage containers and storage conditions ($S \times C$). Higher values of seedling dry weight was found in vacuum packed bags stored under cold storage (S_2C_1) (78.3 cm) followed by vacuum packed bags stored under ambient storage (S_1C_1) (74.6 cm). Lower values of seedling dry weight was observed in gunny bags stored under ambient storage (C_4S_1) (64.6 cm) followed by cloth bags stored under ambient storage (C_3S_1) (68.3 cm), which was lower compared to all other treatments and did not differ significantly among themselves. A similar trend continued from 10 months of storage and up to 18 months of storage. Among interactions, cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2), gunny bags stored under ambient storage (C_4S_1) and gunny bags stored under cold storage (C_4S_2) and polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), vacuum packed bags stored under ambient condition (C_1S_1) and vacuum packed bags stored under cold storage (C_1S_2) were at par with each other. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher seedling dry weight (71.0 cm) compared to gunny bags (C_4) (52.1 cm) under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1) and gunny bags (C_4). Lower seedling dry weight found in gunny bags stored under ambient storage (C_4S_1), which was significantly lower compared to all other treatments, except gunny bags stored under cold storage (C_4S_2). Similarly, cloth bags stored under cold storage (C_3S_2) and polythene bags stored under ambient storage (C_2S_1) and polythene bags stored under cold storage (C_2S_2) and polythene bags stored under ambient storage (C_2S_1) did not differ significantly among themselves. It is clear from results that vacuum packaged bags (C_1) maintained higher values of seedling dry weight compared to all other containers at all the stages of storage period.

Table 5: Influence of packaging and storage conditions on seedling dry weight (mg/10seedlings) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	81.2	80.5	80.9	81.3	81.6	81.5	80.1	80.3	80.2	76.2	78.7	77.4	74.6	78.3	76.5
C ₂	80.4	80.8	80.6	78.8	80.4	79.6	77.6	79.0	78.3	73.5	75.3	74.5	73.0	73.6	73.3
C ₃	80.8	81.2	81.0	79.7	80.3	80.0	71.3	73.6	72.5	69.6	73.2	71.5	68.3	70.5	69.5
C ₄	81.1	80.7	80.9	78.3	78.6	78.5	70.2	72.1	71.2	68.0	70.6	69.3	64.6	70.1	67.3
Mean	80.9	80.8		79.5	80.2		74.8	76.2		71.9	74.5		70.1	73.2	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.30	NS		0.51	NS		0.47	NS		0.54	1.65		0.59	1.80	
C	0.48	NS		0.71	NS		0.67	2.02		0.77	2.33		0.84	2.55	
S × C	0.67	NS		1.01	NS		0.94	NS		1.09	NS		1.19	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	74.2	76.0	75.1	73.3	75.3	74.3	70.6	74.0	72.3	68.4	73.3	70.8	63.3	71.0	67.2
C ₂	71.3	73.0	72.1	70.6	71.3	71.0	69.5	69.6	69.6	64.6	67.3	66.0	60.3	63.1	61.7
C ₃	67.0	70.3	68.7	64.3	67.8	66.0	60.6	67.3	64.0	60.3	66.1	63.2	58.0	59.3	58.6
C ₄	63.2	66.7	64.9	60.3	65.3	62.8	56.3	62.6	59.5	50.0	61.3	55.6	48.4	52.1	50.2
Mean	68.9	71.5		67.1	69.9		64.3	68.4		60.8	67.0		57.5	61.4	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.63	1.91		0.66	2.01		0.69	2.11		0.70	2.12		0.72	2.18	
C	0.89	2.71		0.94	2.85		0.98	2.98		0.99	3.00		1.02	3.08	
S × C	1.26	NS		1.33	NS		1.39	NS		1.40	4.24		1.44	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

4.1.6 Seedling vigour index (SVI)

The data pertaining to seedling vigour index as influenced by storage containers and storage conditions measured up to 18 months presented in Table 6 showed significant differences between treatments and storage containers and their interaction. Among the containers, more declining trend was found in gunny bags (C_4) followed cloth bags (C_3), while gradual and less decline showed in vacuum packaged bags (C_1) followed by polythene bags (C_2) at all the stages of storage period. No significant differences were observed between the storage containers, storage conditions and their interaction, up to 4 months of storage. Among the storage containers, maximum seedling vigour index was observed in vacuum packaged bags (C_1) compared to polythene bags (C_2) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to all other treatments. Significantly lower seedling vigour index was found in gunny bags (C_4), which was significantly lower compared to all other containers. However, no significant differences were observed at this stage.

At 8th months of storage, among the interactions, lower seedling vigour index (1833) was recorded in gunny bags stored under ambient storage (C_4S_1) followed by cloth bags stored under ambient storage (C_3S_1), which was lower over all other treatments while, vacuum packed bags stored under cold storage (S_2C_1) recorded maximum seedling vigour index followed by vacuum packed bags stored under ambient storage (S_1C_1), but both did not differ significantly among themselves. A similar trend was continued at 10, 12, 14, 16, 18 months. At the end of 18 months, among the containers, vacuum packaged bags (C_1) recorded significantly higher seedling vigour index compared to all other treatments under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1). Among the interactions, significantly lower seedling vigour index (1060) values were observed in gunny bags stored under ambient storage (C_4S_1) and higher values were observed in vacuum packed bags stored under cold storage (C_1S_2) (1956). It was further observed that, no significant differences were found within the treatments. Similarly, cloth bags stored under ambient storage (C_3S_1) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves. It was noticed from the results that vacuum packaged bags (C_1) maintained significantly higher seedling vigour index over all other containers throughout the storage period.

4.1.7 Mobilization efficiency (%)

The influence of different packaging and storage conditions on mobilization efficiency presented in Table 7 indicated significant differences between the treatments at all the stages of storage, except at two months of storage. Among storage containers, vacuum packaged bags (C_1) recorded significantly higher values of mobilization efficiency over all other treatments under ambient storage (S_1) and cold storage (S_2). Among the interactions, maximum mobilization efficiency was observed in vacuum packed bags stored under cold storage (S_2C_1) followed by vacuum packed bags stored under ambient storage (S_1C_1). But, both did not differ significantly among themselves and were significantly higher compared to all other treatments. Significantly lower mobilization efficiency was observed in gunny bags (C_4), which was significantly lower compared to all other treatments. As the storage period progressed, the mobilization efficiency decreased among all the containers at all the stages of storage.

At sixth months of storage, significantly higher values of mobilization efficiency (51.1%) were observed in vacuum packaged bags (C_1) under both ambient storage (S_1) and cold storage (S_2) compared to polythene bags (C_2) (48.9%) followed by cloth bags (C_3) (47.6), respectively. A similar trend was noticed from 8 months of storage and up to 18 months of storage. Lower mobilization efficiency was observed in gunny bags stored under ambient storage (C_4S_1) (44.1%), which was lower over all other treatments. It was further observed that, cold storage (S_2) recorded significantly higher values of mobilization efficiency compared to ambient storage (S_1) throughout the storage period. However, treatment combinations polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) were at par with each other. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher mobilization efficiency (46.1%) over all other containers under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1). Significantly lower mobilization efficiency (%) was observed in gunny bags stored under ambient storage (C_4S_1) (41.1), which was significantly lower compared to all other treatments, except gunny bags stored under cold storage (C_4S_2). Similarly, cloth bags stored under cold storage (C_3S_2), polythene

Table 6. Influence of packaging and storage conditions on seedling vigour index at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	2237	2239	2238	2210	2233	2221	2183	2218	2200	2149	2186	2168	2108	2152	2130
C ₂	2241	2229	2235	2184	2207	2196	2135	2177	2156	2091	2124	2107	2008	2062	2035
C ₃	2227	2232	2229	2127	2173	2150	2089	2137	2113	2044	2090	2067	1981	2027	2004
C ₄	2212	2216	2214	2106	2141	2124	2042	2124	2083	1934	2066	2000	1833	2001	1917
Mean	2229	2229		2157	2188		2112	2164		2055	2116		1983	2060	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	13.38	NS		17.95	NS		20.74	NS		21.51	NS		21.70	65.81	
C	20.26	NS		25.39	NS		29.34	NS		30.42	92.28		30.68	93.07	
S × C	31.90	NS		35.90	NS		41.49	NS		43.02	NS		43.39	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	2089	2118	2104	2055	2093	2074	2030	2063	2047	1967	2016	1992	1922	1956	1939
C ₂	1933	2018	1976	1897	1968	1933	1836	1919	1878	1759	1806	1783	1636	1738	1687
C ₃	1878	1943	1910	1718	1802	1760	1500	1676	1588	1374	1505	1440	1199	1354	1276
C ₄	1729	1917	1823	1476	1654	1565	1329	1605	1467	1196	1481	1338	1060	1286	1173
Mean	1907	1999		1787	1879		1674	1816		1574	1702		1454	1584	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	22.45	68.11		21.95	66.59		23.93	72.57		25.17	76.34		26.13	79.27	
C	31.75	96.32		31.05	94.18		33.84	102.63		35.59	107.96		36.96	112.11	
S × C	44.91	NS		43.91	NS		47.85	NS		50.34	NS		52.27	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 7. Influence of packaging and storage conditions on mobilization efficiency (%) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	52.7	52.8	52.8	52.8	53.0	52.9	52.0	52.1	52.0	49.5	51.1	50.3	48.4	50.8	49.6
C ₂	51.9	52.4	52.2	51.1	52.2	51.7	50.4	51.3	50.8	47.8	48.9	48.3	47.4	47.8	47.6
C ₃	52.2	52.4	52.3	51.7	52.1	51.9	46.3	47.8	47.0	45.2	47.6	46.4	44.3	45.8	45.1
C ₄	51.8	51.9	51.8	50.8	51.0	50.9	36.4	46.8	41.6	44.1	45.8	45.0	41.9	45.5	43.7
Mean	52.1	52.43		51.6	52.1		46.2	49.53		46.6	48.3		45.5	47.5	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.23	NS		0.34	NS		0.38	1.15		0.37	1.13		0.36	1.10	
C	0.32	NS		0.49	NS		0.54	1.62		0.53	1.59		0.51	1.55	
S × C	0.44	NS		0.69	NS		0.76	2.30		0.74	NS		0.72	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	48.1	49.3	48.7	47.6	48.9	48.2	45.8	48.0	46.9	44.4	47.6	46.0	41.1	46.1	43.6
C ₂	46.3	47.4	46.8	45.8	46.3	46.1	45.2	45.2	45.2	41.9	43.7	42.8	39.1	41.0	40.1
C ₃	43.5	45.6	44.6	41.8	44.0	42.9	39.3	43.7	41.5	39.1	42.9	41.0	37.6	38.5	38.1
C ₄	41.0	43.3	42.1	39.1	42.4	40.8	36.6	40.6	38.6	32.5	39.8	36.1	31.4	33.8	32.6
Mean	44.7	46.4		43.6	45.4		41.7	44.4		39.5	43.5		37.3	39.8	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.35	1.05		0.34	1.03		0.29	0.89		0.28	0.84		0.27	0.81	
C	0.49	1.49		0.48	1.46		0.42	1.26		0.39	1.19		0.38	1.15	
S × C	0.69	NS		0.68	NS		0.59	1.79		0.55	1.68		0.54	1.62	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

bags stored under ambient storage (C_2S_1) and polythene bags stored under cold storage (C_2S_2) did not differ significantly among themselves. It was also further observed from the results that vacuum packaged bags (C_1) maintained significantly higher mobilization efficiency throughout the storage period compared to all other treatments at all the stages of storage.

4.1.8 Mean daily germination

The data pertaining to mean daily germination indicated significant differences due to storage period (Table 8). The decreased trend was observed in mean daily germination from 6 months of storage and up to 18 months of storage in all the containers and at all the stages of storage. It decreased with an increase in storage period with vacuum packaged bags (C_1) recording significantly higher values of mean daily germination compared to all other treatments, which was significantly superior over all other treatments. Significantly lower values were observed in gunny bags (C_4), which was significantly lower compared to all other treatments. Up to six months, no significant differences were observed between treatments, storage conditions and their interactions.

At 6th months of storage, significantly lower mean daily germination values (7.86) were recorded in vacuum packed bags stored under cold storage (C_1S_2) followed by vacuum packed bags stored under ambient condition (C_1S_1) (7.53). However, both did not differ significantly among themselves. Similarly, the treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) were at par with each other. Significantly higher mean daily germination values (8.03) were recorded in vacuum packed bags stored under cold storage (C_1S_2) followed by vacuum packed bags stored under ambient condition (C_1S_1) (7.97), which was significantly higher over all other treatments. A similar trend was continued 8, 10, 12, 14, 16 and 18 months of storage. At 18 months of storage, vacuum packaged bags (C_1) recorded significant higher values of mean daily germination under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were found between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1). While, gunny bags stored under ambient storage (C_4S_1) had significantly lower mean daily germination, which was significantly lower compared to all other treatments, except cloth bags stored under ambient storage (C_3S_1) and gunny bags stored under ambient storage (C_4S_1). Similarly, cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves. It was further observed that, there were no significant differences within treatments under both in vacuum packaged bags (C_1), polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) throughout the storage period.

4.1.9 Electrical conductivity ($dS\ m^{-1}$)

The observations on electrical conductivity as influenced by different packaging and storage conditions showed significant differences up to 18 months of storage (Table 9). In general, there was increased trend in electrical conductivity from 4 months of storage and up to 18 months of storage. It was further observed that, electrical conductivity was much higher in gunny bags (C_4) followed by cloth bags (C_3) and least and much lesser in vacuum packaged bags (C_1) followed by polythene bags (C_2). Among the storage containers, gunny bags (C_4) recorded maximum values of electrical conductivity under both ambient storage (S_1) and cold storage (S_2), which were significantly higher over all other containers. Significantly lower values of electrical conductivity were observed in vacuum packaged bags (C_1), which was significantly lower compared to all other treatments. The values of electrical conductivity increased with an increased in storage period among all the containers and at all the stages of storage.

At 6th months of storage, higher electrical conductivity ($dS\ m^{-1}$) values were found in gunny bags stored under ambient storage (C_4S_1) (0.251) followed by gunny bags stored under cold storage (C_4S_2) (0.215). However, both did not differ significantly among themselves. While, lower values of electrical conductivity was observed in vacuum packed bags stored under cold storage (C_1S_2) followed by vacuum packed bags stored under ambient condition (C_1S_1), which was significantly lower compared to other containers and both did not differ significantly among themselves. Among the treatments, the parallel trend was continued from 8 months of storage and up to 18 months of storage. At the end of storage period, significantly lower values of electrical conductivity ($dS\ m^{-1}$) was recorded in vacuum packaged bags (C_1) (0.183) followed by

Table 8. Influence of packaging and storage conditions on mean daily germination at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.06	8.02	8.04	8.03	8.05	8.04	7.99	8.05	8.02	7.97	8.03	8.00	7.91	8.01	7.96
C ₂	8.03	8.08	8.05	8.02	8.04	8.03	7.95	7.97	7.96	7.88	7.90	7.89	7.73	7.80	7.77
C ₃	8.09	8.04	8.07	7.95	7.97	7.96	7.92	7.96	7.94	7.85	7.87	7.86	7.72	7.79	7.76
C ₄	8.00	8.07	8.03	7.91	7.96	7.93	7.83	7.93	7.88	7.53	7.86	7.69	7.32	7.76	7.54
Mean	8.04	8.05		7.97	8.00		7.92	7.98		7.81	7.91		7.67	7.84	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.01	NS		0.03	NS		0.03	NS		0.03	0.08		0.03	0.08	
C	0.02	NS		0.04	NS		0.04	NS		0.04	0.12		0.04	0.11	
S × C	0.03	NS		0.06	NS		0.05	NS		0.06	0.17		0.05	0.16	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.88	7.97	7.93	7.86	7.95	7.91	7.83	7.88	7.86	7.80	7.84	7.82	7.77	7.81	7.79
C ₂	7.52	7.70	7.61	7.48	7.64	7.56	7.32	7.50	7.41	7.21	7.27	7.24	6.85	7.13	6.99
C ₃	7.44	7.55	7.49	7.04	7.12	7.08	6.27	6.80	6.53	5.85	6.29	6.07	5.40	5.92	5.66
C ₄	7.02	7.52	7.27	6.37	7.08	6.73	5.97	6.68	6.32	5.59	6.27	5.93	5.29	5.85	5.57
Mean	7.47	7.69		7.19	7.45		6.85	7.21		6.62	6.92		6.33	6.68	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.03	0.08		0.03	0.08		0.02	0.07		0.02	0.07		0.02	0.06	
C	0.04	0.11		0.04	0.11		0.03	0.10		0.03	0.10		0.03	0.09	
S × C	0.05	0.16		0.05	0.15		0.05	0.15		0.05	0.14		0.04	0.13	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 9. Influence of packaging and storage conditions on electrical conductivity (dS m⁻¹) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	0.161	0.169	0.165	0.166	0.164	0.165	0.169	0.167	0.168	0.173	0.170	0.172	0.175	0.172	0.174
C ₂	0.170	0.152	0.161	0.177	0.167	0.172	0.180	0.170	0.175	0.183	0.173	0.178	0.187	0.171	0.179
C ₃	0.154	0.162	0.158	0.202	0.195	0.199	0.207	0.200	0.204	0.212	0.205	0.209	0.217	0.210	0.214
C ₄	0.167	0.151	0.159	0.205	0.198	0.202	0.210	0.203	0.207	0.215	0.208	0.212	0.220	0.213	0.217
Mean	0.163	0.159		0.188	0.181		0.192	0.185		0.196	0.189		0.200	0.192	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.002	NS		0.002	0.005		0.002	0.006		0.002	0.006		0.002	0.007	
C	0.003	NS		0.002	0.007		0.003	0.008		0.003	0.009		0.003	0.009	
S × C	0.004	NS		0.003	NS		0.004	NS		0.004	NS		0.004	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	0.178	0.174	0.176	0.180	0.175	0.177	0.182	0.177	0.179	0.185	0.179	0.182	0.186	0.183	0.185
C ₂	0.188	0.181	0.184	0.189	0.174	0.181	0.191	0.176	0.183	0.194	0.179	0.186	0.198	0.184	0.191
C ₃	0.222	0.215	0.219	0.232	0.225	0.229	0.252	0.245	0.249	0.262	0.255	0.259	0.272	0.265	0.269
C ₄	0.226	0.218	0.222	0.235	0.228	0.232	0.255	0.248	0.252	0.265	0.258	0.262	0.275	0.268	0.272
Mean	0.204	0.197		0.209	0.201		0.220	0.212		0.226	0.218		0.233	0.225	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.002	0.006		0.002	0.006		0.002	0.007		0.002	0.007		0.002	0.008	
C	0.003	0.009		0.003	0.009		0.003	0.010		0.003	0.010		0.003	0.011	
S × C	0.004	NS		0.004	NS		0.005	NS		0.005	NS		0.005	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 10. Influence of packaging and storage conditions on fungal load (cfu/g, 10⁴) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	3.15	3.76	3.46	3.00	2.00	2.50	3.34	2.33	2.84	3.36	2.35	2.86	3.00	2.34	2.67
C ₂	3.80	3.26	3.53	4.33	4.00	4.17	5.35	5.00	5.18	5.67	4.69	5.18	5.36	4.33	4.85
C ₃	3.43	3.35	3.39	7.00	6.00	6.50	7.67	6.68	7.17	8.00	6.00	7.00	8.01	6.03	7.02
C ₄	3.62	3.17	3.40	8.67	7.68	8.17	9.33	8.00	8.67	9.33	8.34	8.84	8.67	8.00	8.33
Mean	3.50	3.39		5.75	4.92		6.42	5.50		6.59	5.34		6.26	5.18	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.04	NS		0.06	0.19		0.08	0.24		0.09	0.27		0.09	0.26	
C	0.06	NS		0.09	0.28		0.11	0.35		0.13	0.39		0.12	0.37	
S × C	0.09	NS		0.13	NS		0.16	NS		0.18	0.55		0.17	0.53	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	2.69	2.33	2.51	2.67	1.34	2.00	2.34	1.34	1.84	2.01	1.00	1.51	1.67	1.00	1.33
C ₂	4.70	5.00	4.85	4.68	4.35	4.52	4.00	3.67	3.83	4.38	4.33	4.36	4.35	3.00	3.68
C ₃	8.69	6.68	7.68	9.00	6.67	7.83	8.68	7.00	7.84	8.67	7.33	8.00	9.33	7.69	8.51
C ₄	9.67	8.33	9.00	11.00	9.01	10.01	10.33	9.00	9.67	10.00	9.00	9.50	10.68	9.67	10.18
Mean	6.43	5.59		6.84	5.34		6.34	5.25		6.27	5.42		6.51	5.34	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.09	0.28		0.10	0.30		0.10	0.29		0.10	0.29		0.10	0.31	
C	0.13	0.40		0.14	0.42		0.13	0.40		0.14	0.41		0.14	0.43	
S × C	0.19	0.56		0.20	0.59		0.19	0.58		0.19	0.58		0.20	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

polythene bags (C_2) (0.184) under ambient storage (S_1) and cold storage (S_2). The maximum values of electrical conductivity ($dS\ m^{-1}$) were recorded in gunny bags stored under ambient storage (C_4S_1) (0.275) followed by gunny bags stored under cold storage (C_4S_2) (0.268) which were significantly higher compared to all other treatments and on par with each other. It was further observed that, ambient storage (S_1) had higher values of electrical conductivity compared to cold storage (S_2) among all the containers at all the stages of storage period.

4.1.10 Fungal load (cfu/g)

The fungal or mold population as influenced by packaging and storage conditions showed significant differences due to storage period (Table 10 and Plates 5a to 5b). In general, there was a decline in mold population under C_1 ; while in gunny bags (C_4), the count fluctuated, which increased up to 12 months and then was on a decreasing trend. Significantly higher population counts were observed in gunny bags (C_4), which was significantly superior over all other treatments and least population counts was observed in vacuum packaged bags (C_1), which was significantly lower compared to all other treatments throughout the storage period.

At 6th months of storage, significantly higher fungal population (cfu/g) count was observed in gunny bags (C_4) (8.84×10^4), which was significantly higher compared to all other treatments, while least was in vacuum packaged bags (C_1) (2.86×10^4), which was significantly lower over all other treatments under both ambient storage (S_1) and cold storage (S_2). At 12 months of storage, a highly significant population count was obtained in gunny bags (C_4) under ambient storage (S_1), the values of which were several times higher than those of vacuum packaged bags (C_1) treatments. The least population count was observed in vacuum packed bags stored under cold storage (C_1S_2) followed by vacuum packed bags stored under ambient condition (C_1S_1). It was further observed that ambient storage (S_1) recorded maximum fungal population counts among all the treatments compared to cold storage (S_2). A similar trend continued at 14, 16 and 18 months. Among the treatments, cloth bags stored under ambient storage (C_3S_1), gunny bags stored under cold storage (C_4S_2) and polythene bags stored under ambient storage (C_2S_1) and polythene bags stored under cold storage (C_2S_2) did not differ significantly and were on par with each other. At 16 months of storage, significantly lower fungal population (cfu/g) was observed in vacuum packaged bags (C_1) (1.51×10^4) over all other containers under cold storage (S_2). While, significantly higher fungal population (cfu/g) count was observed in gunny bags (C_4) (9.58×10^4) under ambient storage (S_1). Similarly, cloth bags stored under ambient storage (C_3S_1) and gunny bags (C_4) cold storage (S_2) differs significantly.

4.2 BIOCHEMICAL PARAMETERS

4.2.1 Copper content (ppm)

The observations on copper content as influenced by storage containers differed significantly between treatments from 14 months of storage and up to 18 months of storage (Table 11). Up to 12 months of storage, no significant differences were observed between storage containers and storage conditions and their interactions. But after 14 months of storage, significant differences were observed in the treatments, not in storage conditions and their interaction at all the stages of storage. Among the storage containers, vacuum packaged bags (C_1) showed significantly higher values of copper content compared to all other treatments. Significantly lower values of copper content were found in gunny bags (C_4), which was significantly lower over all other treatments.

At 10th months of storage, lower values of copper content were observed in gunny bags stored under ambient storage (C_4S_1) (12 ppm) followed by gunny bags stored under cold storage (C_4S_2) (12.4 ppm) compared to cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) under both ambient storage (S_1) and cold storage (S_2). A similar trend continued from 12 months of storage and up to 18 months of storage. While higher values of copper content were observed in vacuum packed bags stored under cold storage (C_1S_2) (13.8 ppm) followed by vacuum packed bags stored under ambient condition (C_1S_1). But both did not differ significantly among themselves. Among the containers, vacuum packaged bags (C_1) recorded significantly higher values of copper content compared to all other containers under both ambient storage (S_1) and cold storage (S_2). It was further observed that there were no significant differences between storage conditions throughout the storage period. At 18 months of storage, significantly higher values of copper content were found in vacuum packaged bags (C_1) (12.5 ppm) compared to all other containers followed by

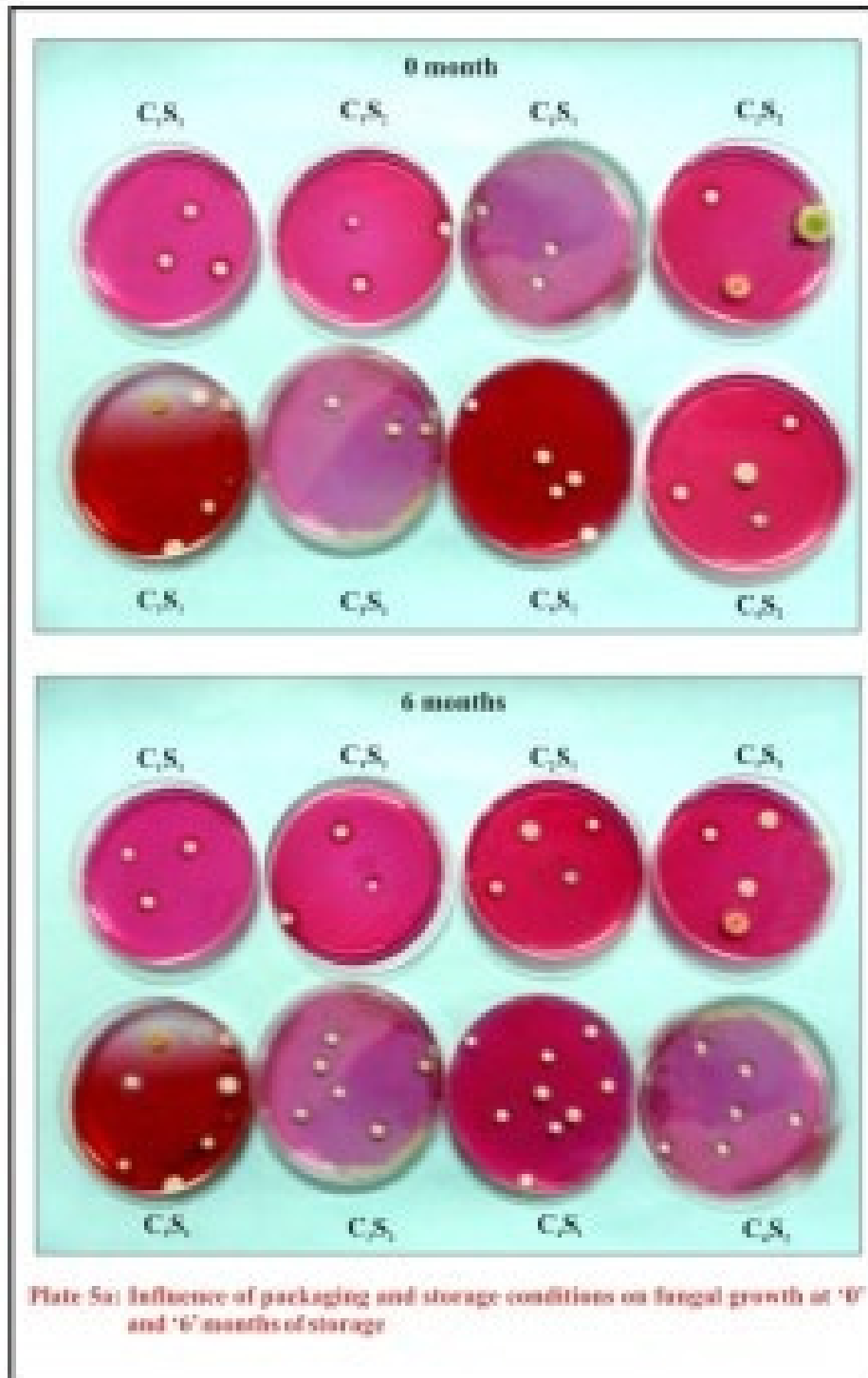


Plate 5a: Influence of packaging and storage conditions on fungal growth at '0' and '6' months of storage

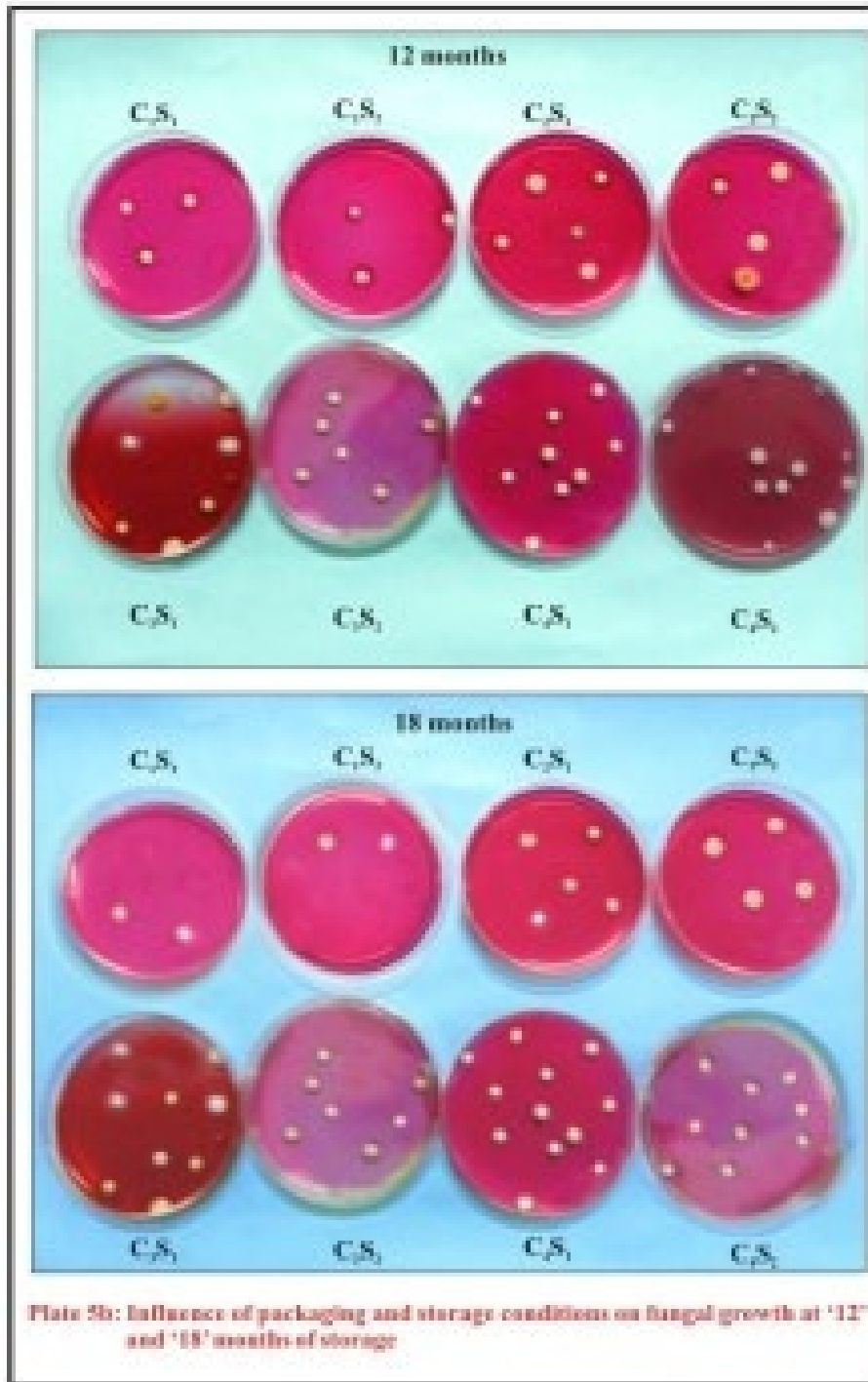


Plate 5b: Influence of packaging and storage conditions on fungal growth at '12' and '18' months of storage kgbh gg

Table 11. Influence of packaging and storage conditions on copper content (Cu, ppm) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C1	14.0	14.1	14.1	13.9	14.1	14.0	13.8	13.9	13.9	13.8	13.9	13.8	13.7	13.8	13.8
C2	14.2	14.1	14.1	13.7	13.9	13.8	13.5	13.8	13.6	13.1	13.6	13.4	12.9	13.4	13.2
C3	14.1	14.2	14.1	13.5	13.6	13.6	13.4	13.5	13.5	12.9	13.0	12.9	12.6	12.7	12.7
C4	14.1	14.2	14.2	13.4	13.6	13.5	13.3	13.4	13.4	12.8	12.9	12.9	12.5	12.7	12.6
Mean	14.1	14.2		13.7	13.8		13.5	13.7		13.2	13.3		12.9	13.1	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.05	NS		0.13	NS		0.17	NS		0.17	NS		0.25	NS	
C	0.08	NS		0.18	NS		0.24	NS		0.24	NS		0.36	NS	
S × C	0.11	NS		0.26	NS		0.33	NS		0.35	NS		0.51	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C1	13.7	13.8	13.7	13.4	13.5	13.5	13.2	13.4	13.3	12.8	13.2	13.0	12.4	12.6	12.5
C2	12.6	13.0	12.8	12.5	12.8	12.6	11.9	12.5	12.2	11.7	12.1	11.9	11.5	11.9	11.7
C3	12.3	12.5	12.4	12.1	12.3	12.2	11.8	11.9	11.9	11.3	11.5	11.4	10.6	10.9	10.8
C4	12.0	12.4	12.2	11.9	12.2	12.0	11.7	11.8	11.8	11.2	11.4	11.3	10.5	10.7	10.6
Mean	12.6	12.9		12.5	12.7		12.2	12.4		11.8	12.0		11.3	11.5	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.28	NS		0.24	NS		0.24	NS		0.17	NS		0.17	NS	
C	0.39	NS		0.34	NS		0.34	1.02		0.25	0.75		0.23	0.71	
S × C	0.56	NS		0.49	NS		0.47	NS		0.35	NS		0.33	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

polythene bags (C_2) under both ambient storage (S_1) and cold storage (S_2); while, significantly lower values were observed in gunny bags (C_4) (10.6 ppm) followed by cloth bags (C_3). Among storage conditions, cold storage (S_2) found to be recorded high values of copper content in both polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) compared to ambient storage (S_1) throughout the storage period. It was observed from the results that, vacuum packaged bags (C_1) maintained higher copper content throughout the storage period under cold storage (S_2) compared to all other treatments and the copper content decreased trend with increase in storage period.

4.2.2 Iron content (ppm)

The data on iron content as influenced by different packaging found to differ significantly between the treatments at all the stages of storage except at initial stages and up to 8 months due to storage period (Table 12). Higher iron content values were found in vacuum packaged bags (C_1) followed by polythene bags (C_2) which did not differ significantly with each other under ambient storage (S_1) and cold storage (S_2). Significantly lower iron content values were observed in gunny bags (C_4) compared to all other treatments, which was significantly lower over all other containers.

At 10th months of storage, higher values of iron content (42.0 ppm) was recorded in vacuum packed bags stored under cold storage (C_1S_2) followed by vacuum packed bags stored under ambient condition (C_1S_1) (41.9 ppm). Lower values of iron content were observed in gunny bags stored under ambient storage (C_4S_1) (41.3 ppm) followed by gunny bags stored under cold storage (C_4S_2) (41.4 ppm), which did not differ significantly among themselves. A Similar trend continued at 12, 14, 16 and 18 months of storage. Among the containers, significant differences were found after 8 months of storage, but no significant differences were observed in storage conditions and their interaction up to 18 months of storage. At 18 months of storage, maximum lower values of iron content (ppm) were recorded in gunny bags stored under ambient storage (C_4S_1) (36.1) and gunny bags stored under cold storage (C_4S_2) (36.2) followed by cloth bags stored under ambient storage (C_3S_1) and cloth bags stored under cold storage (C_3S_2) under both ambient storage (S_1) and cold storage (S_2). Among containers, vacuum packaged bags (C_1) maintained higher iron content values throughout the storage period over all other treatments. However the treatments, vacuum packed bags stored under ambient condition (C_1S_1), polythene bags stored under cold storage (C_2S_2) and polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2) were at par with each other and did not differ significantly among themselves throughout the storage period.

4.2.3 Zinc content (ppm)

Influence of packaging and storage conditions on zinc content presented in Table 13 indicated significant differences between treatments. In general, the zinc content gradually decreased with an advancement in storage period in all the treatments. Up to 8 months of storage, no significant differences were observed between storage containers, storage conditions and their interactions, but significant differences were found from 10 months of storage and up to 18 months of storage. Among the storage containers, zinc content values were maximum in vacuum packaged bags (C_1) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to all other treatments. Significantly lower zinc values were found in gunny bags (C_4), which was significantly lower over all other treatments at all the stages of storage.

At 10th months of storage, higher zinc content was recorded in vacuum packed bags stored under cold storage (C_1S_2) (20.5 ppm) followed by vacuum packed bags stored under ambient condition (C_1S_1) (20.4 ppm), while, the treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2), gunny bags stored under ambient storage (C_4S_1) and gunny bags stored under cold storage (C_4S_2) were at par each other. Lower zinc (19.7 ppm) was observed in gunny bags stored under ambient storage (C_4S_1), which was significantly lower compared to all other treatments. A similar trend continued at 12, 14, 16 and 18 months. At 18 months of storage, vacuum packaged bags (C_1) recorded maximum zinc content (19.6 ppm) under both ambient storage (S_1) and cold storage (S_2) followed by polythene bags (C_2), which was significantly higher compared to all other treatments. However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1) and polythene bags (C_2). It was further observed that cold storage (S_2) recorded higher zinc content among all the containers compared to ambient storage (S_1) at all the stages of storage. It was observed from results clearly that vacuum packaged bags (C_1) maintained higher zinc content compared to all other treatments throughout the storage period.

Table 12. Influence of packaging and storage conditions on iron content (Fe, ppm) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C1	43.1	43.2	43.2	43.1	43.2	43.1	42.8	42.9	42.8	42.4	42.5	42.4	42.2	42.3	42.2
C2	43.2	43.1	43.2	43.0	43.1	43.0	42.6	42.7	42.6	42.2	42.3	42.2	42.1	42.2	42.1
C3	43.1	43.0	43.1	42.8	42.9	42.8	42.5	42.6	42.5	42.0	42.1	42.0	41.8	41.9	41.8
C4	43.2	43.0	43.1	42.5	42.6	42.5	42.4	42.5	42.4	41.9	42.0	42.0	41.7	41.8	41.8
Mean	43.2	43.1		42.8	42.9		42.6	42.7		42.1	42.2		41.9	42.0	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.04	NS		0.14	NS		0.14	NS		0.13	NS		0.12	NS	
C	0.07	NS		0.20	NS		0.19	NS		0.19	NS		0.18	NS	
S × C	0.11	NS		0.27	NS		0.27	NS		0.27	NS		0.26	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C1	41.9	42.0	41.9	41.8	41.9	41.9	41.6	41.7	41.7	41.4	41.5	41.4	41.2	41.3	41.2
C2	41.7	41.8	41.8	41.6	41.7	41.6	41.4	41.5	41.4	41.2	41.3	41.2	41.0	41.1	41.0
C3	41.8	41.4	41.6	41.2	41.3	41.2	38.1	38.4	38.2	37.2	37.3	37.2	36.1	36.3	36.2
C4	41.3	41.4	41.3	41.1	41.2	41.1	38.0	38.2	38.1	37.2	37.2	37.2	36.1	36.2	36.1
Mean	41.6	41.7		41.4	41.5		39.8	39.9		39.2	39.3		38.6	38.7	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.12	NS		0.13	NS		0.12	NS		0.09	NS		0.09	NS	
C	0.17	0.51		0.18	0.55		0.18	0.53		0.13	0.41		0.13	0.40	
S × C	0.24	NS		0.25	NS		0.25	NS		0.19	NS		0.19	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 13. Influence of packaging and storage conditions on zinc content (Zn, ppm) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C1	21.5	21.4	21.4	21.6	21.7	21.6	21.3	21.4	21.3	20.9	20.9	20.9	20.7	20.8	20.7
C2	21.5	21.6	21.5	21.4	21.5	21.4	21.1	21.2	21.1	20.6	20.7	20.7	20.5	20.6	20.6
C3	21.6	21.7	21.6	21.3	21.3	21.3	20.9	21.1	21.0	20.4	20.5	20.5	20.2	20.4	20.3
C4	21.7	21.5	21.6	21.0	21.3	21.2	20.8	20.9	20.9	20.4	20.4	20.4	20.2	20.3	20.2
Mean	21.6	21.5		21.3	21.4		21.0	21.2		20.6	20.7		20.4	20.5	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.04	NS		0.09	NS		0.10	NS		0.09	NS		0.10	NS	
C	0.07	NS		0.13	NS		0.14	NS		0.12	NS		0.14	NS	
S × C	0.10	NS		0.18	NS		0.20	NS		0.17	NS		0.19	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C1	20.4	20.5	20.4	20.3	20.4	20.3	20.1	20.2	20.1	19.8	19.9	19.9	19.6	19.7	19.6
C2	20.2	20.3	20.3	20.1	20.2	20.1	19.8	20.0	19.9	19.6	19.8	19.7	19.4	19.5	19.5
C3	19.8	19.9	19.8	19.6	19.7	19.7	16.6	16.8	16.7	15.7	15.8	15.7	14.7	14.9	14.8
C4	19.7	19.8	19.7	19.5	19.6	19.6	16.4	16.6	16.5	15.6	15.7	15.7	14.5	14.8	14.7
Mean	20.0	20.1		19.9	20.0		18.2	18.4		17.7	17.8		17.1	17.2	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.09	NS		0.08	NS		0.07	NS		0.06	NS		0.05	NS	
C	0.13	0.40		0.12	0.36		0.11	0.32		0.09	0.27		0.09	0.26	
S × C	0.19	NS		0.17	NS		0.15	NS		0.13	NS		0.12	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 14. Influence of packaging and storage conditions on manganese content (Mn, ppm) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C1	41.0	41.0	41.0	41.0	41.1	41.1	40.8	40.8	40.8	40.4	40.5	40.4	40.2	40.3	40.2
C2	41.1	41.2	41.2	40.9	41.0	41.0	40.6	40.6	40.6	40.2	40.3	40.2	40.0	40.2	40.1
C3	41.0	40.8	40.1	40.8	40.9	40.8	40.5	40.6	40.5	40.0	40.1	40.0	39.8	39.9	39.8
C4	41.1	41.0	41.1	40.5	40.8	40.7	40.4	40.5	40.4	39.9	40.0	39.9	39.7	39.8	39.7
Mean	41.0	41.0		40.8	40.9		40.6	40.7		40.1	40.2		39.9	40.0	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.17	NS		0.57	NS		0.55	NS		0.49	NS		0.49	NS	
C	0.25	NS		0.81	NS		0.78	NS		0.70	NS		0.69	NS	
S × C	0.35	NS		1.15	NS		1.10	NS		0.99	NS		0.98	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C1	39.9	40.0	39.9	39.8	39.9	39.9	39.6	39.7	39.6	39.3	39.5	39.4	39.2	39.3	39.2
C2	39.7	39.8	39.8	39.6	39.7	39.6	39.3	39.5	39.4	39.2	39.3	39.2	38.9	39.1	39.0
C3	39.3	39.4	39.4	39.2	39.3	39.2	36.1	36.4	36.3	35.2	35.3	35.3	34.4	34.5	34.4
C4	39.2	39.4	39.3	39.1	39.2	39.1	35.9	36.2	36.1	35.1	35.3	35.2	34.1	34.4	34.2
Mean	39.5	39.6		39.4	39.5		37.8	38.0		37.2	37.3		36.6	36.8	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.48	NS		0.44	NS		0.42	NS		0.40	NS		0.40	NS	
C	0.67	NS		0.63	NS		0.60	1.81		0.58	1.78		0.56	1.71	
S × C	0.96	NS		0.89	NS		0.84	NS		0.82	NS		0.80	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

4.2.4 Manganese content (ppm)

The data pertaining to manganese content as influenced by packaging and storage conditions shown in Table 14 indicated significant differences between the treatments. It decreased with a progress in storage period in all the treatments and at all the stages of storage under both ambient storage (S_1) and cold storage (S_2). There were no significant differences between treatments and storage conditions and their interactions up to 12 months of storage. But, significant differences were noticed from 12 months of storage onwards, only in storage containers, but not in storage conditions and their interactions. Among the treatments, vacuum packaged bags (C_1) recorded higher manganese content, while it was lower in gunny bags (C_4) throughout the storage period.

At 14th months of storage, higher manganese content was recorded in vacuum packed bags stored under cold storage (C_1S_2) (39.7 ppm) compared to all other treatments, which was on par with vacuum packed bags stored under ambient condition (C_1S_1) (37.6 ppm). The lower values of manganese content (ppm) were observed in gunny bags stored under ambient storage (C_4S_1) (35.9 ppm), which was on par with gunny bags stored under cold storage (C_4S_2) (36.2 ppm). Treatments polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2), gunny bags stored under ambient storage (C_4S_1) and gunny bags stored under cold storage (C_4S_2) were at par with each other. At 18 months of storage, significantly higher values of manganese content were recorded in vacuum packaged bags (C_1) (39.2 ppm) followed by polythene bags (C_2) (39.1 ppm) under both ambient storage (S_1) and cold storage (S_2). However, both did not differ significantly among themselves. Lower manganese content was recorded in gunny bags stored under ambient storage (C_4S_1) followed by gunny bags stored under cold storage (C_4S_2) under both ambient storage (S_1) and cold storage (S_2) over all other treatments. It was further observed that cold storage (S_2) recorded significantly higher manganese content among all the treatments compared to ambient storage (S_1) throughout the storage period.

4.2.5 Alpha-Amylase activity (mg maltose released/min)

Results obtained on α -amylase activity as influenced by different packaging and storage conditions presented in Table 15 indicated significant differences between the treatments from 8 months of storage and upto 18 months of storage. Among the storage containers, there was gradual reduction in α -amylase activity with an advancement in storage period under ambient storage (S_1) and cold storage (S_2) at all the stages of storage. gunny bags (C_4) recorded significantly higher values of α -amylase activity over all other treatments, while in vacuum packaged bags (C_1) significantly higher α -amylase activity was observed compared to all other treatments at all the stages of storage.

At 8 months of storage, higher alpha-amylase activity were observed in gunny bags stored under ambient storage (C_4S_1) (52 mg maltose released/min) followed by gunny bags stored under cold storage (C_4S_2) (51.9 mg maltose released/min) over all other treatments. Lower values of alpha-amylase activity (mg maltose released/min) were observed in vacuum packed bags stored under cold storage (C_1S_2) (51.3 mg maltose released/min) followed by vacuum packed bags stored under ambient condition (C_1S_1) (51.6 mg maltose released/min) over all other treatments. A similar trend continued at 10, 12, 14, 16 and 18 months of storage under both ambient storage (S_1) and cold storage (S_2). At the end of storage, significantly higher α -amylase activity was observed in gunny bags (C_4) (46.3 mg maltose released/min) followed by cloth bags (C_3) (46.0 mg maltose released/min) compared to polythene bags (C_2) under both ambient storage (S_1) and cold storage (S_2). It was further observed that ambient storage (S_1) recorded higher α -amylase activity compared to cold storage (S_2); while lower values were observed in vacuum packed bags stored under cold storage (C_1S_2) followed by vacuum packed bags stored under ambient condition (C_1S_1). It is clear from results that comprehensible from results gunny bags (C_4) maintained higher α -amylase activity throughout the storage period in all the treatments.

4.2.6 Lipase activity (meq.free fatty acid/min/g)

The data on lipase activity as influenced by different packaging and storage conditions showed significant differences due to storage period (Table 16).

Table 15. Influence of packaging and storage conditions on α -amylase activity (mg maltose released/min) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	55.8	56.0	56.0	55.5	55.3	55.4	54.3	54.0	54.2	52.8	52.6	52.7	51.6	51.3	51.5
C ₂	55.9	55.8	55.8	55.7	55.4	55.5	54.4	54.2	54.3	52.9	52.7	52.8	51.7	51.5	51.6
C ₃	56.1	56.0	56.1	55.8	55.7	55.5	54.6	54.5	54.5	53.1	53.0	53.0	51.9	51.8	51.8
C ₄	56.0	55.8	55.9	55.9	55.8	55.9	54.7	54.6	54.6	53.2	53.1	53.2	52.0	51.9	51.9
Mean	56.0	55.9		55.7	55.6		54.5	54.3		53.04	52.8		51.8	51.6	
	S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)	
S	0.04	NS		0.10	NS		0.10	NS		0.08	NS		0.07	NS	
C	0.07	NS		0.15	NS		0.14	NS		0.12	NS		0.10	0.30	
S \times C	0.09	NS		0.20	NS		0.19	NS		0.17	NS		0.14	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	50.1	49.9	50.0	48.9	48.7	48.8	47.9	47.6	47.8	46.9	46.6	46.81	45.7	45.6	45.7
C ₂	50.2	50.0	50.2	49.0	48.8	48.9	48.0	47.7	47.9	47.0	46.8	46.92	46.9	45.8	46.3
C ₃	50.4	50.3	50.4	49.2	49.1	49.2	48.2	48.1	48.1	47.2	47.1	47.16	46.1	46.0	46.0
C ₄	50.5	50.4	50.5	49.3	49.2	49.3	48.3	48.2	48.2	47.3	47.2	47.27	46.5	46.1	46.3
Mean	50.3	50.2		49.2	49.0		48.1	47.9		47.1	46.9		46.3	45.9	
	S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)	
S	0.07	NS		0.07	NS		0.06	NS		0.05	0.17		0.06	0.19	
C	0.10	0.29		0.09	0.27		0.08	0.24		0.08	0.23		0.09	0.26	
S \times C	0.13	NS		0.13	NS		0.11	NS		0.11	NS		0.12	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 16. Influence of packaging and storage conditions on lipase activity (m.eq. free fatty acid /min/g) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	1.42	1.45	1.43	1.44	1.43	1.44	1.45	1.44	1.45	1.48	1.46	1.47	1.51	1.49	1.50
C ₂	1.47	1.43	1.45	1.47	1.45	1.46	1.52	1.48	1.50	1.53	1.52	1.53	1.62	1.60	1.61
C ₃	1.44	1.49	1.47	1.51	1.50	1.51	1.57	1.53	1.55	1.71	1.57	1.64	1.75	1.64	1.69
C ₄	1.41	1.47	1.44	1.54	1.52	1.53	1.65	1.63	1.64	1.74	1.73	1.73	1.78	1.77	1.77
Mean	1.44	1.46		1.49	1.48		1.55	1.52		1.61	1.57		1.66	1.62	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.01	NS		0.03	NS		0.03	NS		0.04	NS		0.03	NS	
C	0.02	NS		0.04	NS		0.05	NS		0.05	0.15		0.05	0.14	
S × C	0.03	NS		0.06	NS		0.06	NS		0.07	NS		0.06	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	1.54	1.51	1.53	1.56	1.52	1.54	1.59	1.55	1.57	1.61	1.59	1.60	1.62	1.61	1.62
C ₂	1.65	1.63	1.64	1.68	1.67	1.67	1.71	1.69	1.70	1.73	1.72	1.72	1.74	1.72	1.73
C ₃	1.80	1.71	1.75	1.83	1.75	1.79	1.87	1.82	1.84	1.89	1.86	1.87	1.91	1.88	1.89
C ₄	1.85	1.81	1.83	1.87	1.86	1.86	1.90	1.87	1.88	1.93	1.92	1.92	1.95	1.94	1.95
Mean	1.71	1.66		1.73	1.70		1.77	1.73		1.79	1.77		1.80	1.79	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.03	NS		0.02	NS		0.02	NS		0.02	NS		0.02	NS	
C	0.04	0.12		0.03	0.08		0.03	0.09		0.02	0.07		0.03	0.09	
S × C	0.05	NS		0.04	NS		0.04	NS		0.03	NS		0.04	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 17. Influence of packaging and storage conditions on protease activity (mg amino acid released/min/ml) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	2.14	2.10	2.12	2.12	2.11	2.12	2.16	2.13	2.15	2.17	2.15	2.16	2.21	2.18	2.20
C ₂	2.16	2.15	2.16	2.15	2.13	2.14	2.20	2.18	2.19	2.23	2.22	2.23	2.30	2.28	2.29
C ₃	2.11	2.17	2.14	2.19	2.18	2.19	2.25	2.21	2.23	2.39	2.25	2.32	2.43	2.32	2.37
C ₄	2.12	2.15	2.13	2.22	2.20	2.21	2.33	2.31	2.32	2.42	2.41	2.41	2.46	2.45	2.45
Mean	2.13	2.14		2.17	2.16		2.24	2.21		2.30	2.26		2.35	2.31	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.02	NS		0.03	NS		0.03	NS		0.05	NS		0.05	NS	
C	0.02	NS		0.04	NS		0.04	NS		0.06	NS		0.07	NS	
S × C	0.04	NS		0.06	NS		0.06	NS		0.09	NS		0.09	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	2.24	2.21	2.23	2.26	2.23	2.25	2.28	2.25	2.27	2.29	2.27	2.28	2.31	2.30	2.31
C ₂	2.35	2.32	2.33	2.36	2.35	2.35	2.39	2.37	2.38	2.41	2.39	2.40	2.42	2.40	2.41
C ₃	2.48	2.39	2.43	2.51	2.43	2.47	2.54	2.48	2.51	2.57	2.54	2.56	2.59	2.56	2.58
C ₄	2.53	2.49	2.51	2.55	2.54	2.55	2.52	2.55	2.54	2.61	2.60	2.61	2.63	2.62	2.63
Mean	2.40	2.35		2.42	2.39		2.43	2.41		2.47	2.45		2.49	2.47	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.05	NS		0.05	NS		0.05	NS		0.05	NS		0.05	NS	
C	0.07	NS		0.07	NS		0.07	0.20		0.07	0.22		0.08	0.23	
S × C	0.10	NS		0.11	NS		0.09	NS		0.10	NS		0.11	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Significant differences were observed between the treatments from 6 months of storage and upto 18 months of storage, but not in storage conditions and their interaction. Significantly lower values of lipase activity was observed in vacuum packaged bags (C_1), which was significantly lower compared to all other treatments. Among the storage containers, significantly higher lipase activity were observed in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2), which was significantly superior over all other treatments. Lipase activity decreased with an increase in storage period in all the containers and at all the stages of storage period.

At 8th months of storage, lower lipase activity was observed in vacuum packed bags stored under cold storage (C_1S_2) (1.49 meq.free fatty acid/min/g) followed by vacuum packed bags stored under ambient condition (C_1S_1) (1.51 meq.free fatty acid/min/g). While higher lipase activity (meq.free fatty acid/min/g) was observed in gunny bags stored under ambient storage (C_4S_1) (1.78 meq.free fatty acid/min/g) followed by gunny bags stored under cold storage (C_4S_2) (1.77 meq.free fatty acid/min/g), which was significantly lower compared to all other treatments. Similar trend continued from 10 months of storage and up to 18 months of storage. During 18 months of storage gunny bags (C_4) recorded significantly higher lipase activity (1.95 meq.free fatty acid/min/g) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to all other treatments. However, the treatments cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under ambient storage (C_4S_1), gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves.

4.2.7 Protease activity (mg amino acid released/min/ml)

The observations on protease activity presented in Table 17 revealed significant differences between treatments from 14 months to 18 months of storage. Among the storage containers, maximum protease activity was observed in gunny bags (C_4) followed by cloth bags (C_3) under both ambient storage (S_1) and cold storage (S_2), which were significantly higher compared to all other treatments; while significantly lower protease activity was found in vacuum packaged bags (C_1) followed by polythene bags (C_2) and no significant differences among themselves. No significant differences were found between storage conditions and storage containers and their

interactions up to 12 months of storage. It was further observed that as the storage period progressed, protease activity decreased in all the treatments throughout the storage period.

At 14 months of storage, higher protease activity was observed in gunny bags stored under ambient storage (C_4S_1) (2.52 mg amino acid released/min/ml) followed by gunny bags stored under cold storage (C_4S_2) (2.55 mg amino acid released/min/ml), which was significantly higher compared to all other treatments. The lower values of protease activity (mg amino acid released /min/ml) was observed in vacuum packed bags stored under ambient condition (C_1S_1) (2.28 mg amino acid released/min/ml) followed by vacuum packed bags stored under cold storage (C_1S_2) (2.25 mg amino acid released/min/ml), which was significantly lower compared to all other treatments. A similar trend continued upto 18 months of storage. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1) and cloth bags stored under cold storage (C_3S_2) were at par with each other. At 18 months of storage, higher values of protease activity (mg amino acid released /min/ml) were observed gunny bags (C_4) (2.63 mg amino acid released/min/ml), which was superior over all other treatments under ambient storage (S_1) and cold storage (S_2). While, vacuum packaged bags (C_1) recorded lower protease activity (2.30 mg amino acid released/min/ml) compared to all other treatments. It was further observed that ambient storage (S_1) recorded significantly higher protease activity among all the treatments compared to cold storage (S_2). The treatment combinations vacuum packed bags stored under ambient condition (C_1S_1), vacuum packed bags stored under cold storage (C_1S_2) and polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1) and cloth bags stored under cold storage (C_3S_2) did not differ significantly among themselves.

4.2.8 Peroxidase activity (Δ OD mg protein/ min)

The results of peroxidase activity presented in Table 18 revealed significant differences between storage containers from 10 months of storage and up to 18 months of storage due to storage period. No significant differences were observed among the storage containers and storage conditions and their interaction up to 8 months of storage. Significantly higher peroxidase activity were observed in gunny bags (C_4) compared to all other treatments under both ambient storage (S_1) and cold storage (S_2), which was on par with cloth bags (C_3). Among the containers, vacuum

packaged bags (C₁) recorded significantly lower values of peroxidase activity over all other treatments. However, it was on par with polythene bags (C₂).

At 10th months of storage, lower peroxidase activity (Δ OD mg protein/ min) was found in vacuum packed bags stored under ambient condition (C₁S₁) (11.18) followed by vacuum packed bags stored under cold storage (C₁S₂) (11.22), which were significantly lower compared to all other treatments. Significantly higher peroxidase activity (Δ OD mg protein/ min) was found in gunny bags stored under ambient storage (C₄S₁) (11.51) followed by gunny bags stored under cold storage (C₄S₂) (11.48). Among interactions cloth bags stored under ambient storage (C₃S₁), cloth bags stored under cold storage (C₃S₂), gunny bags stored under cold storage (C₄S₂), polythene bags stored under ambient storage (C₂S₁) and vacuum packed bags stored under ambient condition (C₁S₁) were at par with each other. A similar trend continued up to 18 months of storage. At 18 months of storage, gunny bags (C₄) recorded significantly higher peroxidase activity (11.42 Δ OD mg protein/ min), followed by cloth bags (C₃) (11.38 Δ OD mg protein/ min). The lower peroxidase activity (Δ OD mg protein/ min) was observed in vacuum packed bags stored under cold storage (C₁S₂) (10.62), which was lower over all other treatments followed by vacuum packed bags stored under ambient condition (C₁S₁). The treatments cloth bags stored under ambient storage (C₃S₁), cloth bags stored under cold storage (C₃S₂), gunny bags stored under cold storage (C₄S₂) did not differ significantly among themselves. It is clear from the results that, ambient storage (S₁) recorded higher peroxidase activity among all the treatments compared to cold storage (S₂) throughout the storage. Among the containers, gunny bags (C₄) maintained high peroxidase activity up to 18 months of storage and decreased with a progress in storage period among all the containers.

4.2.9 Soluble protein (mg/g)

The results on soluble protein as influenced by storage containers, storage conditions indicated significant differences at all the stages of storage in all the treatments (Table 19). Soluble protein was decreased with an increase in storage period among all the treatments. The maximum soluble protein was observed in vacuum packaged bags (C₁), which was significantly higher as compared to other treatments, while minimum soluble protein was noticed in gunny bags (C₄), which was significantly lower as compared to all other treatments. The gradual and much lesser decrease was observed in vacuum packaged bags (C₁), while, greater reduction was observed in gunny bags (C₄) followed by cloth bags (C₃) at all the stages of storage period.

At sixth months of storage, lower soluble protein was observed in gunny bags stored under ambient storage (C₄S₁) (3.79 mg/g) followed by gunny bags stored under cold storage (C₄S₂) (3.88 mg/g) and it was significantly lower as compared to other treatments. Significantly higher soluble protein was found in vacuum packaged bags stored under cold storage (C₁S₂) (4.81 mg/g) followed by vacuum packaged bags stored under ambient condition (C₁S₁) (4.75 mg/g), which was significantly superior over all other treatments. However, both treatments did not differ significantly among themselves. Among interactions, cloth bags stored under ambient storage (C₃S₁), gunny bags stored under cold storage (C₄S₂) and polythene bags stored under ambient storage (C₂S₁) were on par with each other. At 18 months of storage, vacuum packaged bags (C₁) recorded significantly higher soluble protein (4.17 mg), which was significantly superior over all other treatments under both cold storage (S₂) and ambient storage (S₁). However, no significant differences were observed between ambient storage (S₁) and cold storage (S₂) under vacuum packaged bags (C₁). Among the containers, vacuum packaged bags (C₁) was on par with polythene bags (C₂) and similarly, cloth bags (C₃) on par with gunny bags (C₄) and they did not differ significantly among themselves. The lower soluble protein was recorded in gunny bags stored under ambient storage (C₄S₁) (2.83 mg/g) followed by gunny bags stored under cold storage (C₄S₂), which was lower compared to all other treatments. It was further observed that, cold storage (S₂) recorded higher soluble protein among all the storage containers as compared to ambient storage (S₁). It is clear from the results that, vacuum packaged bags (C₁) maintained higher soluble protein content among all the treatments throughout the storage period.

Table 18. Influence of packaging and storage conditions on peroxidase activity (Δ OD mg protein/min) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	11.44	11.52	11.47	11.38	11.31	11.35	11.36	11.30	11.33	11.34	11.28	11.31	11.31	11.25	11.28
C ₂	11.41	11.42	11.41	11.36	11.33	11.35	11.35	11.32	11.34	11.31	11.29	11.30	11.28	11.25	11.27
C ₃	11.53	11.56	11.54	11.56	11.54	11.55	11.58	11.54	11.56	11.55	11.53	11.54	11.51	11.48	11.50
C ₄	11.43	11.54	11.49	11.61	11.58	11.60	11.64	11.62	11.63	11.58	11.56	11.57	11.53	11.52	11.53
Mean	11.45	11.51		11.48	11.44		11.48	11.45		11.45	11.42		11.41	11.38	
	S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)	
S	0.02	NS		0.05	NS		0.07	NS		0.06	NS		0.06	NS	
C	0.03	NS		0.08	NS		0.09	NS		0.09	NS		0.09	NS	
S \times C	0.05	NS		0.11	NS		0.13	NS		0.13	NS		0.13	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	11.18	11.22	11.20	11.08	10.96	11.02	11.02	10.81	10.91	10.93	10.76	10.85	10.76	10.62	10.69
C ₂	11.23	11.14	11.18	11.18	11.05	11.11	11.14	10.98	11.06	11.09	10.86	10.97	10.84	10.75	10.80
C ₃	11.49	11.46	11.48	11.45	11.43	11.44	11.42	11.40	11.41	11.41	11.38	11.40	11.38	11.35	11.37
C ₄	11.51	11.48	11.50	11.50	11.46	11.48	11.48	11.43	11.46	11.45	11.41	11.43	11.42	11.40	11.41
Mean	11.35	11.32		11.30	11.22		11.26	11.16		11.22	11.10		11.10	11.03	
	S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)	
S	0.06	NS		0.06	NS		0.04	NS		0.04	0.11		0.03	NS	
C	0.09	0.27		0.08	0.24		0.05	0.15		0.05	0.15		0.05	0.14	
S \times C	0.12	NS		0.11	NS		0.07	NS		0.07	NS		0.07	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 19. Influence of packaging and storage conditions on soluble protein (mg/g) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	4.56	4.76	4.66	4.82	4.86	4.84	4.80	4.83	4.82	4.75	4.81	4.78	4.73	4.78	4.76
C ₂	4.80	4.83	4.82	4.31	4.72	4.51	4.21	4.43	4.32	4.08	4.30	4.19	3.91	4.13	4.02
C ₃	4.44	4.53	4.49	4.11	4.29	4.20	4.02	4.22	4.12	3.87	4.12	4.00	3.70	4.03	3.87
C ₄	4.62	4.46	4.54	4.02	4.08	4.05	3.91	3.98	3.94	3.79	3.88	3.83	3.67	3.76	3.71
Mean	4.60	4.64		4.31	4.49		4.24	4.37		4.12	4.28		4.00	4.18	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.08	NS		0.07	NS		0.07	NS		0.07	NS		0.07	NS	
C	0.10	NS		0.09	0.28		0.10	0.30		0.11	0.32		0.11	0.34	
S × C	0.15	NS		0.13	NS		0.14	NS		0.15	NS		0.16	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	4.67	4.70	4.68	4.53	4.63	4.58	4.47	4.57	4.52	4.27	4.43	4.35	4.13	4.20	4.17
C ₂	3.82	3.97	3.89	3.67	3.90	3.78	3.57	3.80	3.68	3.40	3.67	3.53	3.07	3.42	3.24
C ₃	3.53	3.88	3.71	3.37	3.67	3.52	3.17	3.57	3.37	3.03	3.40	3.22	2.81	3.27	3.04
C ₄	3.51	3.80	3.65	3.33	3.57	3.45	3.13	3.43	3.28	3.00	3.30	3.15	2.83	2.95	2.89
Mean	3.88	4.09		3.73	3.94		3.58	3.84		3.43	3.70		3.21	3.46	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.07	0.20		0.07	0.21		0.08	0.23		0.08	0.24		0.08	0.24	
C	0.09	0.29		0.10	0.30		0.11	0.32		0.11	0.33		0.11	0.34	
S × C	0.13	NS		0.14	NS		0.16	NS		0.17	NS		0.17	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 20. Influence of packaging and storage conditions on moisture content (%) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.0	8.1	8.0	8.0	8.0	8.0	8.04	8.05	8.0	8.0	8.1	8.1	8.0	8.0	8.0
C ₂	8.1	8.0	8.1	8.2	8.4	8.3	8.39	8.41	8.4	8.3	8.3	8.3	8.2	8.3	8.3
C ₃	8.0	8.1	8.1	8.9	12.7	10.8	9.79	12.8	11.3	9.9	12.8	11.3	9.7	12.8	11.2
C ₄	8.2	8.1	8.2	9.8	12.8	11.3	9.92	12.9	11.4	9.9	12.9	11.4	9.8	12.8	11.3
Mean	8.1	8.1		8.7	10.5		9.0	10.5		9.0	10.5		9.0	10.5	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.03	NS		0.17	0.52		0.19	0.57		0.20	0.60		0.20	0.61	
C	0.05	NS		0.24	0.73		0.26	0.80		0.28	0.85		0.28	0.86	
S × C	0.07	NS		0.34	1.03		0.37	1.13		0.40	1.20		0.41	1.22	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.0	8.0	8.0	7.9	8.0	7.9	7.9	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.8
C ₂	8.2	8.2	8.2	8.1	8.2	8.2	8.1	8.15	8.1	8.0	8.1	8.1	7.9	8.00	7.9
C ₃	10.6	12.7	11.6	10.5	12.7	11.6	10.3	12.7	11.5	10.4	12.6	11.5	11.05	12.6	11.8
C ₄	10.7	12.8	11.7	10.6	12.8	11.7	10.4	12.8	11.6	10.5	12.8	11.6	11.25	12.7	11.9
Mean	9.3	10.4		9.3	10.4		9.2	10.41		9.2	10.4		9.53	10.3	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.21	0.62		0.20	0.62		0.20	0.60		0.16	0.47		0.19	0.60	
C	0.29	0.88		0.29	0.88		0.28	0.85		0.22	0.67		0.26	0.85	
S × C	0.41	1.25		0.41	1.24		0.40	1.21		0.31	0.95		0.38	1.17	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

4.3 PROXIMATE COMPOSITION

4.3.1 Moisture content (%)

The data on moisture content as influenced by storage containers and storage conditions revealed significant differences among the treatments at all the stages of storage (Table 20). Among the storage containers, the moisture content was maximum in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to other treatments. Significantly lower moisture content was observed in vacuum packaged bags (C_1), followed by polythene bags (C_2), which was significantly lower compared to all other treatments. In general, no much change in the moisture content was observed in vacuum packaged bags (C_1) under both ambient storage (S_1) and cold storage (S_2). But, there was a slight decrease in the moisture content with advancement in storage period, which was almost negligible in the vacuum packaged bags (C_1) compared to polythene bags (C_2). But, Lot of fluctuations were noticed in the moisture content in cloth bags (C_3) and gunny bags (C_4) throughout the storage period.

At 4th months of storage, significantly lower moisture content was recorded in vacuum packed bags stored under ambient condition (C_1S_1) (8.04%) followed by vacuum packed bags stored under cold storage (C_1S_2) (8.05%). However, both did not differ among themselves. Significantly higher moisture content was observed in gunny bags (C_4) (12.9%) followed by cloth bags (C_3) under both ambient storage (S_1) and cold storage (S_2), which was significantly superior over all other treatments. However, both did not differ significantly with each other. A similar trend continued from 6 months of storage and up to 18 months of storage. It was further observed that cold storage (S_2) recorded significantly higher moisture content among all the containers compared to ambient storage (S_1). The treatments cloth bags stored under ambient storage (C_3S_1), gunny bags stored under ambient storage (C_4S_1) and cloth bags stored under cold storage (C_3S_2), gunny bags stored under cold storage (C_4S_2) were at par with each other. At 18 months of storage, gunny bags (C_4) recorded significantly higher moisture content (12.7%) over all other containers under both ambient storage (S_1) and cold storage (S_2). However, no significant differences were observed between ambient storage (S_1) and cold storage (S_2). Significantly lower moisture content (7.8%) was observed in vacuum

packed bags stored under ambient condition (C_1S_1) compared to all other treatments except cold storage (S_2). Among the interactions, cloth bags stored under ambient storage (C_3S_1), gunny bags stored under ambient storage (C_4S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves. It is clearly from the results that, cold storage (S_2) maintained higher moisture content compared to ambient storage (S_1) among all the treatments at all the stages of storage period.

4.3.2 Crude protein (%)

The observations on crude protein influenced by storage containers and storage conditions showed significant differences up to 18 months of storage (Table 21). Among the containers, vacuum packaged bags (C_1) recorded significantly higher crude protein, while, significantly lower crude protein was observed in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2). Up to 4 months of storage, no significant differences were observed between storage containers, storage conditions and their interaction. It was observed that, no significant differences were within the treatments under both ambient storage (S_1) and cold storage (S_2) throughout the storage period. Crude protein content was decreased with an advancement of storage period among all the storage containers at all the stages of storage period.

At 8th months of storage, the higher crude protein content was observed in vacuum packed bags stored under cold storage (C_1S_2) (7.48%) followed by vacuum packed bags stored under ambient condition (C_1S_1) (7.43%), which was superior over all other treatments. The lower crude protein content was observed in gunny bags stored under ambient storage (C_4S_1) (7.22%) followed by gunny bags stored under cold storage (C_4S_2) (7.29%), which was lower compared to all other treatments. A similar trend continued from 10 months of storage and upto 18 months of storage. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) were on par with each other. At 18 months of storage, significantly higher crude protein content (%) was found in vacuum packed bags (C_1) (7.39%), which was significantly higher over all other treatments. The lower crude protein content was observed in gunny bags stored

Table 21. Influence of packaging and storage conditions on crude protein (%) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.50	7.58	7.54	7.47	7.51	7.49	7.45	7.50	7.47	7.44	7.49	7.47	7.43	7.48	7.46
C ₂	7.57	7.48	7.53	7.43	7.44	7.43	7.42	7.43	7.43	7.41	7.42	7.42	7.40	7.41	7.41
C ₃	7.44	7.51	7.47	7.35	7.43	7.39	7.33	7.35	7.34	7.31	7.33	7.32	7.27	7.31	7.29
C ₄	7.45	7.54	7.50	7.32	7.36	7.34	7.30	7.34	7.32	7.28	7.32	7.30	7.22	7.29	7.26
Mean	7.49	7.53		7.39	7.43		7.37	7.40		7.36	7.39		7.33	7.37	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.03	NS		0.04	NS		0.04	NS		0.03	NS		0.03	NS	
C	0.05	NS		0.06	NS		0.06	NS		0.04	0.13		0.04	0.13	
S × C	0.07	NS		0.09	NS		0.09	NS		0.06	NS		0.06	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.42	7.47	7.45	7.41	7.46	7.44	7.40	7.45	7.43	7.38	7.43	7.41	7.36	7.41	7.39
C ₂	7.39	7.40	7.39	7.37	7.39	7.38	7.35	7.38	7.37	7.33	7.36	7.35	7.31	7.34	7.33
C ₃	7.22	7.28	7.25	7.18	7.22	7.20	7.15	7.18	7.17	7.11	7.14	7.13	7.00	7.11	7.06
C ₄	7.17	7.23	7.20	7.13	7.20	7.17	7.09	7.16	7.13	7.06	7.11	7.09	6.94	7.02	6.98
Mean	7.30	7.35		7.28	7.32		7.25	7.30		7.22	7.26		7.15	7.22	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.03	NS		0.02	NS		0.02	NS		0.01	0.03		0.02	0.06	
C	0.04	0.11		0.03	0.08		0.03	0.08		0.02	0.06		0.03	0.08	
S × C	0.05	NS		0.04	NS		0.04	NS		0.03	NS		0.04	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 22. Influence of packaging and seed conditions on fat content (%) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	2.26	2.32	2.29	2.20	2.31	2.25	2.15	2.26	2.20	2.10	2.21	2.15	2.05	2.16	2.10
C ₂	2.25	2.31	2.28	2.17	2.30	2.23	2.12	2.25	2.18	2.07	2.20	2.13	2.02	2.15	2.08
C ₃	2.24	2.28	2.26	2.16	2.24	2.20	2.08	2.16	2.12	1.97	2.08	2.03	1.92	2.00	1.96
C ₄	2.22	2.25	2.23	2.16	2.17	2.17	2.08	2.09	2.09	1.96	2.01	1.99	1.92	1.93	1.93
Mean	2.24	2.29		2.17	2.26		2.11	2.19		2.02	2.13		1.98	2.06	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.02	NS		0.05	NS		0.03	NS		0.04	NS		0.03	NS	
C	0.02	NS		0.06	NS		0.05	NS		0.06	NS		0.04	0.13	
S × C	0.03	NS		0.09	NS		0.07	NS		0.08	NS		0.06	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	2.03	2.11	2.07	2.02	2.07	2.04	1.97	2.05	2.01	1.92	2.02	1.97	1.89	1.96	1.93
C ₂	1.97	2.10	2.03	1.95	2.05	2.00	1.93	2.02	1.98	1.92	1.98	1.95	1.87	1.93	1.90
C ₃	1.84	1.92	1.88	1.76	1.84	1.80	1.68	1.76	1.72	1.60	1.68	1.64	1.52	1.60	1.56
C ₄	1.84	1.85	1.85	1.76	1.77	1.77	1.67	1.69	1.68	1.57	1.61	1.59	1.48	1.53	1.51
Mean	1.92	2.00		1.87	1.93		1.81	1.88		1.75	1.82		1.69	1.76	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.03	0.08		0.02	0.05		0.02	0.05		0.02	0.06		0.02	0.06	
C	0.04	0.11		0.03	0.09		0.03	0.09		0.03	0.09		0.03	0.08	
S × C	0.05	NS		0.04	NS		0.04	NS		0.04	NS		0.04	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

under ambient storage (C_4S_1) (6.94%), followed by gunny bags stored under cold storage (C_4S_2) (7.02%), which was lower over all other treatments. It was further observed that, cold storage (S_2) recorded significantly higher crude protein content in polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) compared to ambient storage (S_1) throughout the storage period.

4.3.3 Fat content (%)

The data on fat content as influenced by storage containers and storage conditions measured up to 18 months of storage presented in Table 22 revealed significant differences between storage containers and conditions. In general, decreased trend was observed in fat content with an advancement in storage period among all the treatments, but lesser decrease was observed in vacuum packaged bags (C_1) and greater decrease was found in gunny bags (C_4) followed by cloth bags (C_3) throughout the storage period. Up to 6 months of storage, no significant differences were observed between storage containers and storage conditions and their interaction. Among the containers, vacuum packaged bags (C_1) recorded significantly higher fat content compared to all other treatments under both cold storage (S_2) and ambient storage (S_1), which was significantly superior over all other treatments. The lower fat content was observed in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2), which was significantly lower compared to all other treatments.

At 8 months of storage, the lower fat content was observed in gunny bags stored under ambient storage (C_4S_1) (1.92%) followed by gunny bags stored under cold storage (C_4S_2) (1.93%), which was lower compared to all other treatments. The higher fat content was found in vacuum packed bags stored under cold storage (C_1S_2) (2.16%) followed by vacuum packed bags stored under ambient condition (C_1S_1) (2.05%), which was superior over all other treatments. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2) and cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2), gunny bags stored under cold storage (C_4S_2) were at par with each other. Similar trend was continued from 10 months of storage and up to 18 months of storage. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher fat content (1.93%), which was significantly superior over all other treatments. The lower fat content was

observed in gunny bags stored under ambient storage (C_4S_1) (1.48%) followed by gunny bags stored under cold storage (C_4S_2) (1.53%), which was lower over as compared to all other treatments. Similarly, cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves. It was further noticed that cold storage (S_2) recorded significantly higher fat content among all the containers compared to ambient storage (S_1). It is clear from the results that, vacuum packaged bags (C_1) maintained significantly higher fat content compared to all other treatments throughout the storage period.

4.3.4 Ash content (%)

The results of ash content as influenced by storage containers, storage conditions and their interactions presented in Table 23. Ash content differed significantly between storage conditions and storage containers from 6 months of storage and continued upto 18 months of storage. Significantly higher ash content was observed in vacuum packaged bags (C_1) followed by polythene bags (C_2), under both ambient storage (S_1) and cold storage (S_2), which was significantly higher over all other treatments. Among the containers, gunny bags (C_4) recorded significantly lower ash content followed by cloth bags (C_3), which was significantly lower compared to all other treatments. The decreased trend was seen in ash content with a progress in storage period among all the treatments, but gradual decrease was found in vacuum packaged bags (C_1) and faster decrease was observed in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2).

During eighth months of storage, higher ash content (1.36%) was recorded in vacuum packed bags stored under cold storage (C_1S_2) followed by vacuum packed bags stored under ambient condition (C_1S_1) (1.25%) and lower ash content were observed in gunny bags stored under ambient storage (C_4S_1) (1.12%). followed by gunny bags stored under cold storage (C_4S_2). A similar trend was continued from 10 months of storage and up to 18 months of storage. The treatments vacuum packaged bags (C_1) was on par with polythene bags (C_2) and cloth bags (C_3) on par with gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2). The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2),

Table 23. Influence of packaging and storage conditions on ash content (%) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	1.50	1.54	1.52	1.47	1.51	1.49	1.35	1.46	1.41	1.32	1.41	1.37	1.25	1.36	1.31
C ₂	1.53	1.55	1.54	1.37	1.51	1.44	1.32	1.45	1.39	1.27	1.43	1.35	1.22	1.35	1.29
C ₃	1.56	1.48	1.52	1.36	1.44	1.40	1.28	1.36	1.32	1.17	1.28	1.23	1.12	1.20	1.16
C ₄	1.47	1.42	1.45	1.36	1.37	1.37	1.28	1.29	1.29	1.16	1.21	1.19	1.12	1.13	1.12
Mean	1.51	1.50		1.39	1.46		1.31	1.39		1.23	1.33		1.18	1.26	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.01	NS		0.03	NS		0.03	NS		0.03	0.09		0.03	0.07	
C	0.02	NS		0.05	NS		0.04	NS		0.04	0.13		0.04	0.12	
S × C	0.03	NS		0.06	NS		0.06	NS		0.06	NS		0.06	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	1.23	1.31	1.27	1.22	1.27	1.25	1.17	1.25	1.21	1.12	1.22	1.17	1.09	1.16	1.12
C ₂	1.17	1.32	1.25	1.15	1.25	1.20	1.13	1.22	1.17	1.12	1.18	1.15	1.07	1.13	1.10
C ₃	1.04	1.12	1.08	0.96	1.04	1.00	0.88	0.96	0.92	0.75	0.88	0.82	0.72	0.76	0.74
C ₄	1.04	1.05	1.04	0.96	0.97	0.97	0.87	0.89	0.88	0.77	0.81	0.79	0.68	0.73	0.71
Mean	1.12	1.20		1.07	1.13		1.01	1.08		0.94	1.02		0.89	0.95	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.03	0.07		0.02	0.06		0.02	0.05		0.02	0.05		0.02	0.05	
C	0.04	0.11		0.03	0.08		0.03	0.08		0.02	0.07		0.02	0.07	
S × C	0.05	NS		0.04	NS		0.04	NS		0.03	NS		0.03	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

cloth bags stored under ambient storage (C_3S_1) and gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher ash content over all other treatments under both ambient storage (S_1) and cold storage (S_2). The lower values of ash content were recorded in gunny bags stored under ambient storage (C_4S_1) compared to all other treatments. It was further observed that cold storage (S_2) showed higher ash content compared to ambient storage (S_1) among all storage containers at all the stages of storage period.

4.3.5 Carbohydrate content (%)

The data on carbohydrate content as influenced by different packaging and storage conditions differed significantly between treatments from 4 months of storage and up to 18 months of storage due to the storage period presented Table 24. Up to 6 months of storage no significant differences were found between storage containers, storage conditions and their interaction. Among the storage containers, the carbohydrate content was higher in vacuum packaged bags (C_1), which was significantly higher over all other treatments, while lower in gunny bags (C_4), which was significantly lower compared to all other containers under both ambient storage (S_1) and cold storage (S_2).

At 8th months of storage, higher carbohydrate content (81.2%) was observed in vacuum packed bags stored under ambient condition (C_1S_1) followed by vacuum packed bags stored under cold storage (C_1S_2) (80.9%), which was superior over all other treatments. Lower carbohydrate content (79.8%) was observed in gunny bags stored under ambient storage (C_4S_1) followed by gunny bags stored under cold storage (C_4S_2), which was lower compared to all other treatments throughout the storage period. Among interactions cloth bags stored under ambient storage (C_3S_1), gunny bags stored under ambient storage (C_4S_1) and cloth bags stored under cold storage (C_3S_2), gunny bags stored under cold storage (C_4S_2) did not differ significantly among themselves. Similar trend continued at 10, 12, 14, 16 and 18 months. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher carbohydrate content (81.7%), which was significantly higher compared to all other treatments. Among the containers, vacuum packaged bags (C_1) was on par with polythene bags (C_2) and cloth bags (C_3) on par with gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2). The lower carbohydrate content was observed in gunny bags stored under cold storage (C_4S_2) (77.9%), which was lower over all other treatments. It is clear from the results that, ambient storage (S_1) recorded higher values of carbohydrate content compared to cold storage (S_2) among all the treatments at all the stages of storage period.

EXPERIMENT-II: RICE GRAINS

4.4 BIOCHEMICAL PARAMETERS

4.4.1 Copper content (ppm)

The observations on copper content as influenced by storage containers and storage conditions as presented in Table 25 and Fig. 1 revealed significant differences between the treatments from 10 months of storage and up to 18 months of storage. Among the containers and conditions, no significant differences were observed up to 8 months of storage. Among the containers, vacuum packaged bags (C_1) recorded significantly higher values of copper content, which was significantly higher compared to all other treatments. Significantly lower values of copper content were observed in gunny bags (C_4), which was significantly lower as compared to all other treatments.

At 10th months of storage, higher values of copper content were observed in vacuum packed bags stored under cold storage (C_1S_2) (11.9 ppm) followed by vacuum packed bags stored under ambient condition (C_1S_1) (11.8 ppm), while lower values of copper content were observed in gunny bags stored under ambient storage (C_4S_1) (10.5 ppm) followed by gunny bags stored under cold storage (C_4S_2) (10.1 ppm) under both ambient storage (S_1) and cold storage (S_2). A similar trend continued at 12, 14, 16 and 18 months of storage. However, both did not differ significantly among themselves. Among the containers, C_1 recorded significantly higher values of copper content over all other containers under both ambient storage (S_1) and cold storage (S_2). Hence, no significant differences were observed between container and storage conditions. At 18 months of storage, significantly higher copper content was observed in vacuum packaged bags (C_1) (10.6 ppm) followed by polythene bags (C_2) (9.8 ppm), while lower copper content was observed in gunny bags stored under ambient storage (C_4S_1) (8.55 ppm) followed by gunny bags stored under cold storage (C_4S_2) (8.78 ppm).

Table 24. Influence of packaging and storage conditions on carbohydrate content (%) at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	80.8	80.4	80.6	80.8	80.6	80.7	81.0	80.7	80.8	81.1	80.8	80.9	81.2	80.9	81.1
C ₂	80.4	80.7	80.5	80.7	80.3	80.5	80.7	80.4	80.6	80.9	80.6	80.7	81.1	80.7	80.9
C ₃	80.7	80.6	80.6	80.2	76.1	78.1	79.5	76.2	77.9	79.6	76.4	78.0	79.9	76.6	78.3
C ₄	80.6	80.7	80.7	79.3	76.3	77.8	79.4	76.3	77.8	79.5	76.5	78.1	79.8	76.8	78.4
Mean	80.7	80.6		80.3	78.4		80.2	78.4		80.4	78.6		80.5	78.8	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.17	NS		0.69	NS		0.66	NS		0.59	NS		0.60	NS	
C	0.26	NS		0.98	NS		0.94	NS		0.83	2.52		0.84	2.54	
S × C	0.35	NS		1.38	NS		1.33	NS		1.17	NS		1.20	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	81.3	81.0	81.2	81.4	81.2	81.3	81.5	81.2	81.4	81.6	81.4	81.5	81.8	81.7	81.7
C ₂	81.2	80.9	81.1	81.3	81.1	81.2	81.4	81.2	81.3	81.5	81.3	81.4	81.7	81.6	81.6
C ₃	79.3	77.0	78.2	79.5	77.2	78.4	79.9	77.5	78.7	80.1	77.7	78.9	79.7	77.9	78.8
C ₄	79.2	76.9	78.1	79.4	77.1	78.3	79.9	77.4	78.6	80.1	77.6	78.8	79.6	77.9	78.8
Mean	80.3	79.0		80.4	79.1		80.7	79.4		80.8	79.5		80.7	79.8	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.46	NS		0.41	1.24		0.44	1.34		0.45	1.36		0.31	0.91	
C	0.65	1.98		0.58	1.76		0.63	1.90		0.63	1.92		0.44	1.35	
S × C	0.92	NS		0.82	NS		0.89	NS		0.90	NS		0.63	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 25. Influence of packaging and storage conditions on copper content (Cu, ppm) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	12.1	12.2	12.2	12.0	12.0	12.0	11.9	12.0	11.9	11.8	11.9	11.9	11.8	11.9	11.8
C ₂	12.2	12.1	12.2	11.8	12.0	11.9	11.6	11.9	11.7	11.2	11.7	11.5	11.0	11.5	11.2
C ₃	12.1	12.2	12.1	11.6	11.7	11.6	11.5	11.6	11.5	11.0	11.1	11.1	10.7	10.8	10.8
C ₄	12.2	12.3	12.2	11.5	11.7	11.6	11.4	11.5	11.4	10.9	11.0	11.0	10.6	10.8	10.7
Mean	12.1	12.2		11.7	11.8		11.6	11.8		11.3	11.4		11.0	11.3	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.05	NS		0.14	NS		0.13	NS		0.17	NS		0.21	NS	
C	0.07	NS		0.20	NS		0.19	NS		0.24	NS		0.30	NS	
S × C	0.10	NS		0.28	NS		0.26	NS		0.34	NS		0.42	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	11.8	11.9	11.8	11.5	11.6	11.6	11.3	11.5	11.4	10.9	11.3	11.1	10.53	10.77	10.6
C ₂	10.7	11.1	10.9	10.6	10.9	10.7	10.0	10.6	10.3	9.8	10.2	10.0	9.63	9.99	9.8
C ₃	10.4	10.6	10.5	10.2	10.4	10.3	9.9	10.0	9.9	9.4	9.6	9.5	8.76	9.12	8.9
C ₄	10.1	10.5	10.3	10.0	10.3	10.2	9.8	9.9	9.9	9.3	9.5	9.4	8.55	8.78	8.6
Mean	10.76	11.0		10.61	10.8		10.3	10.5		9.8	10.15		9.37	9.67	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.23	NS		0.24	NS		0.24	NS		0.21	NS		0.17	NS	
C	0.32	0.97		0.34	1.04		0.33	1.01		0.30	0.90		0.24	0.74	
S × C	0.45	NS		0.48	NS		0.47	NS		0.42	NS		0.34	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

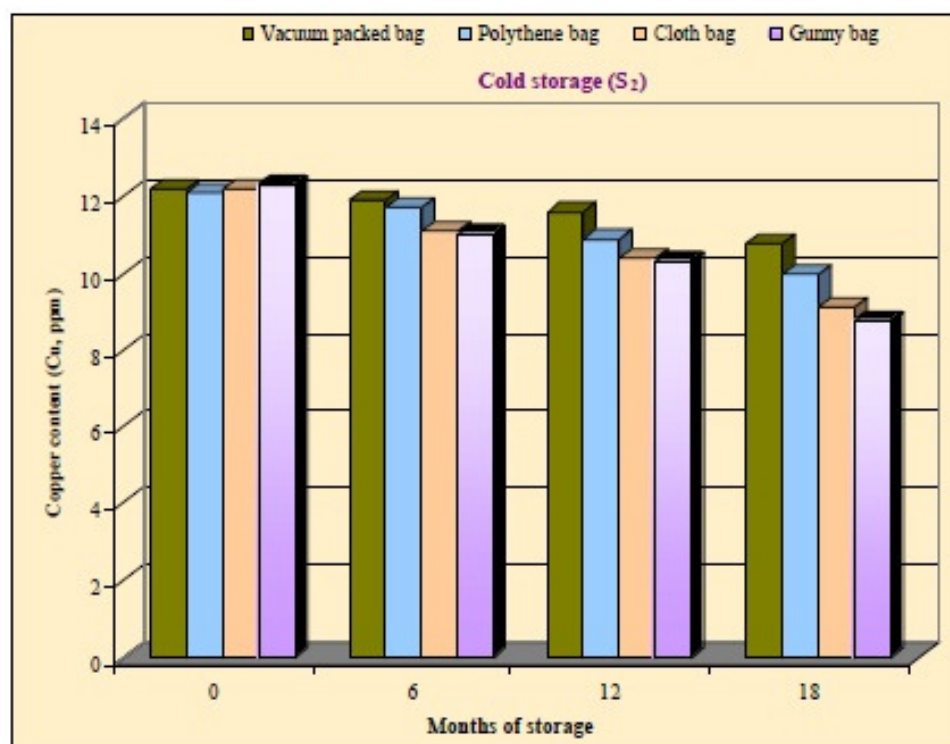
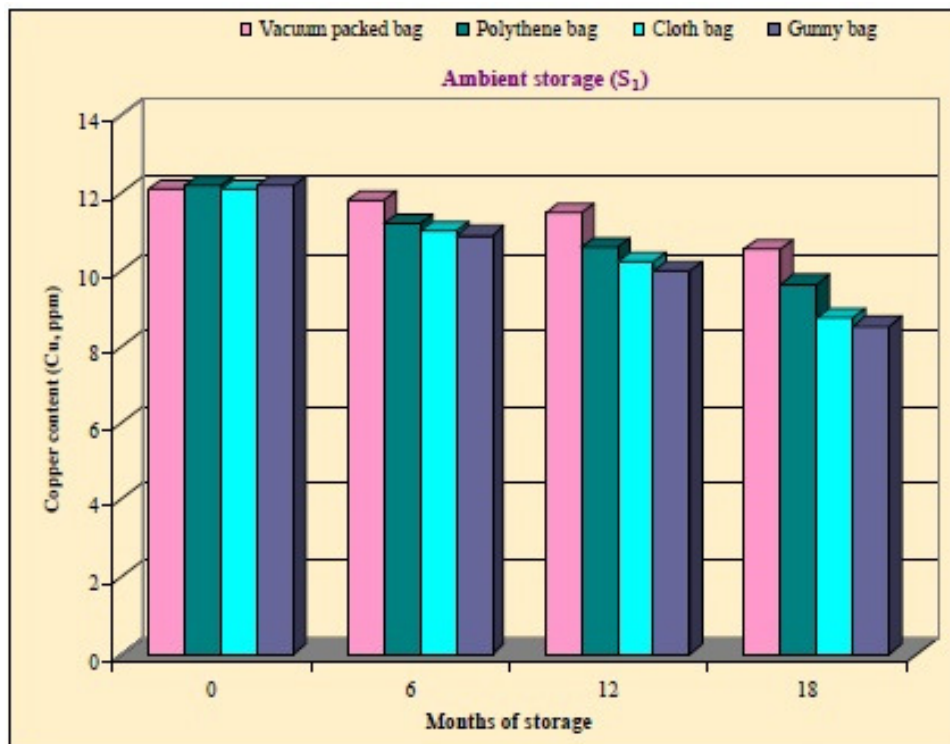


Fig 1: Influence of packaging and storage conditions on copper content (Cu, ppm) at different periods of storage in rice grains

Among storage conditions, cold storage (S_2) recorded higher copper content compared to ambient storage (S_1) throughout the storage period. As the storage period progressed, copper content was decreased in vacuum packaged bags (C_1), polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) at all the stages of storage period.

4.4.2 Iron content (ppm)

The results of iron content as influenced by different packaging and storage conditions showed significantly differ with the treatments due to storage period (Table 26 and Fig. 2). Up to 8th months of storage, no significant differences were found between treatments, but after 10 months of storage significant differences were found in the treatments at all the stages of storage. The iron content of vacuum packaged bags (C_1) followed by polythene bags (C_2) were not differed significantly with each other under ambient storage (S_1) and cold storage (S_2), but gunny bags (C_4) followed by cloth bags (C_3) differed significantly with each other from 10 months of storage and upto 18 months of storage. Among the containers, vacuum packaged bags (C_1) recorded significantly higher values of iron content followed by polythene bags (C_2), which was significantly superior over all other treatments and significantly lower values of iron content was observed in gunny bags (C_4), which was significantly lower compare to all other treatments throughout the storage period.

At 10th months of storage, higher values of iron content were recorded in vacuum packed bags stored under cold storage (C_1S_2) (39.9 ppm) followed by vacuum packed bags stored under ambient condition (C_1S_1) (39.8 ppm) compared to all other treatments. Lower values of iron content were found in gunny bags stored under ambient storage (C_4S_1) (39.2 ppm) followed by gunny bags stored under cold storage (C_4S_2) (39.3 ppm). A similar trend continued up to 18 months of storage. At end of 18 months of storage, lower iron content found in gunny bags stored under ambient storage (C_4S_1) (34.0 ppm) followed gunny bags stored under cold storage (C_4S_2) (34.3 ppm), while higher iron content was observed in vacuum packed bags stored under cold storage (C_1S_2) (39.1 ppm) under both ambient storage (S_1) and cold storage (S_2). However, the treatments vacuum packed bags stored under ambient condition (C_1S_1), polythene bags stored under cold storage (C_2S_2), polythene bags stored under ambient storage (C_2S_1) and polythene bags stored under cold storage (C_2S_2) were at par with each other and did not differ significantly among themselves throughout the storage period. It was observed from the results that, vacuum packaged bags (C_1) maintained higher iron content compared to all other treatments at all the stages of storage period.

4.4.3 Zinc content (ppm)

The observations on zinc content were differed significantly with treatments due to storage period as well as storage conditions (Table 27 and Fig. 3). Upto 10 months of storage, no significant differences were observed between storage containers, storage conditions and their interaction, but significant difference were noticed from 12 month of storage and upto 18 months of storage. In general, zinc content gradually decreased with an advancement in storage period in cold storage (S_2), vacuum packed bags stored under ambient condition (C_1S_1) and polythene bags stored under cold storage (C_2S_2), polythene bags stored under ambient storage (C_2S_1) throughout the storage period, but decreased to great extent found in gunny bags stored under ambient storage (C_4S_1), gunny bags stored under cold storage (C_4S_2) followed by cloth bags stored under ambient storage (C_3S_1), gunny bags stored under cold storage (C_4S_2) from 14 months of storage and upto 18 month of storage. Among the storage containers, zinc content values are maximum in vacuum packaged bags (C_1) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to other treatments.

At 12th months of storage, higher zinc content was recorded in vacuum packed bags stored under cold storage (C_1S_2) (18.3 ppm) followed by vacuum packed bags stored under ambient condition (C_1S_1) (18.2 ppm) over all other treatments. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2), gunny bags stored under ambient storage (C_4S_1) and gunny bags stored under cold storage (C_4S_2) were at par with each other. Lower zinc (17.4 ppm) was observed in gunny bags stored under ambient storage (C_4S_1), which was significantly lower compared to all other treatments. A similar trend continued at 14, 16 and 18 months of storage. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher zinc content (17.6 ppm) under both ambient storage (S_1) and cold storage (S_2) followed by polythene bags (C_2). However,

Table 26. Influence of packaging and storage conditions on iron content (Fe, ppm) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	41.1	40.9	41.0	41.0	41.1	41.0	40.7	40.8	40.8	40.3	40.4	40.4	40.1	40.2	40.2
C ₂	41.0	41.0	41.0	40.9	41.0	40.9	40.5	40.6	40.6	40.1	40.2	40.2	40.0	40.1	40.0
C ₃	40.9	41.0	41.0	40.7	40.8	40.8	40.4	40.5	40.5	39.9	40.0	40.0	39.8	39.8	39.8
C ₄	41.0	41.1	41.1	40.4	40.7	40.6	40.3	40.5	40.4	39.9	39.9	39.9	39.6	39.8	39.7
Mean	41.0	41.0		40.8	40.9		40.5	40.6		40.1	40.1		39.9	40.0	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.04	NS		0.16	NS		0.15	NS		0.13	NS		0.10	NS	
C	0.06	NS		0.22	NS		0.21	NS		0.19	NS		0.14	NS	
S × C	0.09	NS		0.32	NS		0.30	NS		0.27	NS		0.20	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	39.8	39.9	39.9	39.7	39.8	39.8	39.5	39.6	39.6	39.3	39.5	39.4	39.1	39.2	39.1
C ₂	39.7	39.8	39.7	39.5	39.6	39.6	39.3	39.4	39.4	39.1	39.3	39.2	38.9	39.0	39.0
C ₃	39.3	39.3	39.3	39.1	39.2	39.2	36.1	36.3	36.2	35.2	35.3	35.2	34.3	34.4	34.3
C ₄	39.2	39.3	39.2	39.0	39.1	39.1	35.9	36.1	36.0	35.1	35.2	35.1	34.0	34.3	34.2
Mean	39.5	39.6		39.3	39.5		37.7	37.9		37.2	37.3		36.6	36.7	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.10	NS		0.12	NS		0.12	NS		0.11	NS		0.09	NS	
C	0.14	0.43		0.17	0.52		0.16	0.50		0.16	0.48		0.12	0.37	
S × C	0.20	NS		0.24	NS		0.23	NS		0.22	NS		0.17	NS	

Storage conditions (S)
S₁= Ambient storage
S₂= Cold storage

Storage containers (C)
C₁= Vacuum packed bags
C₂= Polythene bags

C₃= Cloth bags
C₄= Gunny bags

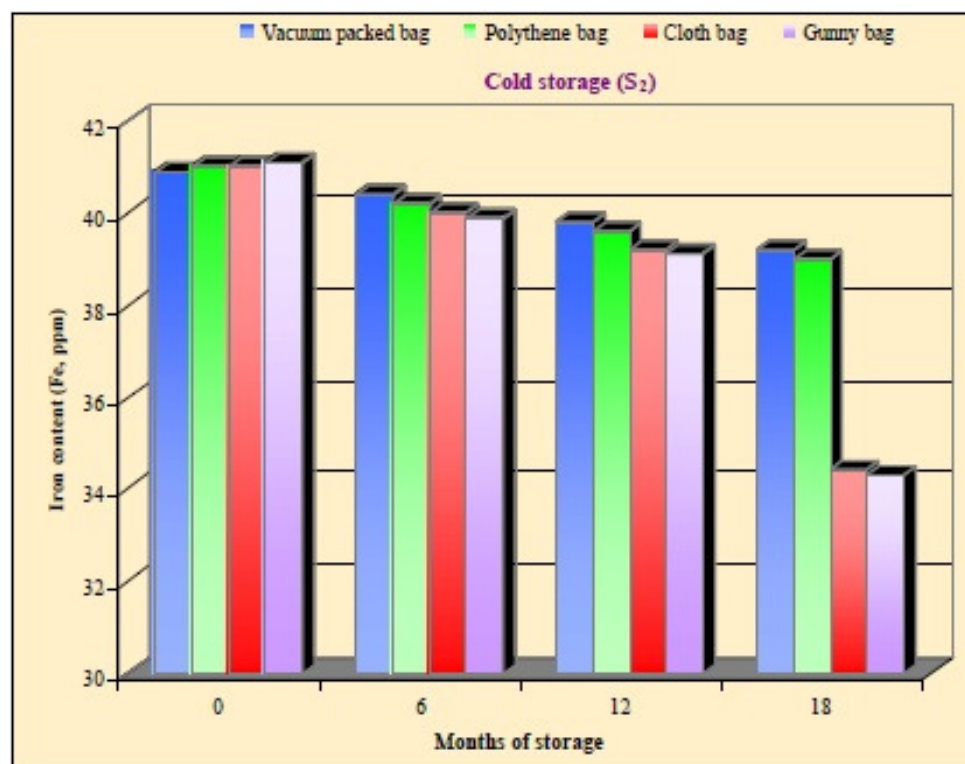
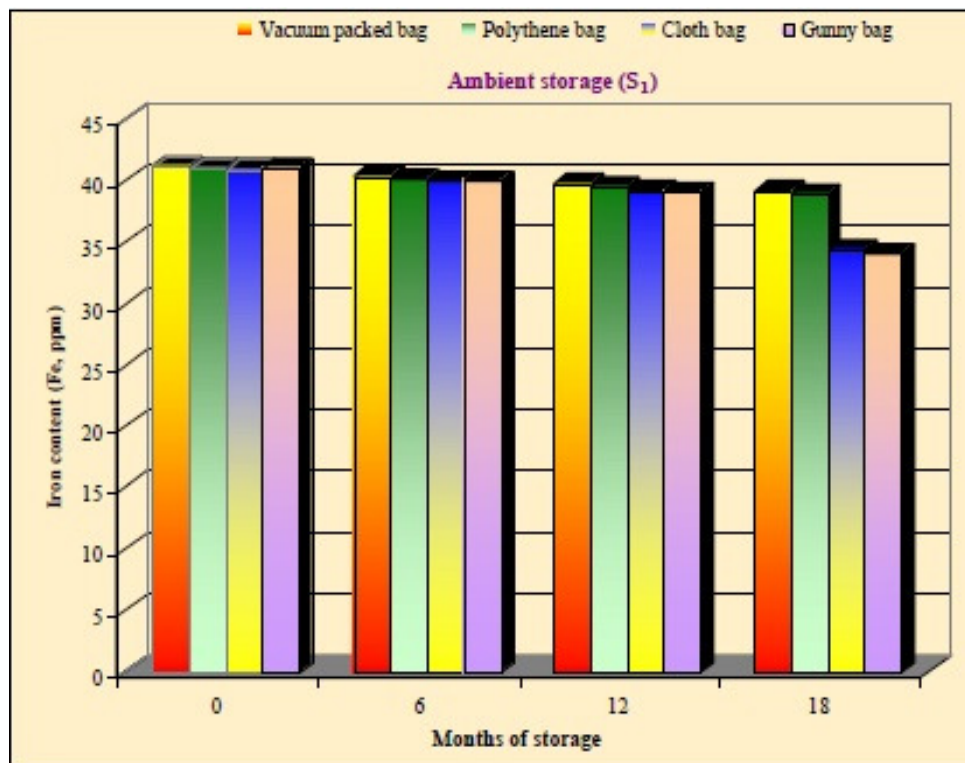


Fig 2: Influence of packaging and storage conditions on iron content (Fe, ppm) at different periods of storage in rice grains

Table 27. Influence of packaging and storage conditions on zinc content (Zn, ppm) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	19.6	19.5	19.5	19.4	19.5	19.5	19.2	19.2	19.2	18.8	18.8	18.8	18.6	18.6	18.6
C ₂	19.4	19.3	19.4	19.3	19.4	19.4	19.0	19.1	19.0	18.6	18.6	18.6	18.4	18.5	18.5
C ₃	19.5	19.4	19.5	19.2	19.2	19.2	18.8	19.0	18.9	18.4	18.4	18.4	18.2	18.3	18.2
C ₄	19.4	19.5	19.4	18.9	19.2	19.0	18.7	18.8	18.8	18.3	18.3	18.3	18.1	18.2	18.1
Mean	19.5	19.4		19.2	19.3		18.9	19.0		18.5	18.6		18.3	18.4	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.03	NS		0.08	NS		0.09	NS		0.10	NS		0.12	NS	
C	0.05	NS		0.11	NS		0.13	NS		0.15	NS		0.17	NS	
S × C	0.08	NS		0.15	NS		0.18	NS		0.20	NS		0.23	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	18.3	18.4	18.3	18.2	18.3	18.2	18.0	18.1	18.0	17.7	17.9	17.8	17.5	17.6	17.6
C ₂	18.1	18.2	18.2	18.0	18.0	18.0	17.7	17.9	17.8	17.5	17.7	17.6	17.3	17.4	17.4
C ₃	17.7	17.8	17.7	17.5	17.6	17.6	14.5	14.7	14.6	13.6	13.7	13.7	12.6	12.8	12.7
C ₄	17.6	17.7	17.7	17.4	17.6	17.5	14.3	14.5	14.4	13.5	13.6	13.6	12.4	12.7	12.6
Mean	17.9	18.07		17.8	17.9		16.2	16.3		15.6	15.7		15.0	15.2	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.13	NS		0.13	NS		0.07	NS		0.06	NS		0.05	NS	
C	0.18	NS		0.19	0.57		0.11	0.32		0.09	0.27		0.09	0.26	
S × C	0.25	NS		0.26	NS		0.15	NS		0.13	NS		0.12	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

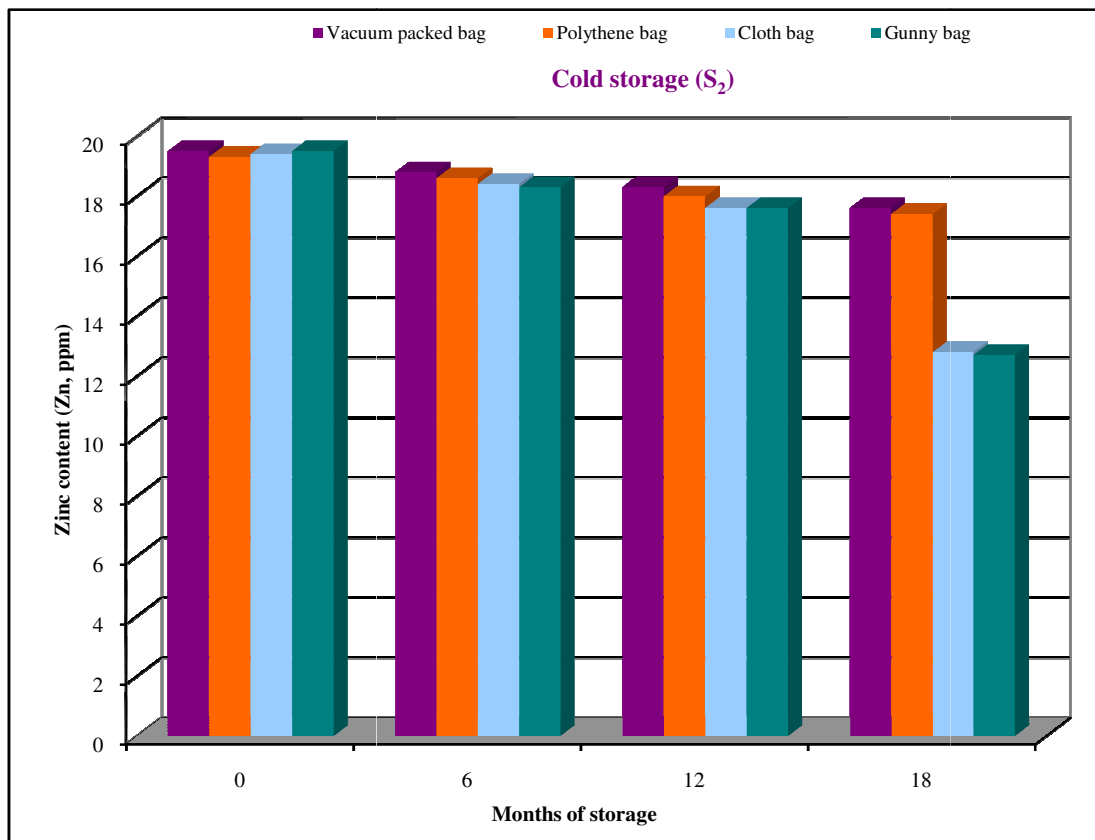
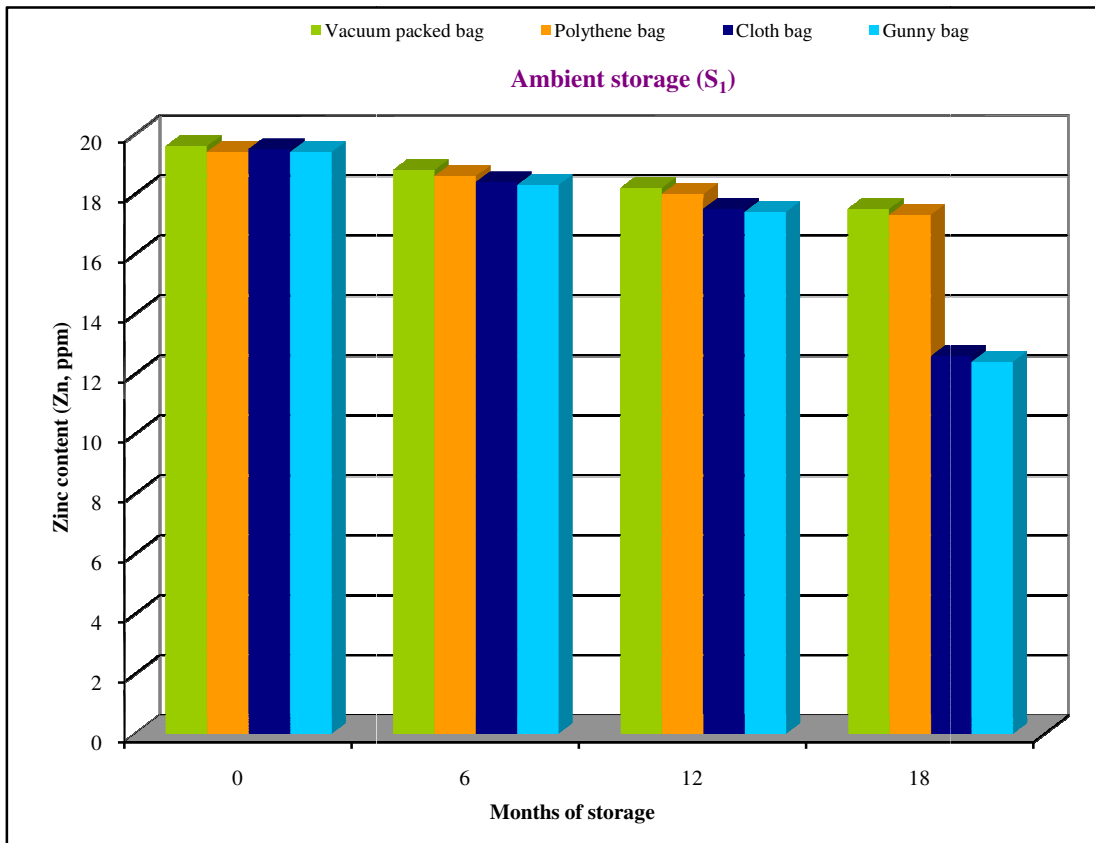


Fig. 3: Influence of packaging and storage conditions on zinc content (Zn, ppm) at different periods of storage in rice grains

Table 28. Influence of packaging and storage conditions on manganese content (Mn, ppm) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	39.1	39.2	39.2	39.1	39.2	39.1	38.8	38.9	38.8	38.4	38.5	38.4	38.2	38.3	38.2
C ₂	39.0	38.9	38.9	39.0	39.1	39.0	38.6	38.7	38.7	38.2	38.3	38.2	38.1	38.2	38.1
C ₃	38.9	39.1	39.0	38.6	38.9	38.7	38.4	38.6	38.5	38.0	38.1	38.0	37.8	37.9	37.8
C ₄	39.1	39.0	39.0	38.5	38.7	38.6	38.4	38.5	38.5	37.9	38.0	38.0	37.7	37.8	37.8
Mean	39.0	39.1		38.8	38.9		38.60	38.7		38.1	38.2		37.9	38.0	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.04	NS		0.12	NS		0.14	NS		0.13	NS		0.12	NS	
C	0.07	NS		0.17	NS		0.19	NS		0.18	NS		0.16	NS	
S × C	0.09	NS		0.24	NS		0.27	NS		0.26	NS		0.23	NS	

Treatments	Storage period (Months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	37.9	38.0	37.9	37.8	37.9	37.9	37.6	37.7	37.7	37.4	37.5	37.4	37.2	37.3	37.2
C ₂	37.7	37.8	37.8	37.6	37.7	37.6	37.4	37.5	37.4	37.2	37.3	37.2	36.9	37.1	37.0
C ₃	37.3	37.4	37.4	37.2	37.3	37.2	34.1	34.4	34.2	33.3	33.4	33.3	32.2	32.5	32.3
C ₄	37.3	37.4	37.3	37.1	37.2	37.1	34.0	34.2	34.1	33.2	33.3	33.2	32.1	32.2	32.1
Mean	37.6	37.7		37.4	37.5		35.8	35.9		35.2	35.3		34.6	34.8	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.13	NS		0.11	NS		0.09	NS		0.08	NS		0.08	NS	
C	0.18	NS		0.15	0.44		0.13	0.39		0.12	0.35		0.11	0.33	
S × C	0.25	NS		0.21	NS		0.18	NS		0.16	NS		0.15	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

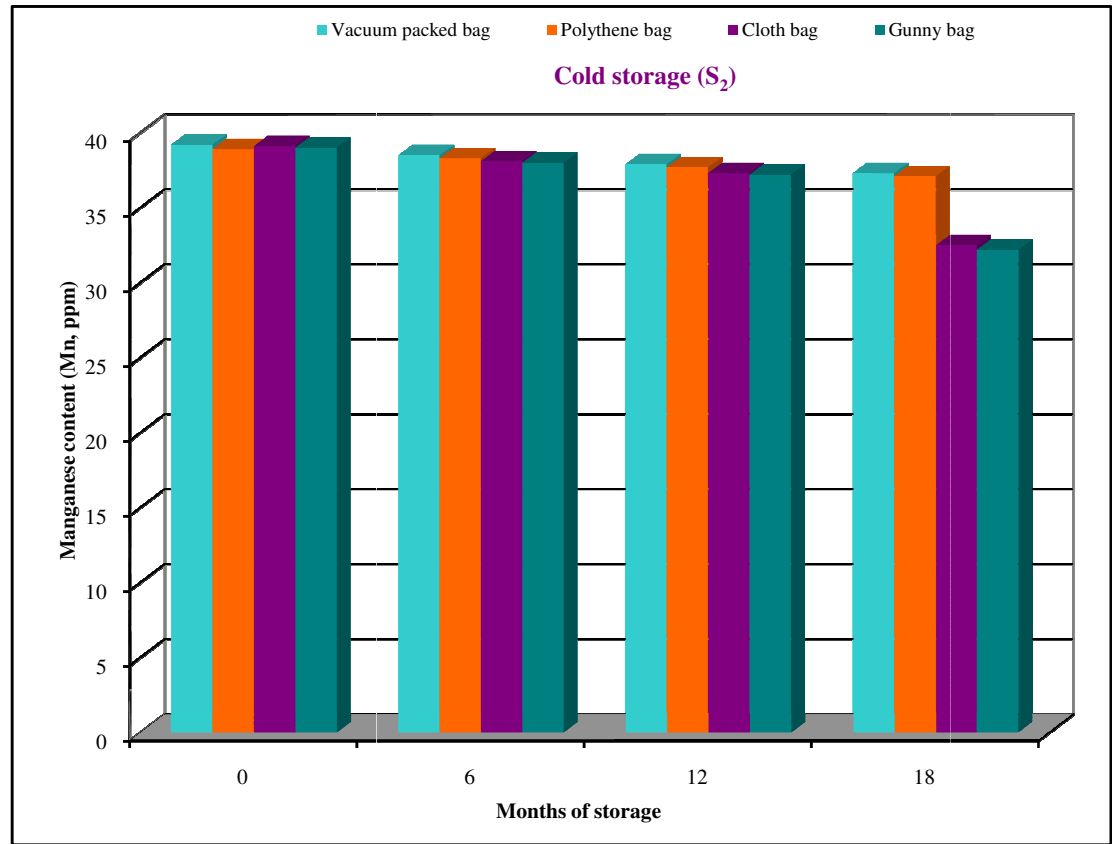
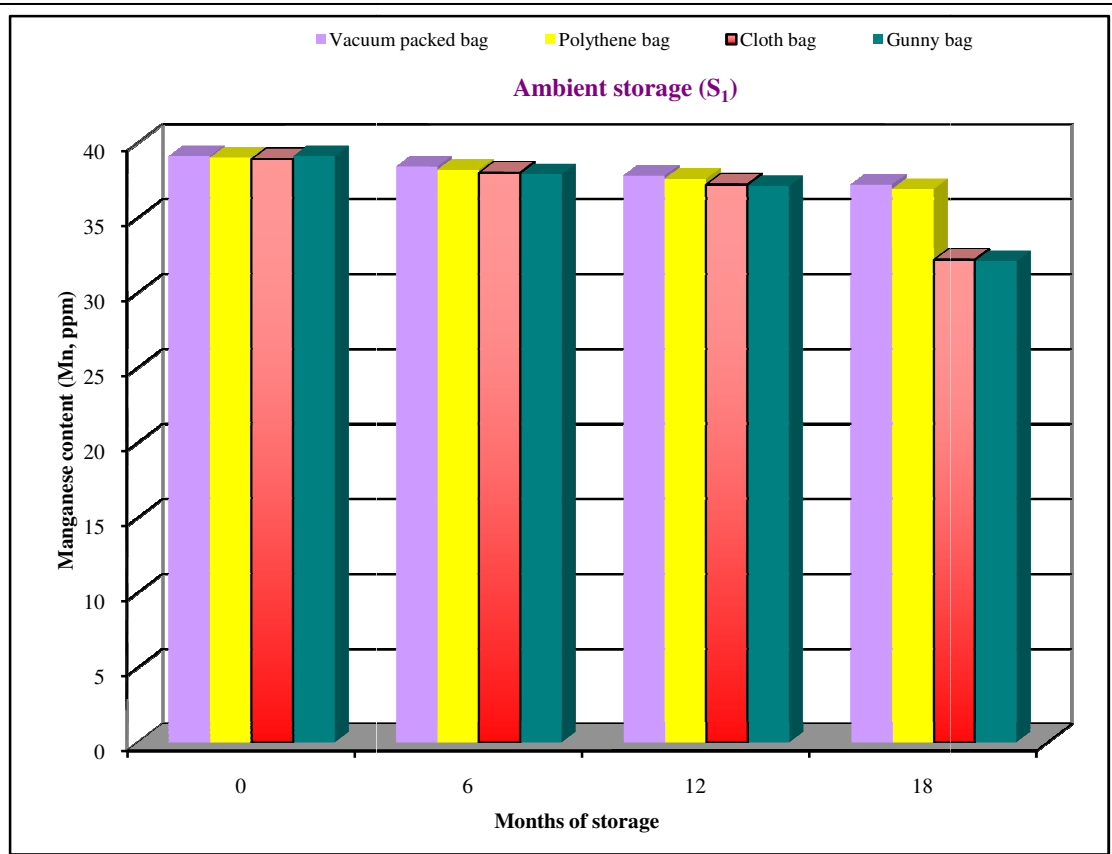


Fig. 4: Influence of packaging and storage conditions on manganese content (Mn, ppm) at different periods of storage in rice grains

no significant differences were seen between ambient storage (S_1) and cold storage (S_2) under vacuum packed bags (C_1) and polythene bags (C_2). It is clear from the results that cold storage (S_2) recorded higher zinc content among all the containers compared to ambient storage (S_1) at all the stages of storage.

4.4.4 Manganese content (ppm)

The data on manganese content as influenced by different packaging and storage conditions as shown in Table 28 and Fig. 4 was found to differ significantly with storage period. There was general decline found in manganese content with an increased in storage period among all storage containers, but rapid decline was observed in gunny bags (C_4) followed by cloth bags (C_3) and slow decline was observed in vacuum packaged bags (C_1) followed by polythene bags (C_2) from two months of storage period and continued up to 18 months of storage. Up to 10 months of storage, no significant differences were observed between treatments and storage conditions and their interactions, but significant differences were observed from 12 months of storage onwards. Among the containers, gunny bags (C_4) showed lower manganese content compared to all other treatments, while, vacuum packaged bags (C_1) recorded higher manganese content, which was significantly higher over all other treatments.

At 12 month, higher manganese content was recorded in vacuum packed bags stored under cold storage (C_1S_2) (37.9 ppm), which was on par with vacuum packed bags stored under ambient condition (C_1S_1) (37.8 ppm). The lower manganese content were observed in gunny bags stored under cold storage (C_4S_2) (37.2 ppm), which was on par with gunny bags stored under ambient storage (C_4S_1) (37.1 ppm). While, treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2), gunny bags stored under ambient storage (C_4S_1) and gunny bags stored under cold storage (C_4S_2) were at par with each other. At 18 months of storage, significantly higher manganese content was recorded in vacuum packaged bags (C_1) (37.3 ppm) followed by polythene bags (C_2) (37.2 ppm) under both ambient storage (S_1) and cold storage (S_2). The lower values of manganese content were recorded in gunny bags stored under ambient storage (C_4S_1) (32.1 ppm) followed by gunny bags stored under cold storage (C_4S_2) under both ambient storage (S_1) and cold storage (S_2)

compared to all other treatments. However, no significant differences were found among treatments. Among storage conditions, cold storage (S_2) had higher values of manganese content compared to ambient storage (S_1) among all the treatments were observed. It is clear from the results that, vacuum packed bags (C_1) recorded higher manganese content over all other containers at all the stages of storage period.

4.4.5 Alpha-Amylase activity (mg maltose released/min)

The influence of different packaging and storage conditions on α -amylase activity differ significantly between the treatments due to storage period (Table 29 and Fig. 5). There was gradual reduction in α -amylase activity among all the treatments and storage conditions with an advancement in storage period. The gradual decline in α -amylase activity, irrespective of storage containers was seen under both ambient storage (S_1) and cold storage (S_2). Up to 6 months of storage, no significant differences between storage containers, storage conditions and their interaction. Among the treatments, gunny bags (C_4) showed higher values of α -amylase activity; while in vacuum packaged bags (C_1) lower values of α -amylase activity were noticed.

At 8 months of storage, higher α -amylase activity was recorded in gunny bags stored under ambient storage (C_4S_1) (50.2 mg maltose released/min) followed by gunny bags stored under cold storage (C_4S_2) (50.1 mg maltose released/min). Lower α -amylase activity (mg maltose released/min) was observed in vacuum packed bags stored under ambient condition (C_1S_1) (49.8 mg maltose released/min) followed by vacuum packed bags stored under cold storage (C_1S_2) (49.5 mg maltose released/min). A similar trend continued at 10, 12, 14, 16 and 18 months of storage under both ambient storage (S_1) and cold storage (S_2). The treatments vacuum packed bags stored under ambient condition (C_1S_1), polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1) and cloth bags stored under cold storage (C_3S_2) were at par with each other. At end of 18 months of storage, significantly higher α -amylase (mg maltose released/min) was observed in gunny bags (C_4) (44.4 mg maltose released/min) followed by cloth bags (C_3) under both ambient storage (S_1) and cold storage (S_2). Lower α -amylase activity (mg maltose released/min) were observed in gunny bags stored under cold storage (C_4S_2) (43.7 mg maltose released/min). It was further observed that ambient storage (S_1)

recorded higher α -amylase activity in vacuum packaged bags (C_1), polythene bags (C_2) and cloth bags (C_3) compared to ambient storage (S_1). It is clear from the results that, gunny bags (C_4) maintained higher α -amylase activity throughout the storage period compared to all other treatments.

4.4.6 Lipase activity (meq. free fatty acid/min/g)

The results pertaining to lipase activity presented in Table 30 and Fig. 6 were found to differ significantly with treatments due to storage period as well as storage conditions. Up to 6 months of storage, no significant differences were found among the treatments and storage conditions. Among storage containers, the higher values of lipase activity were observed in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher over all other treatments. Significantly lower values of lipase activity were observed in vacuum packaged bags (C_1), which was significantly lower compared to all other treatments.

At 8th months of storage, higher values of lipase activity were observed in gunny bags stored under ambient storage (C_4S_1) (0.75 meq.free fatty acid/min/g) followed by gunny bags stored under cold storage (C_4S_2) (0.74 meq.free fatty acid/min/g). Lower values of lipase activity were seen in vacuum packed bags stored under ambient condition (C_1S_1) (0.48 meq.free fatty acid/min/g) followed by vacuum packed bags stored under cold storage (C_1S_2) (0.46 meq.free fatty acid/min/g), which was lower compared to all other treatments. Similar trend continued from 10, 12, 14, 16 and 18 months of storage. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1) and cloth bags stored under cold storage (C_3S_2) were at par with each other and they did not differ significantly. At 18 months of storage, gunny bags (C_4) recorded significantly higher lipase activity (0.92 meq.free fatty acid/min/g) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher over all other treatments throughout the storage period. Significantly lower lipase activity were observed in vacuum packed bags (C_1), which was significantly lower compared to all other treatments. The treatments cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and polythene bags stored under ambient

Table 29. Influence of packaging and storage conditions on α -amylase activity (mg maltose released/min) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	54.0	54.2	54.1	53.7	53.5	53.6	52.5	52.2	52.4	51.0	50.8	50.9	49.8	49.5	49.7
C ₂	54.2	54.1	54.2	53.8	53.6	53.7	52.6	52.4	52.5	51.1	50.9	51.0	49.9	49.7	49.8
C ₃	54.3	54.1	54.2	54.0	53.9	54.0	52.8	52.7	52.7	51.3	51.2	51.2	50.1	50.0	50.0
C ₄	54.1	54.3	54.3	54.1	54.0	54.1	52.9	52.7	52.8	51.4	51.3	51.3	50.2	50.1	50.1
Mean	54.3	54.2		53.9	53.7		52.7	52.5		51.2	51.0		50.0	49.8	
	S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)	
S	0.02	NS		0.11	NS		0.10	NS		0.09	NS		0.07	NS	
C	0.03	NS		0.16	NS		0.15	NS		0.13	NS		0.10	0.29	
S \times C	0.05	NS		0.22	NS		0.21	NS		0.18	NS		0.13	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	48.3	48.1	48.2	47.1	46.9	47.0	46.1	45.8	45.9	45.1	44.8	45.0	43.8	43.7	43.8
C ₂	48.4	48.2	48.3	47.2	47.0	47.1	46.2	45.9	46.1	45.2	45.0	45.1	44.3	44.0	44.2
C ₃	48.6	48.5	48.6	47.4	47.3	47.3	46.3	46.3	46.3	45.4	45.3	45.3	44.4	44.3	44.4
C ₄	48.7	48.6	48.6	47.5	47.4	47.4	46.4	46.4	46.4	45.5	45.4	45.4	44.5	44.3	44.4
Mean	48.5	48.3		47.3	47.2		46.3	46.1		45.3	45.1		44.3	44.1	
	S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)	
S	0.04	0.13		0.04	0.11		0.03	0.09		0.03	0.08		0.02	0.07	
C	0.05	0.16		0.05	0.15		0.04	0.13		0.04	0.12		0.03	0.10	
S \times C	0.07	NS		0.07	NS		0.06	NS		0.05	NS		0.05	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

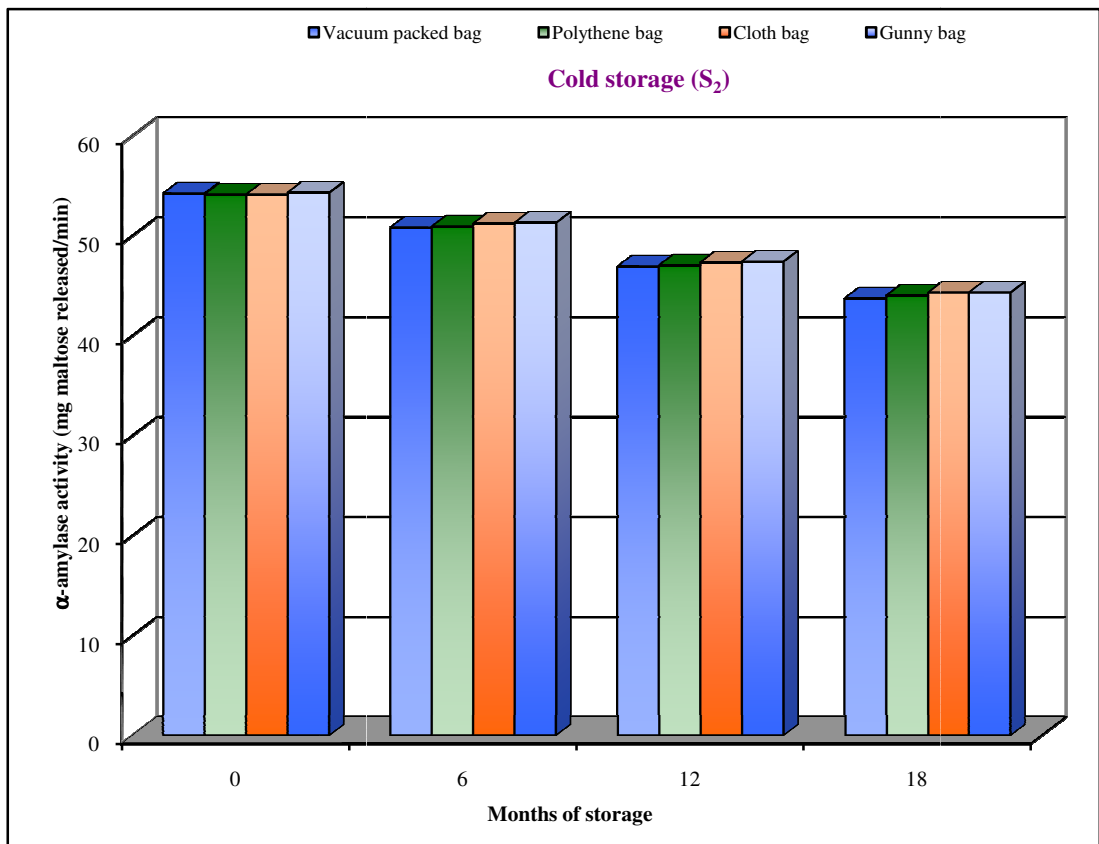
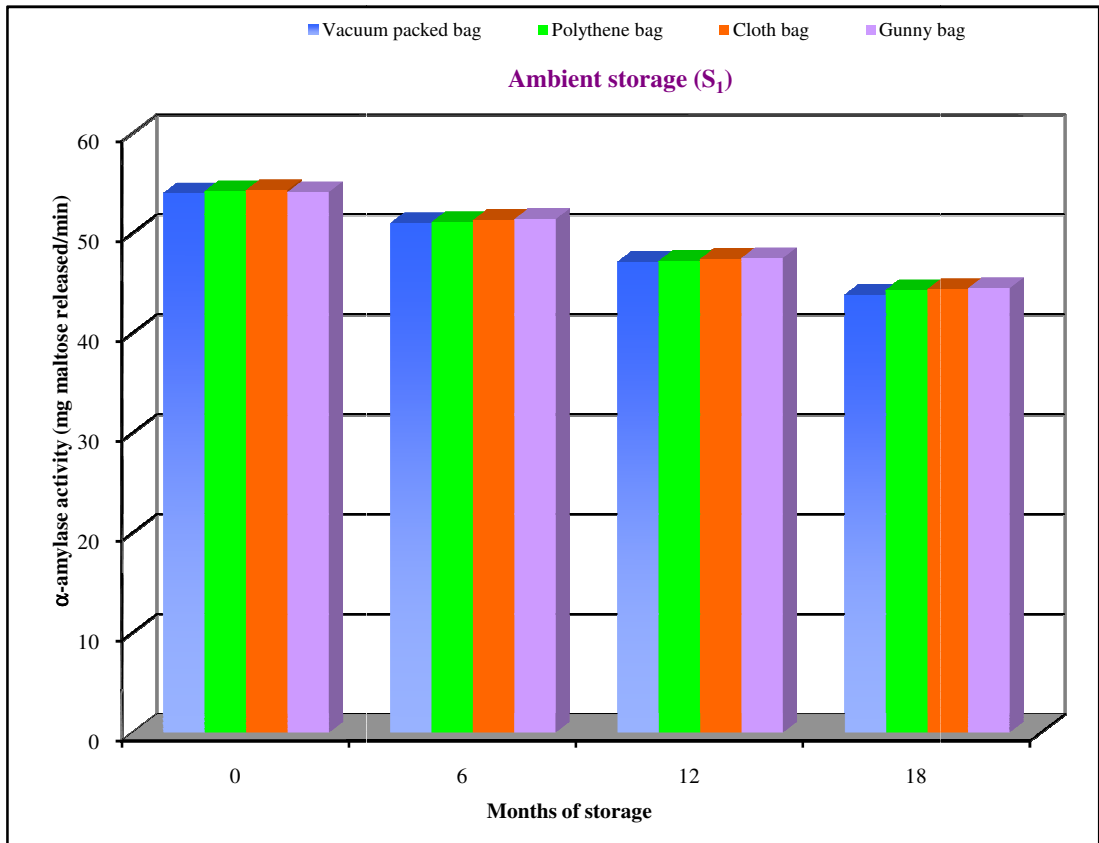


Fig 5: Influence of packaging and storage conditions on α -amylase activity (mg maltose released/min) at different periods of storage in rice grains

Table 30. Influence of packaging and storage conditions on lipase activity (m.eq. free fatty acid /min/g) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	0.40	0.43	0.41	0.41	0.40	0.41	0.42	0.41	0.42	0.45	0.43	0.44	0.48	0.46	0.47
C ₂	0.41	0.42	0.41	0.44	0.42	0.43	0.49	0.45	0.47	0.50	0.49	0.50	0.59	0.57	0.58
C ₃	0.44	0.40	0.42	0.48	0.47	0.48	0.54	0.50	0.52	0.68	0.54	0.61	0.72	0.61	0.67
C ₄	0.44	0.46	0.45	0.51	0.49	0.50	0.62	0.60	0.61	0.71	0.70	0.71	0.75	0.74	0.75
Mean	0.42	0.43		0.46	0.45		0.52	0.49		0.59	0.54		0.64	0.60	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.01	NS		0.02	NS		0.02	NS		0.02	NS		0.01	0.03	
C	0.02	NS		0.03	NS		0.03	NS		0.03	0.08		0.02	0.05	
S × C	0.02	NS		0.03	NS		0.04	NS		0.04	NS		0.02	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	0.51	0.48	0.50	0.53	0.49	0.51	0.55	0.52	0.54	0.58	0.56	0.57	0.59	0.58	0.59
C ₂	0.62	0.60	0.61	0.65	0.64	0.65	0.68	0.66	0.67	0.70	0.69	0.70	0.71	0.70	0.71
C ₃	0.77	0.68	0.73	0.80	0.72	0.76	0.84	0.79	0.82	0.86	0.83	0.85	0.88	0.85	0.87
C ₄	0.82	0.78	0.80	0.84	0.83	0.84	0.87	0.84	0.86	0.90	0.89	0.90	0.92	0.91	0.92
Mean	0.68	0.64		0.71	0.67		0.74	0.70		0.76	0.74		0.78	0.76	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.01	0.03		0.01	0.03		0.01	0.03		0.02	NS		0.02	NS	
C	0.02	0.06		0.02	0.06		0.02	0.06		0.02	0.07		0.02	0.07	
S × C	0.03	NS		0.03	NS		0.03	NS		0.03	NS		0.03	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

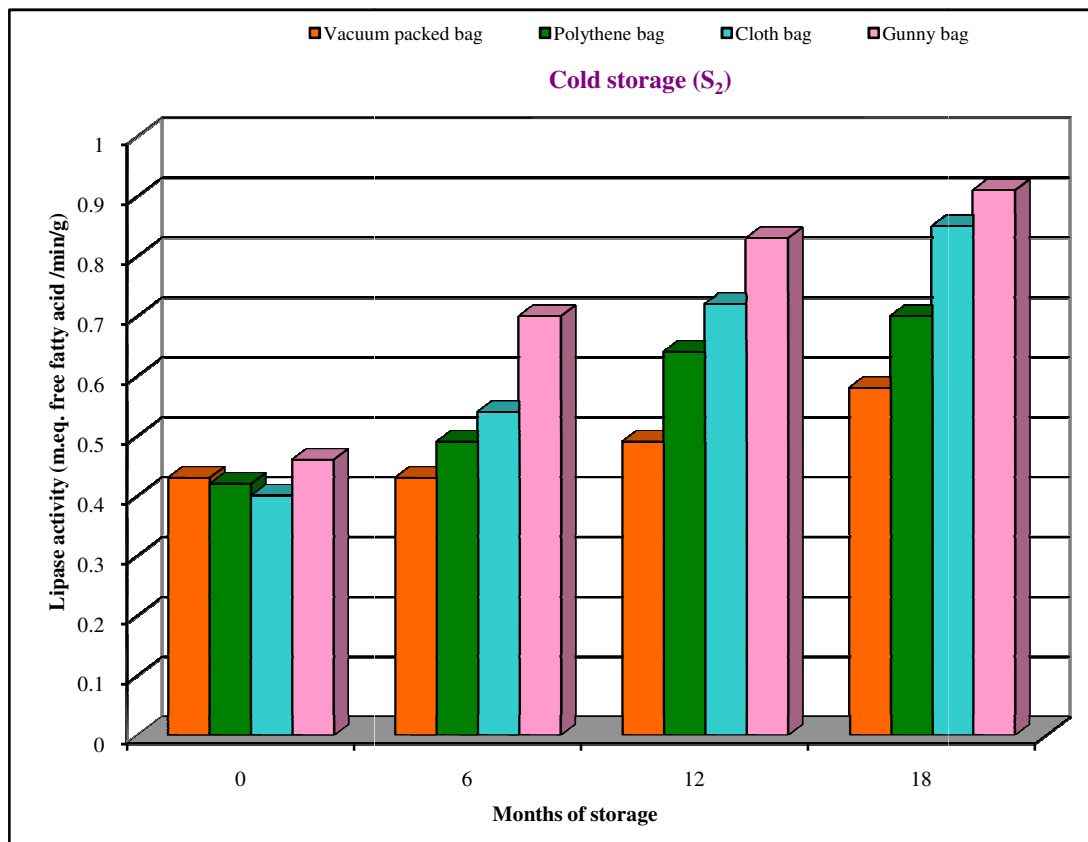
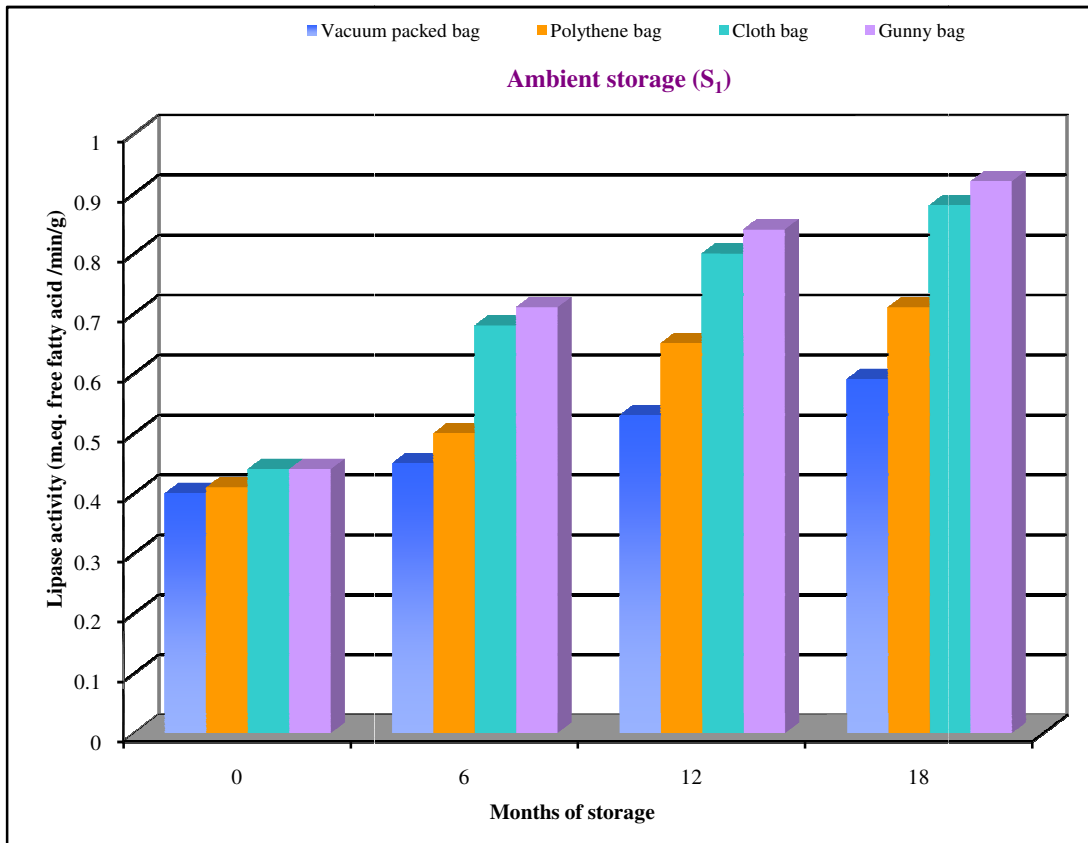


Fig. 6: Influence of packaging and storage conditions on lipase activity (m.eq. free fatty acid /min/g) at different periods of storage in rice grains

storage (C_2S_1), polythene bags stored under cold storage (C_2S_2) were at par with each other. It is clear from the results that, ambient storage (S_1) exhibited higher lipase activity compared to cold storage (S_2) throughout the storage period.

4.4.7 Protease activity (mg amino acid released /min/ml)

The observations on protease activity as influenced by different packaging and storage conditions measured up to 18 months presented in Table 31 and Fig. 7 revealed significant differences from 10 months of storage and up to 18 months of storage. Among the storage containers, the values of protease activity was observed maximum in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2) followed by cloth bags (C_3), which was significantly higher compared to all other treatments. No significant differences were found between storage conditions and storage containers and their interaction up to 8 months of storage. Protease activity was decreased with a progress in storage period among all the storage containers throughout the storage period.

At 10 months of storage, lower values of protease activity was observed in vacuum packed bags stored under ambient condition (C_1S_1) (1.21 mg amino acid released/min/ml) followed by vacuum packed bags stored under cold storage (C_1S_2) (1.18 mg amino acid released/min/ml), which was lower compared to all other treatments. The higher protease activity (mg amino acid released/min/ml) was observed in gunny bags stored under ambient storage (C_4S_1) (1.50 mg amino acid released/min/ml) followed by gunny bags stored under cold storage (C_4S_2) (1.46 mg amino acid released/min/ml), which was higher over all other treatments and did not differ significantly among themselves. A similar trend continued up to 18 months of storage. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1) and cloth bags (C_3) cold storage (S_2) were at par with each other. At 18 months of storage, significantly higher protease activity was observed in gunny bags (C_4) (1.60 mg amino acid released/min/ml), which was superior over all other treatments under ambient storage (S_1) and cold storage (S_2). Among containers, vacuum packaged bags (C_1) recorded lower protease activity (1.27 mg amino acid released/min/ml) compared to all other treatments. It was further observed that, ambient storage (S_1) recorded significantly higher values of protease activity in both vacuum packaged bags (C_1), polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) compared to cold storage (S_2).

4.4.8 Peroxidase activity (Δ OD mg protein/ min)

The data on peroxidase activity presented in Table 32 and Fig. 8 indicated significant differences between storage containers and storage conditions and their interaction. Up to 4 months of storage, no significant differences were observed between storage containers and storage conditions and their interaction, but significant differences were observed from 6 months of storage and up to 18 months of storage. Among the containers, gunny bags (C_4) recorded higher values of peroxidase activity over all other treatments under both ambient storage (S_1) and cold storage (S_2). Significantly lower values of peroxidase activity were observed in vacuum packaged bags (C_1) compared to all other treatments, which was on par with polythene bags (C_2).

At 6th months of storage, higher peroxidase activity (Δ OD mg protein/min) was found in gunny bags stored under ambient storage (C_4S_1) (9.91) followed by gunny bags stored under cold storage (C_4S_2) (9.89), which was higher compared over all other treatments. The low peroxidase activity (Δ OD mg protein/min) was found in vacuum packed bags stored under ambient condition (C_1S_1) (9.63) followed by vacuum packed bags stored under cold storage (C_1S_2) (9.62), which was lower compared to all other treatments. A similar trend followed from 8 months and up to 18 months of storage. Among the interactions, cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2), gunny bags stored under ambient storage (C_4S_1) and gunny bags stored under cold storage (C_4S_2) were at par with each other. During 18 months of storage, gunny bags (C_4) recorded significantly higher peroxidase activity (9.74 Δ OD mg protein/min) over all other treatments followed by cloth bags (C_3) (9.72 Δ OD mg protein/min), which were at par with each other. The lower peroxidase activity (Δ OD mg protein/min) was found in vacuum packed bags stored under cold storage (C_1S_2) (9.09) followed by vacuum packed bags stored under ambient condition (C_1S_1), which was lower over all other treatments. It is clear from the results; ambient storage (S_1) recorded higher peroxidase activity among all the treatments compared to cold storage (S_2) throughout the storage period. Peroxidase activity decreased with a progress in storage period among all the containers.

Table 31. Influence of packaging and storage conditions on protease activity (mg amino acid released/min/ml) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	1.08	1.11	1.10	1.09	1.08	1.08	1.13	1.10	1.11	1.14	1.12	1.13	1.17	1.15	1.16
C ₂	1.10	1.09	1.09	1.12	1.10	1.11	1.17	1.15	1.16	1.20	1.19	1.20	1.27	1.25	1.26
C ₃	1.08	1.07	1.08	1.16	1.15	1.15	1.22	1.18	1.20	1.36	1.22	1.29	1.40	1.29	1.35
C ₄	1.13	1.12	1.13	1.19	1.17	1.18	1.30	1.28	1.29	1.39	1.38	1.39	1.43	1.42	1.43
Mean	1.10	1.10		1.14	1.12		1.20	1.18		1.27	1.23		1.32	1.28	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.01	NS		0.04	NS		0.04	NS		0.04	NS		0.04	NS	
C	0.02	NS		0.06	NS		0.06	NS		0.06	NS		0.06	NS	
S × C	0.02	NS		0.08	NS		0.08	NS		0.09	NS		0.10	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	1.21	1.18	1.20	1.23	1.20	1.22	1.25	1.21	1.23	1.26	1.24	1.25	1.28	1.27	1.28
C ₂	1.32	1.29	1.31	1.33	1.32	1.33	1.36	1.34	1.35	1.38	1.36	1.37	1.39	1.37	1.38
C ₃	1.45	1.36	1.41	1.48	1.40	1.44	1.51	1.45	1.48	1.54	1.51	1.53	1.56	1.53	1.55
C ₄	1.50	1.46	1.48	1.52	1.51	1.52	1.53	1.52	1.53	1.57	1.54	1.56	1.60	1.59	1.60
Mean	1.37	1.32		1.39	1.36		1.41	1.38		1.08	1.42		1.46	1.19	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.05	NS		0.05	NS		0.04	NS		0.05	0.14		0.04	0.12	
C	0.07	0.20		0.07	0.21		0.06	0.19		0.07	0.20		0.06	0.17	
S × C	0.09	NS		0.10	NS		0.09	NS		0.09	0.28		0.08	0.24	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

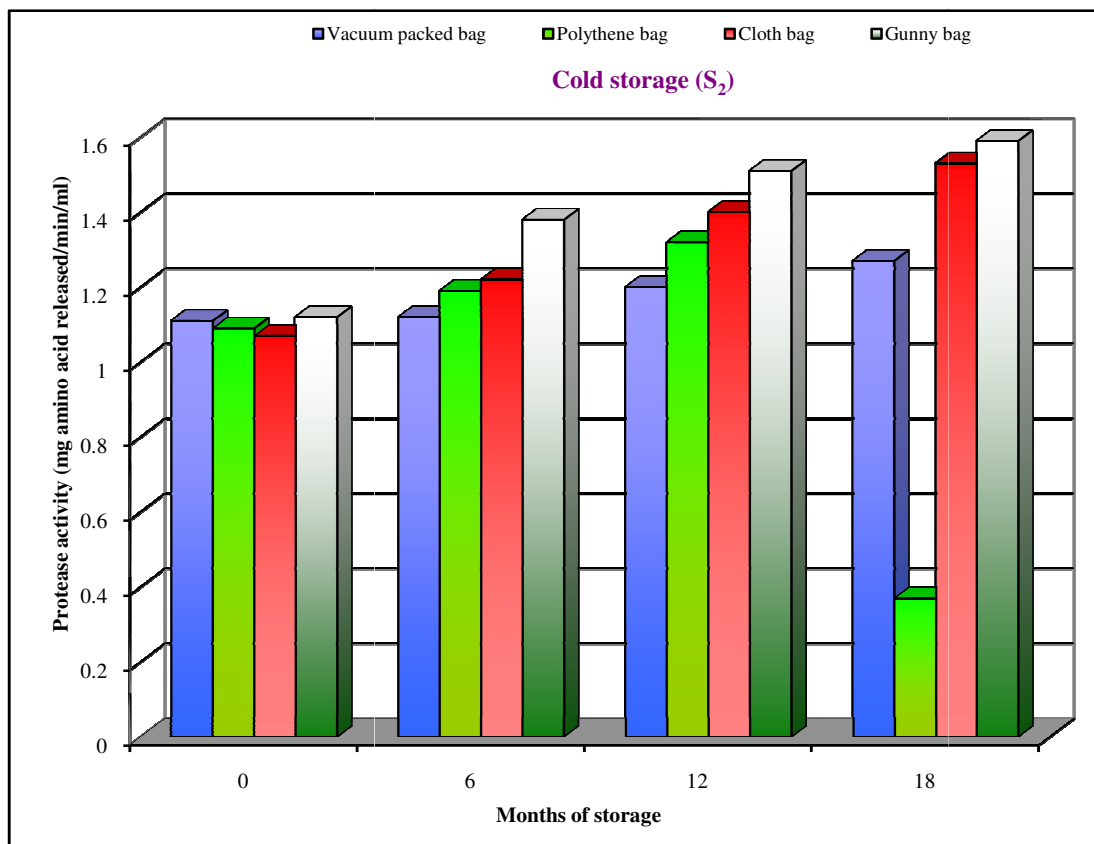
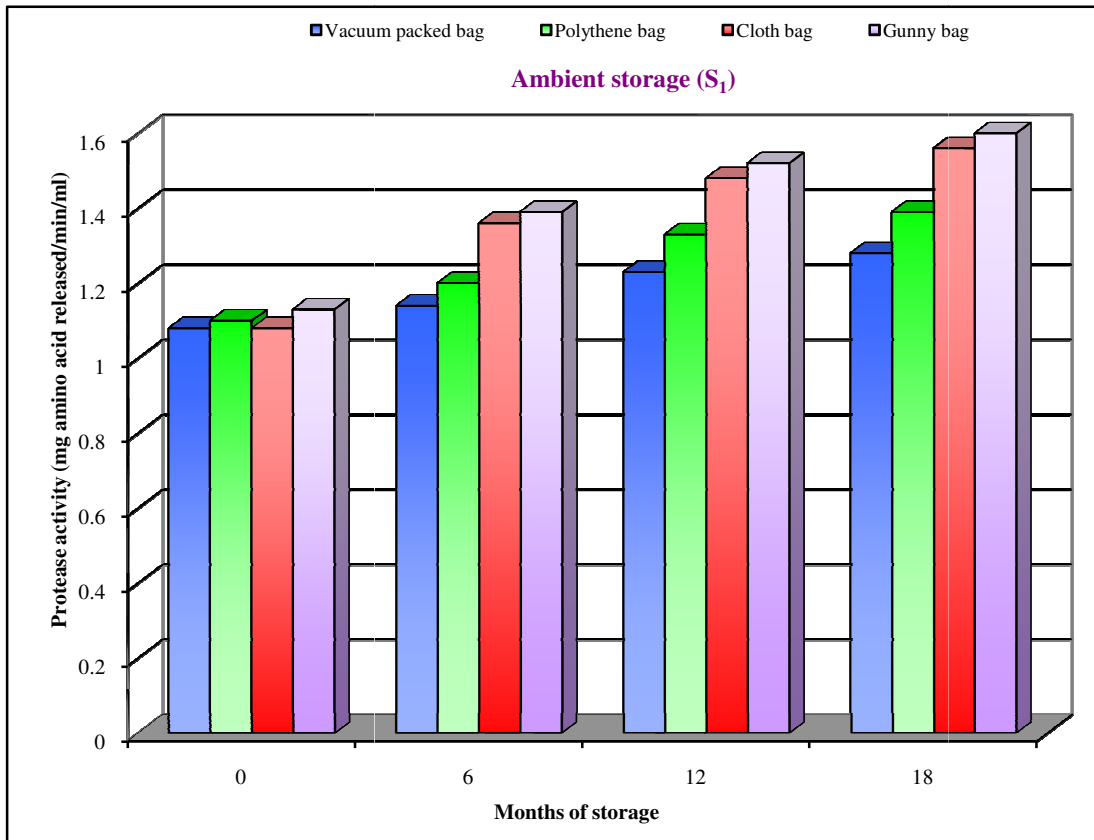


Fig. 7: Influence of packaging and storage conditions on protease activity (mg amino acid released/min/ml) at different periods of storage in rice grains

Table 32. Influence of packaging and storage conditions on peroxidase activity (Δ OD mg protein/min) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	9.74	9.80	9.77	9.67	9.65	9.66	9.66	9.64	9.65	9.63	9.62	9.63	9.61	9.59	9.60
C ₂	9.78	9.71	9.75	9.75	9.72	9.74	9.71	9.69	9.70	9.68	9.65	9.67	9.65	9.62	9.64
C ₃	9.83	9.86	9.85	9.92	9.89	9.91	9.94	9.92	9.93	9.89	9.88	9.89	9.85	9.82	9.84
C ₄	9.77	9.72	9.75	9.95	9.91	9.93	9.94	9.93	9.94	9.91	9.89	9.90	9.86	9.84	9.85
Mean	9.78	9.77		9.82	9.79		9.81	9.80		9.78	9.76		9.74	9.72	
	S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)	
S	0.02	NS		0.06	NS		0.06	NS		0.06	NS		0.05	NS	
C	0.03	NS		0.09	NS		0.09	NS		0.09	0.26		0.08	0.23	
S \times C	0.05	NS		0.13	NS		0.12	NS		0.12	NS		0.11	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	9.52	9.48	9.50	9.42	9.39	9.41	9.34	9.32	9.33	9.26	9.21	9.24	9.15	9.09	9.12
C ₂	9.57	9.56	9.57	9.52	9.48	9.50	9.48	9.41	9.45	9.43	9.32	9.38	9.28	9.16	9.22
C ₃	9.83	9.80	9.82	9.79	9.77	9.78	9.76	9.74	9.75	9.75	9.72	9.74	9.72	9.68	9.70
C ₄	9.85	9.81	9.83	9.83	9.78	9.81	9.77	9.75	9.76	9.76	9.73	9.75	9.74	9.71	9.73
Mean	9.69	9.66		9.64	9.61		9.59	9.56		9.55	9.50		9.47	9.41	
	S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)		S.Em \pm	C.D. (1%)	
S	0.04	NS		0.04	NS		0.04	NS		0.03	NS		0.03	NS	
C	0.06	0.18		0.05	0.16		0.05	0.15		0.05	0.14		0.05	0.14	
S \times C	0.08	NS		0.07	NS		0.07	NS		0.07	NS		0.06	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

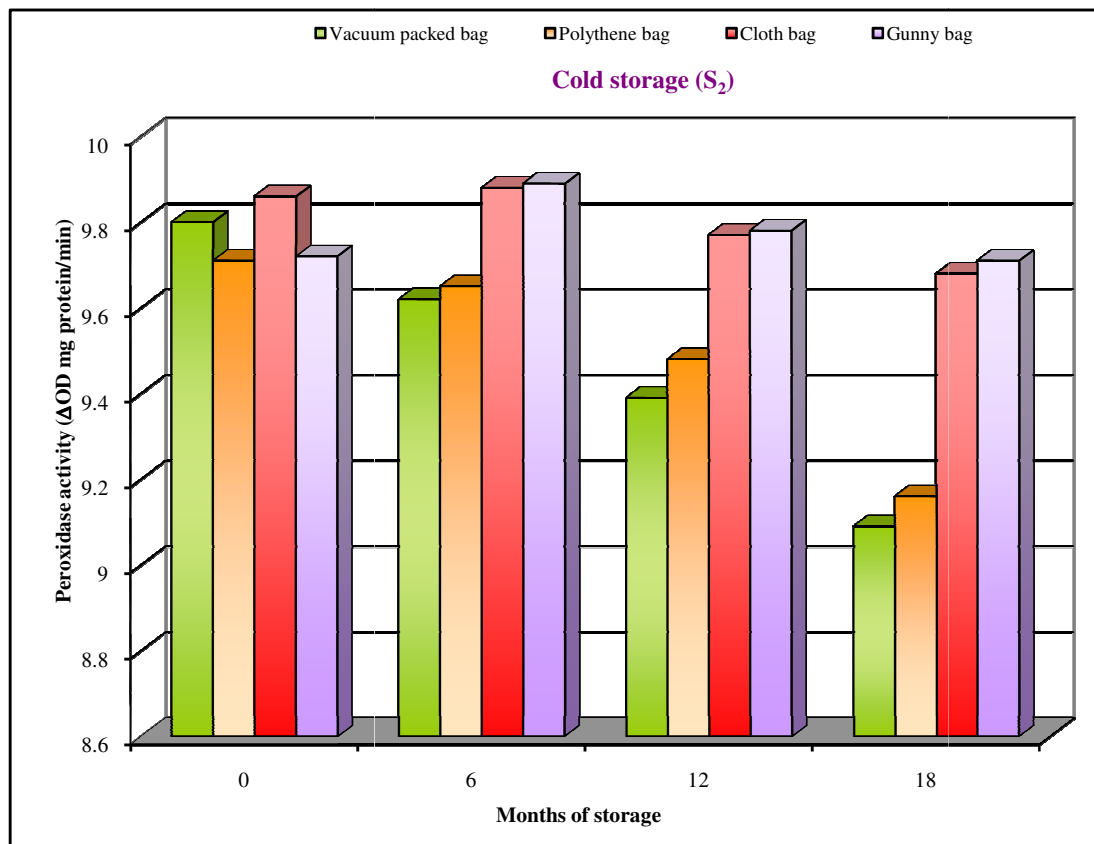
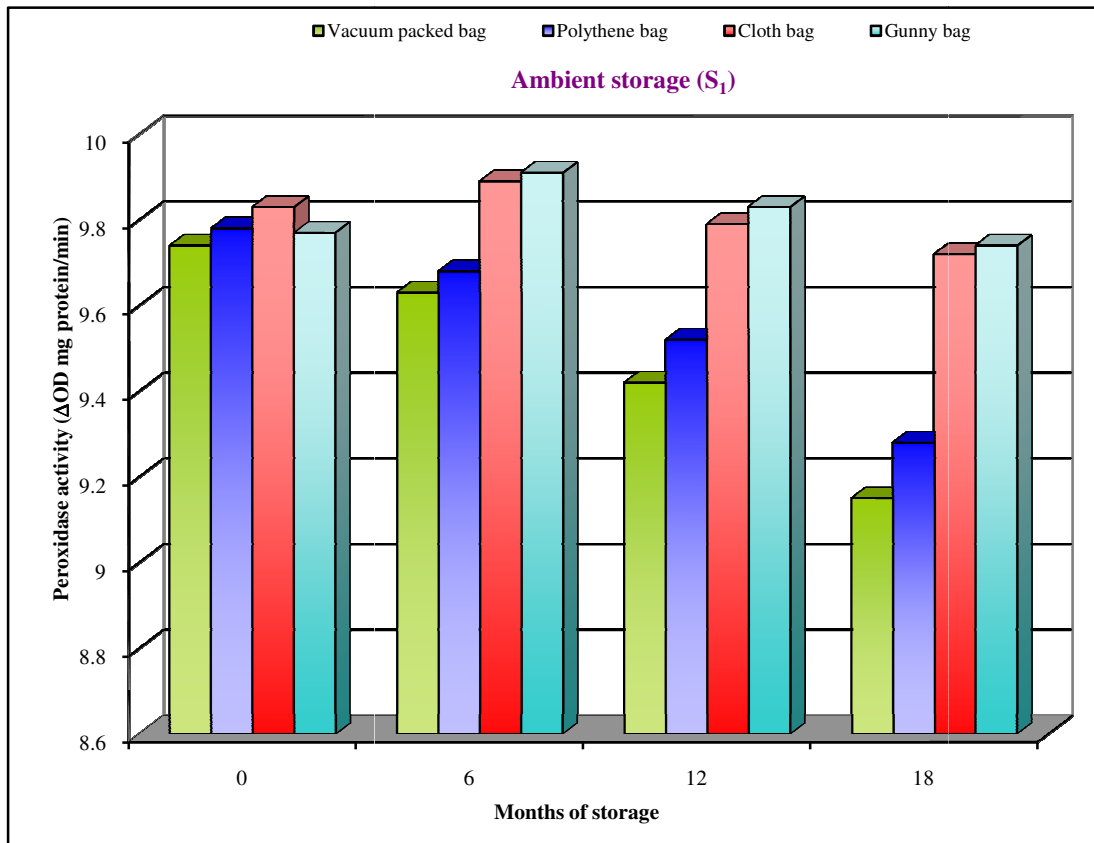


Fig. 8: Influence of packaging and storage conditions on peroxidase activity (Δ OD mg protein/min) at different periods of storage in rice grains

Table 33. Influence of packaging and storage conditions on moisture content (%) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	13.8	14.0	14.0	13.8	13.8	13.8	13.9	13.9	13.9	13.9	13.9	13.9	13.8	13.9	13.9
C ₂	13.9	14.0	13.9	13.9	13.9	13.8	13.9	14.0	14.0	13.9	14.0	13.9	14.0	14.0	14.0
C ₃	14.1	14.0	14.0	16.0	18.6	17.3	15.9	18.6	17.3	16.0	18.5	17.3	16.0	18.1	17.1
C ₄	14.0	14.1	14.0	17.7	18.8	18.3	17.8	18.9	18.4	17.9	18.7	18.3	17.4	18.6	18.0
Mean	13.9	14.0		15.3	16.3		15.4	16.4		15.4	16.3		15.3	16.1	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.06	NS		0.23	0.71		0.24	0.74		0.24	0.74		0.23	0.70	
C	0.08	NS		0.33	1.00		0.35	1.05		0.34	1.02		0.32	0.98	
S × C	0.12	NS		0.47	1.42		0.49	NS		0.48	NS		0.46	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	13.8	13.91	13.8	13.8	13.9	13.9	13.8	13.8	13.8	13.7	13.8	13.8	13.8	13.7	13.7
C ₂	13.9	14.0	13.9	13.8	13.9	13.9	13.9	13.8	13.9	13.9	13.8	13.9	13.7	13.8	13.8
C ₃	16.1	18.3	17.2	16.0	18.2	17.1	15.6	18.1	16.9	15.3	17.8	16.5	14.9	17.8	16.3
C ₄	17.3	18.5	17.9	17.3	18.4	17.9	16.2	18.3	17.3	15.9	18.1	17.0	15.2	18.0	16.6
Mean	15.3	16.1		15.3	16.1		14.9	16.0		14.7	15.91		14.4	15.86	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.22	0.65		0.20	0.62		0.20	0.62		0.19	0.57		0.18	0.54	
C	0.30	0.92		0.29	0.88		0.28	0.85		0.27	0.81		0.25	0.77	
S × C	0.43	NS		0.41	NS		0.41	1.23		0.38	1.15		0.36	1.08	

Storage conditions (S)
S₁= Ambient storage
S₂= Cold storage

Storage containers (C)
C₁= Vacuum packed bags
C₂= Polythene bags

C₃= Cloth bags
C₄= Gunny bags

4.5 PROXIMATE COMPOSITION

4.5.1 Moisture content (%)

The influence of different packaging and storage conditions on moisture content presented indicated significant differences between the storage containers and storage conditions at all the stages of storage *i.e.* up to 18 months (Table 33). In general, no much change and slight decline in the moisture content were observed in the vacuum packed bags stored under ambient condition (C_1S_1), vacuum packed bags stored under cold storage (C_1S_2) and polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2) during 18 months of storage, which was almost negligible. Among interactions, lot of fluctuations and high moisture content were noticed in gunny bags stored under ambient storage (C_4S_1), gunny bags stored under cold storage (C_4S_2) followed by cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) throughout the storage period. Among the storage containers, the moisture content was maximum in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to other treatments. Significantly lower moisture content was observed in vacuum packaged bags (C_1) followed by polythene bags (C_2), which was significantly lower compared to all other treatments.

At 2th month, maximum moisture content was observed in gunny bags (C_4) (18.3%) under both ambient storage (S_1) and cold storage (S_2), which was significantly superior over all other treatments followed by cloth bags (C_3). Significantly lower moisture content was recorded in vacuum packed bags stored under ambient condition (C_1S_1) (13.8%) followed vacuum packed bags stored under cold storage (C_1S_2) (13.8%). A similar trend was followed up to 18 months of storage. It was further observed that cold storage (S_2) recorded significantly higher moisture content in both vacuum packaged bags (C_1), polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) compared

to ambient storage (S_1). The treatments cloth bags stored under ambient storage (C_3S_1), gunny bags stored under ambient storage (C_4S_1) and cloth bags stored under cold storage (C_3S_2), gunny bags stored under cold storage (C_4S_2) were at par with each other. Among the containers, vacuum packaged bags (C_1) exhibited very less moisture content compared to other treatments throughout the storage period.

4.5.2 Crude protein (%)

Storage containers, Storage conditions and their interaction differ significantly with respect to crude protein as presented in Table 34. Among the treatments, vacuum packaged bags (C_1) recorded significantly higher crude protein content over all other treatments and gunny bags (C_4) recorded significantly lower crude protein content under both ambient storage (S_1) and cold storage (S_2). Up to 4 months of storage, no significant differences were observed between storage containers, storage conditions and their interaction. Significant differences were observed from 6 months of storage and up to 18 months of storage.

At 6th months of storage, the higher crude protein content was observed in vacuum packed bags stored under cold storage (C_1S_2) (7.08%) followed by vacuum packed bags stored under ambient condition (C_1S_1) (7.06%), which was superior over all other treatments. Lower crude protein content was observed in gunny bags stored under cold storage (C_4S_2) (7.01%) followed by gunny bags stored under ambient storage (C_4S_1) (6.98%), which was significantly lower compared to all other treatments. A similar trend continued from 8 months of storage and upto 18 months of storage. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) were at par with each other. At 18 months of storage, crude protein content was found in vacuum packed bags stored under cold storage (C_1S_2) (6.95%) followed by vacuum packed bags stored under ambient condition (C_1S_1) (6.89%) compared to all other treatments. The lower crude protein content was found in gunny bags stored under cold storage (C_4S_2) (6.67%) followed by gunny bags stored under ambient storage (C_4S_1) (6.52%), which was lower over all other treatments. It was further observed that, cold storage (S_2) recorded significantly higher crude protein content in polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) compared to ambient storage (S_1).

4.5.3 Fat content (%)

The data on fat content as influenced by different packaging and storage conditions due to storage period (Table 35). Among the treatments, decreased trend was observed in fat content with an increase in storage period. No significant differences were observed between storage containers and storage conditions and their interaction up to 6 months of storage. Significant differences were noticed from 8 months of storage onwards and up to 18 months of storage. Among the containers, vacuum packaged bags (C_1) recorded significantly higher fat content compared to all other treatments under both cold storage (S_2) and ambient storage (S_1), which was significantly superior over polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) treatments. The lower fat content was observed in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2), which was significantly lower over all other treatments. It was noticed among the treatments vacuum packaged bags (C_1) on par with polythene bags (C_2) and cloth bags (C_3) on par with gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2).

At 8 months of storage, the lower fat content was observed in gunny bags stored under ambient storage (C_4S_1) (0.88%) followed by gunny bags stored under cold storage (C_4S_2) (0.94%), which was lower compared to all other treatments. The higher fat content was noticed in vacuum packed bags stored under cold storage (C_1S_2) (1.08%) followed by vacuum packed bags stored under ambient condition (C_1S_1) (0.97%), which was higher over all other treatments. The treatments polythene bags stored under ambient storage (C_2S_1), polythene bags stored under cold storage (C_2S_2), cloth bags stored under ambient storage (C_3S_1), cloth bags stored under cold storage (C_3S_2) and gunny bags stored under cold storage (C_4S_2) were at par with each other. During 18 months of storage period, lower fat content was observed in gunny bags (C_4) (0.40%), which was significantly lower over all other treatments followed by cloth bags (C_3) (0.44%). Among the containers, vacuum packaged bags (C_1) recorded significantly higher fat content (0.88%) compared to all other treatments followed by polythene bags (C_2) (0.85%). It is clear from the results that, cold storage (S_2) showed higher fat content among all the treatments compared to ambient storage (S_1) throughout the storage period.

4.5.4 Ash content (%)

Influence of packaging and storage conditions on ash content presented in Table 36 revealed that significantly differ with storage containers due to storage period. Among the treatments, at initial stage and up to 4 months of storage, no significant differences were found in ash content, but after sixth months of storage and upto 18 month of storage, significant differences were observed at all the stages of storage. The significantly higher ash content was observed in vacuum packaged bags (C_1) followed by polythene bags (C_2) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to all other treatments. Significantly lower ash content was observed in gunny bags (C_4) followed by cloth bags (C_3) under both ambient storage (S_1) and cold storage (S_2), which was significantly lower over all other treatments.

At sixth month, higher ash content (0.99%) was recorded in vacuum packed bags stored under cold storage (C_1S_2) followed by vacuum packed bags stored under ambient condition (C_1S_1) (0.88%) and lower ash content were observed in gunny bags stored under cold storage (C_4S_2) (0.77%) followed by gunny bags stored under ambient storage (C_4S_1) (0.72%). A similar trend was continued up to 18 months of storage period. The treatments vacuum packaged bags (C_1) on par with polythene bags (C_2) and cloth bags (C_3) on par with gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2). At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher ash content (0.95%) over all other treatments under both ambient storage (S_1) and cold storage (S_2). The lower ash content was seen in gunny bags stored under ambient storage (C_4S_1) (6.52%) compared to all other treatments. It is clear from the results that, vacuum packaged bags (C_1) showed higher ash content compared to all other containers throughout the storage period.

Table 34. Influence of packaging and storage conditions on crude protein (%) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.12	7.10	7.11	7.09	7.13	7.11	7.07	7.12	7.10	7.06	7.08	7.07	7.04	7.06	7.05
C ₂	7.13	7.16	7.15	7.05	7.06	7.06	7.05	7.05	7.05	7.02	7.04	7.03	7.00	7.02	7.01
C ₃	7.14	7.13	7.14	6.98	7.06	7.02	6.95	6.97	6.96	6.94	6.95	6.95	6.89	6.92	6.91
C ₄	7.17	7.14	7.16	6.94	7.04	6.99	6.92	7.03	6.98	6.90	7.01	6.96	6.85	6.90	6.87
Mean	7.14	7.13		7.02	7.07		7.00	7.04		6.98	7.02		6.94	6.98	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.01	NS		0.02	NS		0.03	NS		0.02	NS		0.03	NS	
C	0.02	NS		0.03	NS		0.04	NS		0.03	0.10		0.04	0.12	
S × C	0.03	NS		0.04	NS		0.06	NS		0.05	NS		0.06	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.02	7.05	7.04	6.98	7.03	7.00	6.96	7.02	6.99	6.93	7.01	6.97	6.89	6.95	6.92
C ₂	6.97	7.00	6.99	6.95	6.98	6.97	6.92	6.96	6.94	6.85	6.93	6.89	6.76	6.85	6.81
C ₃	6.81	6.86	6.84	6.78	6.83	6.81	6.74	6.82	6.78	6.70	6.77	6.73	6.64	6.72	6.68
C ₄	6.79	6.82	6.81	6.75	6.81	6.78	6.72	6.78	6.75	6.65	6.75	6.70	6.52	6.67	6.60
Mean	6.90	6.94		6.87	6.91		6.83	6.89		6.78	6.86		6.70	6.80	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.03	NS		0.03	NS		0.02	NS		0.02	0.07		0.03	0.09	
C	0.05	0.14		0.05	0.14		0.03	0.09		0.03	0.10		0.05	0.14	
S × C	0.07	NS		0.06	NS		0.04	NS		0.04	NS		0.07	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 35. Influence of packaging and storage conditions on fat content (%) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	1.22	1.24	1.23	1.12	1.23	1.17	1.07	1.18	1.12	1.02	1.13	1.07	0.97	1.08	1.02
C ₂	1.23	1.26	1.25	1.09	1.22	1.15	1.04	1.17	1.10	0.99	1.12	1.05	0.94	1.07	1.00
C ₃	1.20	1.23	1.22	1.08	1.16	1.12	1.01	1.05	1.03	0.95	1.01	0.98	0.90	0.99	0.94
C ₄	1.27	1.21	1.24	1.05	1.10	1.08	0.98	1.03	1.00	0.93	0.97	0.95	0.88	0.94	0.91
Mean	1.23	1.24		1.08	1.18		1.02	1.11		0.97	1.06		0.92	1.02	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.01	NS		0.03	NS		0.03	NS		0.03	NS		0.02	0.07	
C	0.02	NS		0.04	NS		0.04	NS		0.04	NS		0.03	0.09	
S × C	0.03	NS		0.06	NS		0.06	NS		0.05	NS		0.05	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	0.95	1.03	0.99	0.94	0.99	0.96	0.89	0.97	0.93	0.84	0.94	0.89	0.81	0.88	0.85
C ₂	0.89	1.02	0.95	0.87	0.97	0.92	0.85	0.94	0.90	0.84	0.90	0.87	0.79	0.85	0.82
C ₃	0.80	0.92	0.86	0.76	0.89	0.82	0.60	0.68	0.64	0.52	0.60	0.56	0.44	0.52	0.48
C ₄	0.77	0.88	0.83	0.74	0.85	0.79	0.59	0.61	0.60	0.49	0.53	0.51	0.40	0.45	0.43
Mean	0.85	0.96		0.83	0.92		0.73	0.80		0.67	0.74		0.61	0.68	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.02	0.07		0.02	0.07		0.02	0.06		0.02	0.06		0.02	0.05	
C	0.03	0.10		0.03	0.10		0.03	0.09		0.03	0.09		0.03	0.09	
S × C	0.05	NS		0.04	NS		0.04	NS		0.04	NS		0.04	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

4.5.5 Carbohydrate content (%)

Carbohydrate content as influenced by different packaging were found to be differed significantly with storage period (Table 37, Fig. 9). Up to 12 months of storage, no significant differences were found between storage containers, storage conditions and their interaction. Among the storage containers, the carbohydrate content was significantly higher in vacuum packaged bags (C_1) and lower in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2). It was further observed, ambient storage (S_1) showed higher carbohydrate content compared to cold storage (S_2) among all the treatments throughout the storage period.

At 10 months of storage, higher carbohydrate content was observed in vacuum packed bags stored under ambient condition (C_1S_1) (77.5%) followed by vacuum packed bags stored under cold storage (C_1S_2) (77.1%). Lower carbohydrate content (73.1%) was observed in gunny bags (C_4) followed by cloth bags (C_3) (73.2%) under both ambient storage (S_1) and cold storage (S_2). Treatments vacuum packaged bags (C_1) on par with polythene bags (C_2) and cloth bags (C_3) was on par with gunny bags (C_4) was observed. At 18 months of storage, vacuum packaged bags (C_1) showed significantly higher carbohydrate content (77.8%) under both ambient storage (S_1) and cold storage (S_2), which was significantly higher compared to all other treatments. The lower carbohydrate content was observed in gunny bags stored under cold storage (C_4S_2) (74.5%), which was lower over all other treatments. The treatments cloth bags stored under ambient storage (C_3S_1), gunny bags stored under cold storage (C_4S_2) and cloth bags stored under cold storage (C_3S_2) were on par with each other and did not differ significantly among themselves. It is clear from the results that, vacuum packaged bags (C_1) recorded higher carbohydrate content compared to other treatments throughout the storage period.

4.5.6 Soluble protein (mg/g)

The data on soluble protein as influenced by different packaging and storage conditions differed significantly between treatments from 2 months of storage and up to 18 months of storage due to storage period as presented in Table 38. Soluble protein decreased with an increase in storage period was observed in vacuum packaged bags (C_1), polythene bags (C_2), cloth bags (C_3) and gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2). No significant differences were found between storage conditions and their interaction up to 4 months of storage, but after 6 months of storage significant difference were observed between storage containers and storage conditions. Among the treatments, vacuum packaged bags (C_1) showed significantly higher values of soluble protein, which was significantly higher over all other treatments. Significantly lower soluble protein was observed in gunny bags (C_4), which was significantly lower compared to all other treatments throughout the storage period. During 6th month of storage, higher soluble protein was observed in vacuum packed bags stored under cold storage (C_1S_2) (3.69 mg/g) compared to vacuum packed bags stored under ambient condition (C_1S_1) (3.65 mg/g) followed by polythene bags stored under cold storage (C_2S_2) (3.38 mg/g), respectively. Lower soluble protein was observed in gunny bags stored under ambient storage (C_4S_1) (2.88 mg/g) followed by gunny bags stored under cold storage (C_4S_2) (3.06 mg/g) under both cold storage (S_2) and ambient storage (S_1). The treatments cloth bags stored under ambient storage (C_3S_1), gunny bags stored under cold storage (C_4S_2) and polythene bags stored under ambient storage (C_2S_1), cloth bags stored under ambient storage (C_3S_1) were at par with each other. A similar trend continued from 8 months of storage and up to 18 months of storage. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher soluble protein (3.58 mg/g) over all other treatments under both ambient storage (S_1) and cold storage (S_2). The lower soluble protein was observed in gunny bags stored under cold storage (C_4S_2) (2.14 mg/g), which was lower compared to all other treatments. It was further noticed that cold storage (S_2) showed higher soluble protein compared to ambient storage (S_1) among all the storage containers at all the stages of storage period.

Table 36. Influence of packaging and storage conditions on ash content (%) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	1.07	1.04	1.06	1.03	1.07	1.05	0.91	1.02	0.96	0.88	0.99	0.93	0.81	0.92	0.87
C ₂	1.09	1.08	1.09	0.93	1.07	1.00	0.88	1.01	0.94	0.83	0.97	0.91	0.78	0.91	0.85
C ₃	1.08	1.06	1.07	0.92	1.04	0.98	0.84	0.92	0.88	0.73	0.84	0.79	0.68	0.76	0.72
C ₄	1.03	1.05	1.04	0.92	0.93	0.93	0.84	0.85	0.85	0.72	0.77	0.75	0.68	0.69	0.69
Mean	1.07	1.06		0.95	1.03		0.87	0.95		0.79	0.89		0.74	0.82	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.01	NS		0.03	NS		0.02	0.07		0.02	0.06		0.02	0.06	
C	0.01	NS		0.04	NS		0.03	NS		0.03	0.10		0.03	0.09	
S × C	0.02	NS		0.05	NS		0.05	NS		0.05	NS		0.04	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	0.79	0.88	0.83	0.78	0.83	0.81	0.73	0.81	0.77	0.68	0.78	0.73	0.65	0.72	0.69
C ₂	0.73	0.86	0.81	0.71	0.81	0.76	0.69	0.78	0.74	0.66	0.74	0.71	0.63	0.69	0.66
C ₃	0.60	0.68	0.64	0.52	0.60	0.56	0.44	0.52	0.48	0.31	0.44	0.38	0.28	0.32	0.30
C ₄	0.60	0.61	0.61	0.52	0.53	0.53	0.43	0.45	0.44	0.33	0.37	0.35	0.24	0.29	0.27
Mean	0.68	0.76		0.63	0.69		0.57	0.64		0.50	0.58		0.45	0.51	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.02	0.06		0.02	0.05		0.02	0.05		0.01	0.03		0.01	0.03	
C	0.03	0.08		0.02	0.07		0.02	0.06		0.02	0.05		0.01	0.04	
S × C	0.04	NS		0.03	NS		0.03	NS		0.02	NS		0.02	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 37. Influence of packaging and storage conditions on carbohydrate content (%) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	76.6	76.5	76.6	76.8	76.6	76.7	77.2	76.7	77.0	77.2	76.9	77.1	77.4	77.0	77.2
C ₂	76.5	76.4	76.4	76.0	76.5	76.3	77.0	76.6	76.8	77.1	76.8	77.0	77.3	77.0	77.2
C ₃	76.4	76.5	76.4	74.9	72.1	73.5	75.2	72.3	73.8	75.3	72.6	74.0	75.4	73.1	74.3
C ₄	76.5	76.4	76.5	73.3	72.0	72.7	73.3	72.1	72.7	73.5	72.4	73.0	74.1	72.8	73.5
Mean	76.5	76.4		75.3	74.3		75.7	74.4		75.8	74.7		76.1	75.0	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.13	NS		0.91	NS		0.90	NS		0.92	NS		0.82	NS	
C	0.17	NS		1.28	NS		1.26	NS		1.30	NS		1.15	NS	
S × C	0.26	NS		1.81	NS		1.78	NS		1.85	NS		1.63	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	77.5	77.1	77.3	77.6	77.2	77.4	77.6	77.5	77.6	77.8	77.6	77.7	78.0	77.8	77.9
C ₂	77.3	77.0	77.1	77.4	77.1	77.3	77.4	77.3	77.4	77.6	77.4	77.5	77.8	77.6	77.7
C ₃	75.6	73.2	74.4	75.9	73.4	74.7	76.5	73.8	75.2	77.1	74.3	75.7	77.6	74.6	76.1
C ₄	74.4	73.1	73.7	74.6	73.3	74.0	75.9	73.8	74.9	76.5	74.2	75.4	77.5	74.5	76.0
Mean	76.2	75.1		76.4	75.3		76.9	75.6		77.3	75.9		77.7	76.1	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.71	NS		0.66	NS		0.54	NS		0.46	1.39		0.39	1.18	
C	1.00	3.04		0.94	2.84		0.76	2.31		0.65	1.97		0.55	1.66	
S × C	1.42	NS		1.32	NS		1.08	NS		0.92	NS		0.78	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

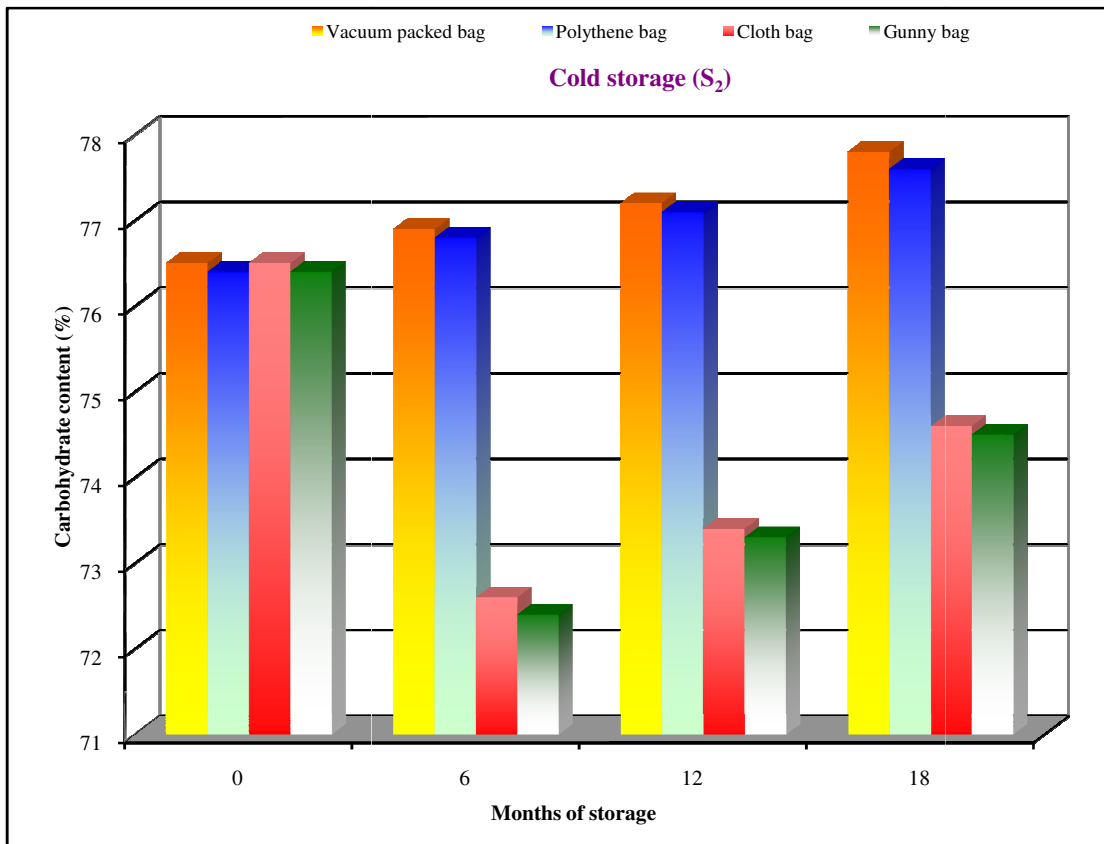
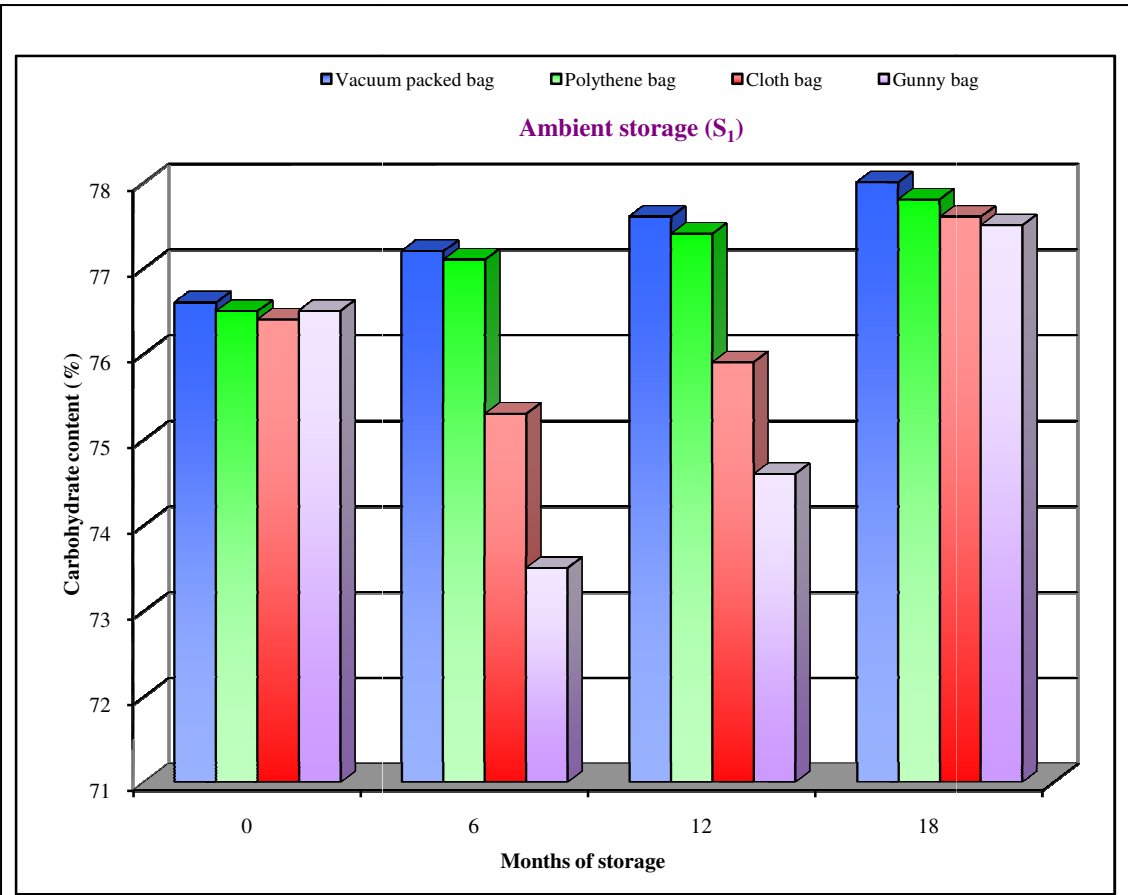


Fig. 9: Influence of packaging and storage conditions on carbohydrate content (%) at different periods of storage in rice

Table 38. Influence of packaging and storage conditions on soluble protein (mg/g) at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	3.79	3.80	3.79	3.76	3.81	3.79	3.74	3.78	3.76	3.65	3.69	3.67	3.61	3.65	3.63
C ₂	3.62	3.77	3.70	3.25	3.66	3.45	3.18	3.45	3.32	3.12	3.38	3.25	3.19	3.32	3.25
C ₃	3.54	3.62	3.58	3.08	3.24	3.16	3.04	3.18	3.11	3.04	3.11	3.08	2.91	3.07	2.99
C ₄	3.67	3.74	3.71	3.01	3.14	3.07	2.97	3.11	3.04	2.88	3.06	2.97	2.68	2.94	2.81
Mean	3.65	3.73		3.28	3.46		3.23	3.38		3.17	3.31		3.10	3.25	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.04	NS		0.06	NS		0.05	NS		0.04	0.12		0.04	0.13	
C	0.06	NS		0.09	0.26		0.07	0.23		0.06	0.17		0.06	0.18	
S × C	0.10	NS		0.12	NS		0.11	NS		0.08	NS		0.08	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	3.57	3.61	3.59	3.54	3.61	3.58	3.51	3.62	3.56	3.47	3.62	3.55	3.35	3.58	3.47
C ₂	3.15	3.29	3.22	3.14	3.25	3.20	3.11	3.22	3.16	3.10	3.19	3.14	3.05	3.09	3.07
C ₃	2.91	2.97	2.94	2.82	2.88	2.85	2.73	2.84	2.79	2.69	2.78	2.74	2.60	2.75	2.68
C ₄	2.53	2.93	2.73	2.46	2.84	2.65	2.29	2.80	2.55	2.23	2.72	2.47	2.14	2.61	2.38
Mean	3.04	3.20		2.99	3.17		2.91	3.12		2.87	3.08		2.79	3.01	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.05	0.15		0.05	0.16		0.06	0.17		0.06	0.18		0.06	0.19	
C	0.07	0.21		0.07	0.22		0.08	0.24		0.09	0.26		0.09	0.27	
S × C	0.10	NS		0.10	NS		0.11	NS		0.13	NS		0.13	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

4.6 SENSORY EVALUATION OF RICE

4.6.1 Appearance

The data on appearance as influenced by storage containers, storage conditions and their interaction presented in Table 39. It was observed that score for appearance of cooked rice was decreased with increase in storage period among all the treatments from 2 months of storage and up to 18 months of storage. Among the containers, vacuum packaged bags (C_1) recorded higher score for appearance compared to all other treatments under both ambient storage (S_1) and cold storage (S_2). Lower score for appearance was observed in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2) followed by cloth bags (C_3). At 6th months of storage, higher score for appearance was observed in vacuum packed bags stored under ambient condition (C_1S_1) (8.0) followed by vacuum packed bags stored under cold storage (C_1S_2) (7.8). The lower score for appearance was observed in gunny bags stored under ambient storage (C_4S_1) (7.2) followed by gunny bags stored under cold storage (C_4S_2) (6.6). A similar trend continued up to 18 months of storage. During the 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher score, which was significantly higher compared to all other treatments under ambient storage (S_1) and cold storage (S_2). It was further noticed that, ambient storage (S_1) recorded higher score for appearance compared to cold storage (S_2) throughout the storage.

4.6.2 Colour

The observations on colour as influenced by different packaging and storage conditions differed between treatments (Table 40). The score for colour of cooked rice was decreased with an advancement in storage period between the treatments and storage conditions and their interaction from 2 months of storage and up to 18 months of storage. Among containers, gunny bags (C_4) recorded lower score for colour compared over all other treatments under both ambient storage (S_1) and cold storage (S_2). Significantly higher score for colour was observed in vacuum packaged bags (C_1) under both ambient storage (S_1) and cold storage (S_2) followed by polythene bags (C_2) at all the stages of storage. At 6th months of storage, higher score for colour was observed in vacuum packed bags stored under ambient condition (C_1S_1) (8.0) followed by vacuum packed bags stored under cold storage (C_1S_2) (7.6). The lower score for appearance was observed in gunny bags stored under ambient storage (C_4S_1) (7.2) followed by gunny bags stored under cold storage (C_4S_2) (6.7). A similar trend continued at 8, 10, 12, 14, 16 and 18 months of storage. At 18 months of storage, vacuum packaged bags (C_1) recorded higher score for colour and lower score in gunny bags (C_4) compared to all other treatments under ambient storage (S_1) and cold storage (S_2). Among the storage conditions, ambient storage (S_1) showed higher score for colour compared to cold storage (S_2) among all the treatments

4.6.3 Texture

The results on texture as influenced by storage containers, storage conditions and their interaction presented in Table 41 indicated differences between the storage containers and their interaction at all the stages of storage period. The decrease trend was observed with progress in storage period among all the treatments under both ambient storage (S_1) and cold storage (S_2). The higher score for texture of cooked rice was observed in vacuum packaged bags (C_1) under both ambient storage (S_1) and cold storage (S_2). Among the containers, gunny bags (C_4) recorded lower score for texture compared to all other treatments under both ambient storage (S_1) and cold storage (S_2). At 6 months of storage, the lower score for texture was observed in gunny bags stored under ambient storage (C_4S_1) (7.2) followed by gunny bags stored under cold storage (C_4S_2) (6.6). The higher score for texture was found in vacuum packed bags stored under ambient condition (C_1S_1) (7.8) followed by vacuum packed bags stored under cold storage (C_1S_2) (7.7), which was higher over all other treatments. A similar trend continued from 8 months and up to 18 months of storage. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher score for colour and significantly lower score was observed in gunny bags (C_4) compared to other treatments under ambient storage (S_1) and cold storage (S_2). Among storage conditions, ambient storage (S_1) recorded higher score for colour compared to cold storage (S_2).

4.6.4 Flavour

The influence of packaging and storage conditions on flavour as shown in Table 42. The score for flavor of cooked rice decreased with an increase in storage period among all the treatments. Among the storage containers, vacuum packaged bags (C_1) recorded higher score for flavour compared to all other treatments under both ambient storage (S_1) and cold storage (S_2). Lower score was observed for flavour in gunny bags (C_4) under both ambient storage (S_1) and cold storage (S_2) followed by cloth bags (C_3). No much difference was observed between ambient storage (S_1) and cold storage (S_2) under vacuum packaged bags (C_1) followed by polythene bags (C_2).

Table 39. Influence of packaging and storage conditions on appearance at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.2	8.2	8.2	8.0	8.0	8.0	8.1	7.9	8.0	8.0	7.8	7.9	7.8	7.5	7.7
C ₂	8.1	8.0	8.1	8.0	7.6	7.8	8.0	7.6	7.8	7.8	7.8	7.8	7.4	7.6	7.5
C ₃	7.8	7.7	7.8	7.8	7.2	7.5	7.6	7.2	7.4	7.4	6.8	7.1	7.4	6.6	7.0
C ₄	7.8	7.6	7.7	7.4	6.8	7.1	7.2	6.6	6.9	7.2	6.6	6.9	6.8	6.4	6.6
Mean	8.0	7.9		7.8	7.4		7.7	7.3		7.6	7.3		7.4	7.0	
	S.Em ±	C.D. (1%)		S.Em ±	C.D. (1%)		S.Em ±	C.D. (1%)		S.Em ±	C.D. (1%)		S.Em ±	C.D. (1%)	
S	0.21	NS		0.31	NS		0.26	NS		0.30	NS		0.25	NS	
C	0.30	NS		0.22	NS		0.18	NS		0.21	NS		0.35	NS	
S × C	0.43	NS		0.44	NS		0.37	NS		0.42	NS		0.36	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.6	7.4	7.5	7.0	7.4	7.2	7.0	7.4	7.2	7.0	7.0	7.0	7.0	7.0	7.0
C ₂	7.2	7.5	7.4	7.0	7.2	7.1	7.0	6.8	6.9	6.6	6.8	6.7	6.0	6.8	6.4
C ₃	7.4	6.4	6.9	7.0	6.4	6.7	6.6	6.4	6.5	6.5	6.0	6.3	6.2	5.2	5.7
C ₄	6.8	6.4	6.6	6.4	6.2	6.3	6.4	6.2	6.3	6.2	5.5	5.9	5.5	5.0	5.3
Mean	7.3	6.9		6.9	6.8		6.8	6.7		6.6	6.3		6.2	6.0	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.25	NS		0.26	NS		0.26	NS		0.27	NS		0.32	NS	
C	0.35	NS		0.37	NS		0.36	NS		0.39	1.12		0.45	1.29	
S × C	0.49	NS		0.53	NS		0.52	NS		0.55	NS		1.30	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 40. Influence of packaging and storage conditions on colour at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.1	8.0	8.1	8.2	8.0	8.1	8.0	7.8	7.9	8.0	7.6	7.8	7.9	7.6	7.8
C ₂	8.0	8.0	8.0	8.0	7.8	7.9	7.8	7.6	7.7	7.8	7.4	7.6	7.6	7.4	7.5
C ₃	7.9	7.8	7.9	7.8	7.5	7.7	7.8	7.3	7.6	7.8	6.8	7.3	7.6	6.8	7.2
C ₄	8.0	7.8	7.9	7.4	6.8	7.1	7.2	6.8	7.0	7.2	6.7	7.0	7.0	6.6	6.8
Mean	8.0	7.9		7.8	7.6		7.7	7.5		7.6	7.4		7.4	7.2	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.22	NS		0.23	NS		0.18	NS		0.20	NS		0.21	NS	
C	0.31	NS		0.33	NS		0.26	NS		0.29	NS		0.30	NS	
S × C	0.44	NS		0.47	NS		0.37	NS		0.41	NS		0.43	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.8	7.5	7.7	7.6	7.3	7.5	7.5	7.2	7.4	7.2	7.1	7.2	7.0	7.0	7.0
C ₂	7.6	7.4	7.5	7.5	7.2	7.4	7.4	7.0	7.2	7.1	6.6	6.9	6.9	6.2	6.6
C ₃	7.6	6.4	7.0	7.3	6.2	6.8	7.0	7.0	7.0	6.2	5.8	6.0	6.3	5.2	5.8
C ₄	6.8	6.4	6.6	6.6	6.5	6.6	6.2	6.2	6.2	6.1	5.5	5.8	5.5	5.2	5.4
Mean	7.3	7.1		7.1	6.9		6.9	6.8		6.4	6.4		6.2	6.1	
	S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)		S.E.m _±	C.D. (1%)	
S	0.18	NS		0.19	NS		0.21	NS		0.21	NS		0.21	NS	
C	0.25	NS		0.27	NS		0.29	0.86		0.30	0.88		0.29	0.86	
S × C	0.36	NS		0.39	NS		0.42	NS		0.43	NS		0.42	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 41. Influence of packaging and storage conditions on texture at different periods of storage in paddy

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.1	8.0	8.1	8.0	8.0	8.0	7.8	7.8	7.8	7.8	7.7	7.8	7.7	7.6	7.7
C ₂	8.0	8.0	8.0	8.0	7.8	7.9	7.6	7.5	7.6	7.5	7.4	7.5	7.5	7.4	7.5
C ₃	7.9	7.9	7.9	7.6	7.2	7.4	7.2	6.9	7.1	7.1	6.8	7.0	7.0	6.6	6.8
C ₄	8.0	7.9	8.0	7.3	7.0	7.2	7.2	6.8	7.0	7.2	6.6	6.9	7.1	6.6	6.9
Mean	8.0	8.0		7.6	7.6		7.4	7.3		7.4	7.2		7.3	7.1	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.22	NS		0.19	NS		0.19	NS		0.23	NS		0.23	NS	
C	0.32	NS		0.27	NS		0.27	NS		0.32	NS		0.32	NS	
S × C	0.45	NS		0.38	NS		0.37	NS		0.45	NS		0.45	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.6	7.6	7.6	7.5	7.5	7.5	7.5	7.5	7.5	7.4	7.2	7.3	7.4	6.5	7.0
C ₂	7.2	7.2	7.2	7.1	6.8	7.0	7.0	7.0	7.0	6.8	6.2	6.5	6.5	6.0	6.3
C ₃	7.0	6.3	6.7	6.7	6.1	6.4	6.6	5.6	6.1	6.1	5.5	5.8	6.0	5.2	5.6
C ₄	7.0	6.4	6.7	6.5	5.8	6.2	6.2	5.5	5.9	6.1	5.2	5.7	5.6	5.2	5.4
Mean	7.6	7.6		7.5	7.5		7.5	7.5		7.4	7.2		7.4	6.5	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.20	NS		0.19	NS		0.22	NS		0.21	NS		0.22	NS	
C	0.28	NS		0.28	NS		0.32	0.92		0.30	0.85		0.32	0.92	
S × C	0.40	NS		0.39	NS		0.45	NS		0.42	NS		0.45	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 42. Influence of packaging and storage conditions on flavour at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.1	8.1	8.1	8.2	8.0	8.2	8	7.8	7.9	7.8	7.7	7.8	7.8	7.7	7.8
C ₂	8.0	7.9	8.0	8.0	7.8	7.9	7.7	7.6	7.7	7.4	7.2	7.3	7.4	7.2	7.3
C ₃	8.0	7.8	7.9	7.5	7.2	7.4	7.4	7.0	7.2	7.3	6.9	7.1	7.3	6.9	7.1
C ₄	7.9	7.9	7.9	7.2	7.0	7.2	7.0	6.6	6.8	6.9	6.5	6.7	6.9	6.5	6.7
Mean	8.0	7.9		7.8	7.4		7.5	7.3		7.3	7.1		7.4	7.1	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.22	NS		0.29	NS		0.28	NS		0.28	NS		0.27	NS	
C	0.32	NS		0.43	NS		0.42	NS		0.41	NS		0.40	NS	
S × C	0.45	NS		0.58	NS		0.57	NS		0.57	NS		0.55	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.6	7.7	7.7	7.6	7.4	7.5	7.5	7.4	7.5	7.4	7.2	7.3	7.3	7.0	7.2
C ₂	7.0	6.6	6.8	6.8	6.5	6.7	6.4	6.3	6.4	6.4	5.6	6.0	6.2	5.4	5.8
C ₃	6.6	6.5	6.6	6.5	6.4	6.5	6.2	6.0	6.1	6.2	5.4	5.8	6.2	5.2	5.7
C ₄	6.8	6.4	6.6	6.4	6.4	6.4	6.3	6.0	6.2	6.0	5.8	5.9	6.0	5.2	5.6
Mean	7.0	6.8		6.8	6.7		6.6	6.4		6.5	6.0		6.4	5.7	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.27	NS		0.25	NS		0.25	NS		0.26	NS		0.28	NS	
C	0.40	NS		0.39	NS		0.40	1.16		0.42	1.21		0.45	1.30	
S × C	0.55	NS		0.53	NS		0.55	NS		0.58	NS		0.61	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

At 8th months of storage, higher score for flavor was observed in vacuum packed bags stored under ambient condition (C_1S_1) (7.8) followed by vacuum packed bags stored under cold storage (C_1S_2) (7.7), which was negligible score among the treatments. The lower score for flavor was observed in gunny bags stored under ambient storage (C_4S_1) (6.9) followed by gunny bags stored under cold storage (C_4S_2) (6.5), which was lower compared to all other treatments. A similar trend continued at 10, 12, 14, 16 and 18 months of storage. At 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher score for flavor, which was significantly higher over all other treatments under ambient storage (S_1) and cold storage (S_2). It was further noticed that, ambient storage (S_1) exhibited higher score for flavor compared to cold storage (S_2) among the treatments throughout the storage period.

4.6.5 Taste

The data on taste as influenced by storage containers, storage conditions presented in Table 43 indicated differences between treatments up to 18 months of storage. Among the containers, vacuum packaged bags (C_1) showed higher score for taste over all other treatments under both ambient storage (S_1) and cold storage (S_2). Lower score was observed for taste in gunny bags (C_4) followed by cloth bags (C_3). The score for taste of cooked rice increased with an advancement in storage period between the treatments under both ambient storage (S_1) and cold storage (S_2) was observed.

At 8 months of storage, higher score for taste was observed in vacuum packed bags stored under ambient condition (C_1S_1) (6.9) followed by vacuum packed bags stored under cold storage (C_1S_2) (6.7) and lower score for taste was observed in gunny bags stored under ambient storage (C_4S_1) (6.4) followed by gunny bags stored under cold storage (C_4S_2) (6.0). A similar trend continued up to 18 months of storage. At end of the 18 months of storage, vacuum packaged bags (C_1) recorded significantly higher score (7.6) for taste, which was significantly superior over all other treatments under ambient storage (S_1) and cold storage (S_2). Lower score was observed in gunny bags stored under cold storage (C_4S_2) (6.5) followed by cloth bags stored under ambient storage (C_4S_1).

4.6.6 Overall acceptability

The observations on overall acceptability as influenced by different packaging and storage conditions measured up to 18 months as presented in Table 44 revealed differences among all the treatments, storage conditions and their interaction. Among the treatments, higher score for overall acceptability was found in vacuum packaged bags (C_1) followed polythene bags (C_2) under both ambient storage (S_1) and cold storage (S_2) which was almost negligible. The treatment gunny bags (C_4) recorded very low score for overall acceptability compared to all other treatments.

At 8 months of storage, score for overall acceptability was higher in vacuum packed bags stored under ambient condition (C_1S_1) (7.6) followed by vacuum packed bags stored under cold storage (C_1S_2) (7.4), which was higher over all other treatments. The lower score for overall acceptability was observed in gunny bags stored under ambient storage (C_4S_1) (7.2) followed by gunny bags stored under cold storage (C_4S_2) (6.4). At 18 months of storage, significantly higher score for overall acceptability was observed in vacuum packaged bags (C_1) (6.9), which was significantly higher compared to all other treatments. Significantly lower score for overall acceptability was seen in gunny bags (C_4) (5.1), which were significantly lower over all other treatments under ambient storage (S_1) and cold storage (S_2). Among storage conditions, ambient storage (S_1) recorded higher score for overall acceptability compared to cold storage (S_2) throughout the storage period.

Table 43. Influence of packaging and storage conditions on taste at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	6.8	6.6	6.7	6.7	6.6	6.7	6.8	6.7	6.8	6.9	6.7	6.8	7.0	6.8	6.9
C ₂	6.7	6.5	6.6	6.5	6.4	6.5	6.6	6.4	6.5	6.7	6.6	6.7	6.9	6.7	6.8
C ₃	6.5	6.4	6.5	6.5	6.5	6.5	6.7	6.6	6.7	6.7	6.6	6.7	6.8	6.7	6.8
C ₄	6.7	6.6	6.7	6.4	6.5	6.5	6.5	6.4	6.5	6.6	6.5	6.6	6.7	6.5	6.6
Mean	6.7	6.5		6.5	6.5		6.7	6.5		6.7	6.6		6.9	6.7	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.22	NS		0.19	NS		0.19	NS		0.23	NS		0.23	NS	
C	0.32	NS		0.27	NS		0.27	NS		0.32	NS		0.32	NS	
S × C	0.45	NS		0.38	NS		0.37	NS		0.45	NS		0.45	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.4	7.2	7.3	7.4	7.3	7.4	7.5	7.3	7.4	7.6	7.3	7.5	7.7	7.4	7.6
C ₂	7.2	6.8	7.0	7.1	7.0	7.1	7.2	7.1	7.2	7.3	7.2	7.3	7.4	7.3	7.4
C ₃	6.7	6.5	6.6	7.0	6.8	6.9	7.1	6.9	7.0	7.2	7.0	7.1	7.0	7.0	7.0
C ₄	6.8	6.4	6.6	6.8	6.7	6.8	7.0	6.8	6.9	6.8	6.6	6.7	6.6	6.5	6.6
Mean	7.0	6.7		7.1	7.0		7.2	7.1		7.2	7.0		7.2	7.1	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.20	NS		0.19	NS		0.22	NS		0.21	NS		0.22	NS	
C	0.28	NS		0.28	NS		0.32	NS		0.30	0.85		0.32	0.92	
S × C	0.40	NS		0.39	NS		0.45	NS		0.42	NS		0.45	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bags

Table 44. Influence of packaging and storage conditions on overall acceptability at different periods of storage in rice grains

Treatments	Storage period (months)														
	0			2			4			6			8		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	8.0	7.9	8.0	8.0	8.0	8.0	7.8	7.8	7.8	7.6	7.7	7.7	7.6	7.4	7.5
C ₂	7.9	7.7	7.8	8.0	7.6	7.8	7.8	7.6	7.7	7.5	7.4	7.5	7.4	7.2	7.3
C ₃	7.8	7.6	7.7	7.8	7.2	7.5	7.4	7.0	7.2	7.2	6.8	7.0	7.2	6.6	6.9
C ₄	7.6	7.7	7.7	7.4	7.3	7.4	7.2	6.8	7.0	7.2	6.8	7.0	7.2	6.4	6.8
Mean	7.8	7.7		7.8	7.5		7.6	7.3		7.4	7.2		7.4	6.9	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.17	NS		0.19	NS		0.22	NS		0.21	NS		0.21	NS	
C	0.25	NS		0.27	NS		0.32	NS		0.30	NS		0.31	NS	
S × C	0.35	NS		0.38	NS		0.45	NS		0.44	NS		0.44	NS	

Treatments	Storage period (months)														
	10			12			14			16			18		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
C ₁	7.5	7.3	7.4	7.4	7.2	7.3	7.2	7.1	7.2	7.0	7.0	7.0	7.0	6.8	6.9
C ₂	7.2	7.2	7.2	7.0	7.0	7.0	7.0	7.0	7.0	6.8	6.4	6.6	6.4	6.0	6.2
C ₃	7.1	6.4	6.8	6.8	6.4	6.6	6.8	5.8	6.3	6.6	5.6	6.1	6.2	5.4	5.8
C ₄	7.0	6.4	6.7	6.8	6.2	6.5	6.6	5.8	6.2	6.2	5.4	5.8	5.6	4.5	5.1
Mean	7.2	6.8		7.0	6.7		6.9	6.4		6.6	6.2		6.2	5.8	
	S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)		S.Em±	C.D. (1%)	
S	0.20	NS		0.21	NS		0.23	NS		0.25	NS		0.26	NS	
C	0.28	NS		0.32	NS		0.34	0.94		0.36	1.13		0.38	1.17	
S × C	0.40	NS		0.43	NS		0.46	NS		0.49	NS		0.50	NS	

Storage conditions (S)

S₁= Ambient storage

S₂= Cold storage

Storage containers (C)

C₁= Vacuum packed bags

C₂= Polythene bags

C₃= Cloth bags

C₄= Gunny bag

DISCUSSION

Indian rice is highly appreciated in the world market for its taste and suitability. Rice is not only a rich source of carbohydrates and proteins but also provides vitamins, minerals and fibers. Rice cultivation in the country is undertaken in the humid tropics and sub-tropical climate characterized by high temperature and high relative humidity, resulting in more rapid deterioration of seeds. Further, storage of seeds till the next sowing season is an essential segment of seed industry. Storage is a critical operation for rice, representing between 4 to 6 per cent of total post-harvest losses as many enzymatic changes, oxidation and respiration which descent the viability and vigour if not maintained properly during storage period. In rice, many physico-chemical factors like moisture content, atmospheric humidity, temperature *etc.*, will operate during storage causing loss in nutritive value because of chemical changes in starch, protein and lipid contents.

Cereal grains constitute a major source of foods and raw materials for industrial processing. Chemical changes, some of which have profound effect on nutritive values are continuously taking place in all grains under storage conditions, if unfavorable can result in the complete spoilage of grains for food purposes within few days. Hence, primary objective is to store grains and its products under control conditions and deteriorative changes to maintain original quality of the products and to minimize during storage.

Generally seeds stored in moisture impervious containers like polythene bags, aluminum foil containers, vacuum sealed containers *etc.*, store for longer period compared to those stored in moisture pervious containers like cloth bags, gunny bags, paper bags *etc.*, under both ambient storage and cold storage. The results of the present investigation on different seed quality, physiological and biochemical parameters in paddy and rice grains by storing them in different packaging materials *viz.*, vacuum, polythene, cloth and gunny bags under different storage conditions like room temperature and cold storage are discussed in this chapter.

5.1 SEED QUALITY PARAMETERS

Results of the present study revealed that there was a gradual decline in seed quality parameters such as germination per cent, mean daily germination, root length, shoot length, total seedling length, seedling dry weight, mobilization efficiency, vigour index and marked increase in electrical conductivity of seed leachates during entire storage period with significant increase in the fungal load from initial to 18 months period. Similar findings were also reported in rice (Yogalakshmi *et al.*, 1996), maize (Kurdikeri, 1991 and Hanegave, 2009), sorghum (Sunilkumar *et al.*, 2005; Jadhav, 2006; Navi *et al.*, 2006 and Kudchi and Balekai, 2009) and soybean (Deshpande *et al.*, 2010).

The higher germination per cent indicates good quality of seeds as well as higher viability. In the present investigation, the paddy seeds stored in cold storage recorded higher germination compared to ambient storage throughout the storage period of 18 months. The seeds preserved in the cold storage maintained higher seed viability vigour and quality because of lower respiration rate and metabolic activity as it is evidenced by higher germination (80.1%) at the end of 18 months of storage period (Fig. 10). Also at low temperature, degradation rate of stored food is lower as compared to higher temperature which helped to increase the germinability and vigour of the seeds for longer time (Mostarin *et al.*, 2012).

Among the containers, vacuum packed seeds of paddy, irrespective of storage conditions were found better over polythene, cloth and gunny bags. In the polythene bags, germination values were higher than cloth and gunny bags; while, it was lower than vacuum packed bags. This could be due to differential response between containers as optimum seed moisture content in vacuum packed and polythene bags is maintained since these are impervious to the exchange of water vapour from the atmosphere. While the cloth and gunny bags contain minute pores through which there is possibility of gain or loss of seed moisture content and hence, the seeds can be stored for longer period without deterioration in the quality. These results are in agreement with the findings of Kurdikeri *et al.* (1995), Angamuthu (1996), Rao and Sastry (2002), Guberac *et al.* (2003), Chiu *et al.* (2003), Ankaiah *et al.* (2006), Ellis and Hong (2007), and YahiYa *et al.* (2012).

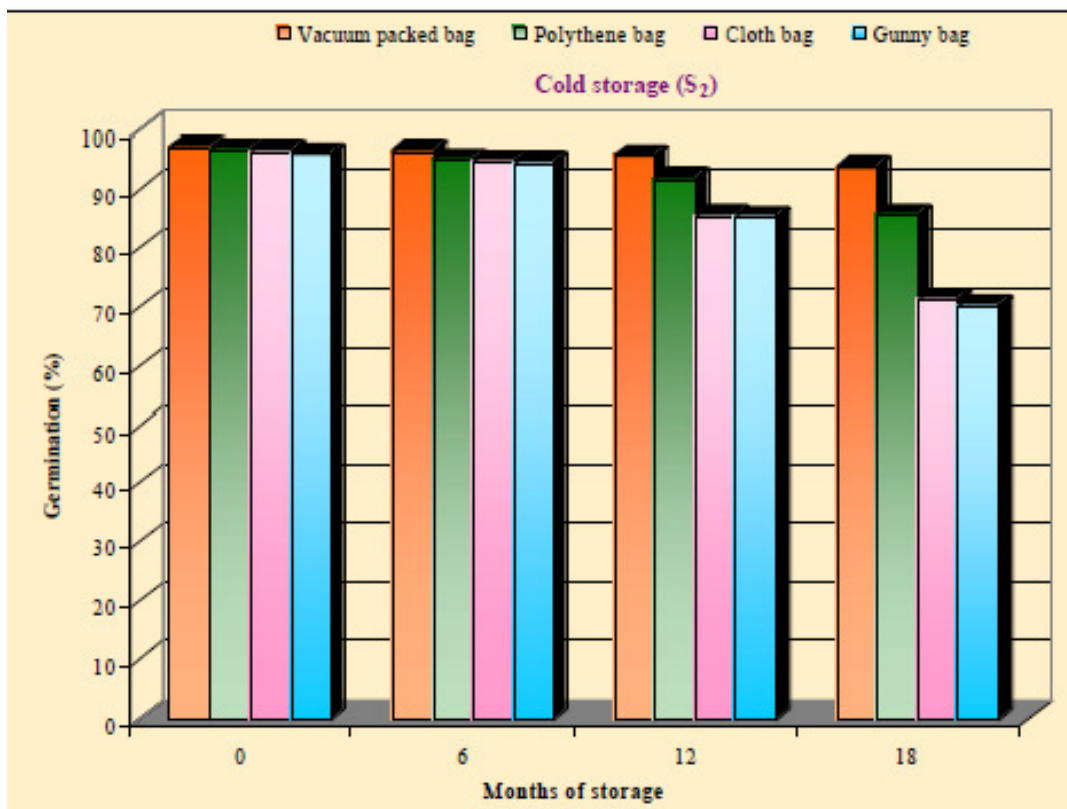
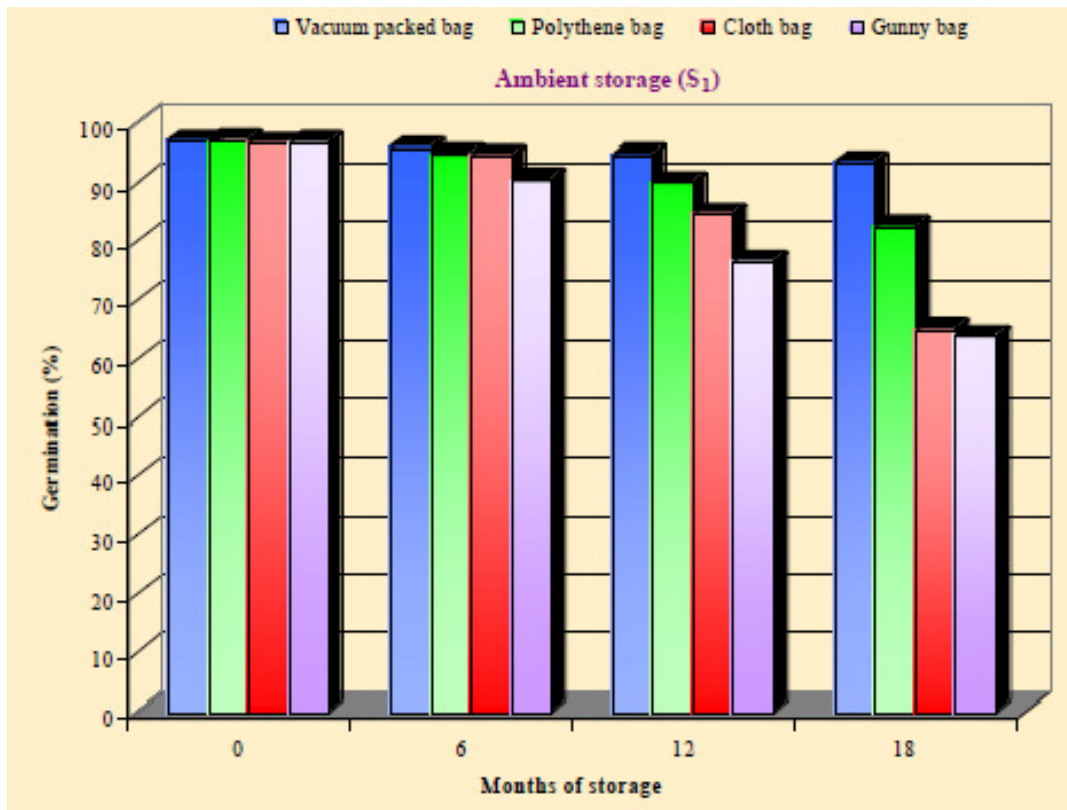


Fig 10: Influence of packaging and storage conditions on germination (%) at different periods of storage in paddy

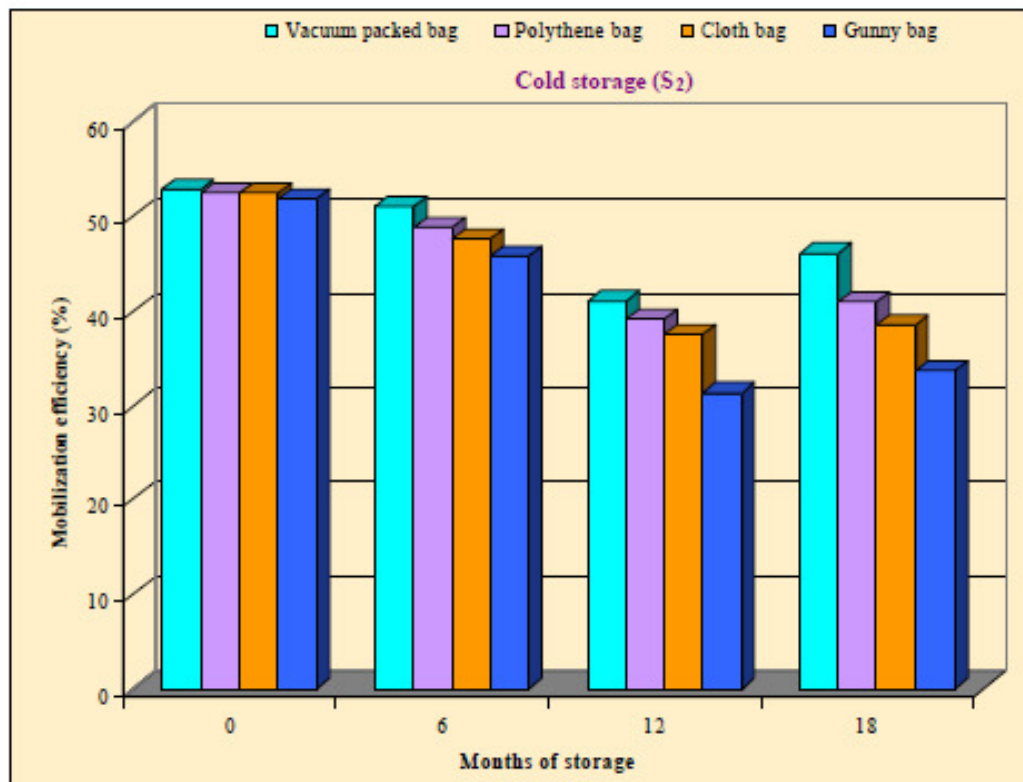
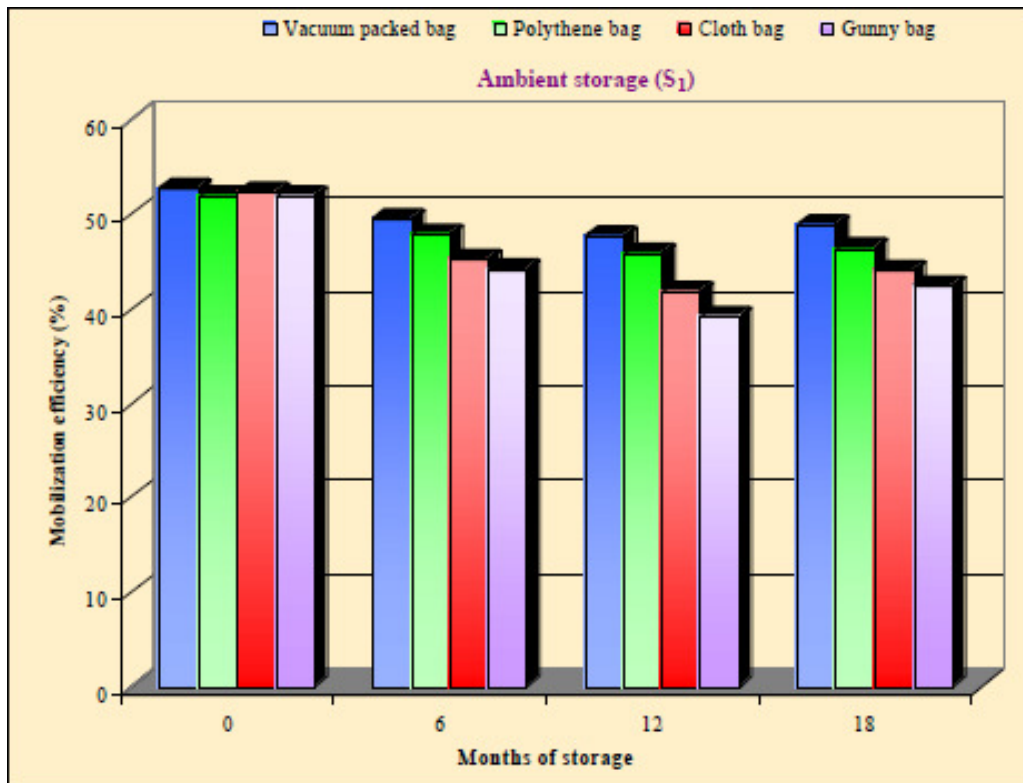


Fig 11: Influence of packaging and storage conditions on mobilization efficiency (%) at different periods of storage in paddy

Seed quality is judged by seedling vigour parameters like root and shoot length, vigour index and seedling dry weight. Generally, higher the seedling length, vigour index and seedling dry weight, higher is the seed quality. Seeds preserved in cold storage recorded higher root length and shoot length compared to ambient condition which may be due to lower respiration rate and metabolic activity at lower temperature, Similar results were reported by Das *et al.*(1998). Higher seedling length is an indication of maintenance of vigour in the seeds preserved in cold storage.

At the end of 18 months of storage, vacuum packed bags recorded significantly higher root length, shoot length, seedling vigour index, mobilization efficiency, mean daily germination, seedling dry weight and seedling length compared to polythene bags followed by gunny bags and cloth bags stored under both ambient (S_1) and cold storage (S_2) (Fig. 11). Among the interactions also vacuum packed bags had higher seedling vigour parameters over all other containers at all the stages of storage. There was a gradual decrease in seedling vigour parameters with a progress in storage period. As vacuum packed and polythene containers experience lesser moisture fluctuation, reduced depletion of food reserves, besides providing protection against external damage due to attack by micro and macro organisms thereby lower pest and fungal activity and hence the decline in all the seedling vigour parameters was less. Similar findings have been reported by Ellis (1998); McDonald (1999); Chiu *et al.* (2003); Bailly (2004) and Ellis and Hong (2007).

Generally, electrical conductivity of seed leachates is negatively correlated with the seed viability and vigour. As seed ages, the cell and cell organelle membranes become weak and leaky on account of decrease membrane phospholipids due to either enzymic or non enzymic lipid oxidation or due to fungal and insect activities (Ching and Schoolcraft, 1968; Koostra and Harrington, 1969 and Chauhan *et al.* (1984). The results of the present study showed that seeds preserved in ambient condition recorded higher electrical conductivity compared to seeds stored in cold storage. Lower electrical conductivity in seeds stored in cold storage could be because of the influence of lower temperature in cold storage which might have helped in controlling respiration rate and metabolic activity there by resulting in the maintenance of vigour (Das *et al.*, 1998). The lower electrical conductivity of seed leachate was mainly governed by lower cell wall permeability which indicates lower respiration rate and metabolic activity and

responsible for the maintenance of vigour during storage. The electrical conductivity was significantly lower in seeds stored in vacuum sealed containers followed by polythene bags and was higher in gunny bags and cloth bags throughout the storage period. Higher electrical conductivity values recorded in seeds stored in gunny bags and cloth may be due to higher level of seed deterioration on account of age induced membrane damage of various cell and cell organelles or degradation or disruption of cell membranes leading to subsequent loss of membrane integrity (Yeh *et al.*, 2005 and Sastry *et al.*, 2007). At 18 months of storage, vacuum packed bags showed significantly lower electrical conductivity compared to polythene bags, while significantly higher electrical conductivity was found in gunny bags and cloth bags stored under both ambient (S_1) and cold storage (S_2).

5.1.1 Fungal load (cfu/g)

The fungal growth showed an irregular trend between different durations of samplings emphasizing that it was dependent on the ambient relative humidity and temperature particularly in the period preceding storage and time of sampling. To minimize the risk of fungi invasion, seeds have to be stored at low moisture content, low temperature and relative humidity. The study revealed relatively lower fungal population in the vacuum packed bags compared to polythene bags followed by cloth bags and gunny bags. This is mainly because of lesser O_2 and moisture content in seeds stored under vacuum and polythene bags. Our results are in agreement with Navarro and Donahaye (2005); Sastry *et al.* (2007). In the polythene bags, fungal growth was less compared to cloth and gunny bags; but was higher than vacuum packed bags. Oxygen supports the growth of aerobic microorganisms, thus, the removal of oxygen from the modified atmosphere will decrease the microbial shelf life (Sanjeev and Ramesh, 2006, Roshny, 2007, Remya, 2007 and Deepa *et al.*, 2011). Several studies have shown that aerobic *Pseudomonas* spp. and *Aspergillus* sp. can grow in an atmosphere of 1-2 per cent oxygen (Dallyn and Everton, 1969). This supports the present study, as fungal growth was also observed in the vacuum packed bags.

Among the containers, vacuum packed bags showed very less fungal population, while gunny bags showed higher fungal population during the 18 months of storage period due to highest seed moisture content due to moisture pervious nature of containers; while vacuum packed bags are impervious nature, which acts as barrier to moisture content (Yahiya *et al.*, 2012).

Fungal infection declined significantly with an increase in storage period. The fluctuations in population counts in gunny stored samples under room temperature as indicated by very high population up to 12 months and then a decrease in the subsequent months may be attributed to the ambient relative humidity at that time of storage. The cold stored gunny samples did not show such drastic fluctuations apparently because of rather constant relative humidity maintained in the cold storage.

5.1.2 Moisture content (%)

Water activity or the condition of the amount of water present in dehydrated foods, affects several deteriorative reactions in foods, such as, non enzymatic browning, lipid oxidation, vitamin degradation, enzyme activity, microbial activity and pigment stability (Hardman, 1976). However, certain moisture content is also required in many dehydrated foods for optimum moisture stability. It was found that moisture may also protect the carotenoids from oxidation through a direct effect on the free radicals produced during pigment oxidation (Labuza *et al.*, 1970).

The seeds are hygroscopic in nature and gain or lose moisture content depending on pervious or impervious nature of containers in which they are stored. Among containers, the seeds stored in vacuum packed bags recorded significantly lower moisture content followed by polythene. In general, no appreciable change in moisture content was observed in the vacuum packed bags throughout the storage period and irrespective of the storage containers. This could be attributed to the impervious nature of the packaging material. High moisture content was observed in gunny bags under cold storage, when compared to room temperature, which may be attributed to moisture pervious nature of containers. Pham and Ramegouda (2007) and Warham (1986) reported that gunny bags offered no resistance to moisture penetration.

Seeds stored whether in vacuum packaging or polythene bags are unlikely to absorb moisture and oxygen from the atmosphere due to property of film which could maintain lower moisture and oxygen and as such they are unlikely to suffer from higher oxidation (Hong and Kim, 2004). The degradation has also been related to the moisture content of the samples during storage. Samples with higher levels of moisture content degrade more rapidly than the lower levels of moisture content due to oxidation Chiu *et al.*, 2003).

The moisture content of the seeds fluctuate more in the moisture pervious containers than in the moisture vapour proof containers. A significant negative correlation was observed between the seed moisture content and viability in sorghum, bajra and maize seeds (Nagarajan and Karivaratharaju, 1976). Fluctuation of moisture content during storage was reported for Paddy (Babu *et al.*, 1982). The concept of storing seeds in moisture impervious sealed containers is to prevent mainly the migration of moisture content in stored seeds. In sealed hermetic storage conditions, the seeds retain viability and vigour for longer period owing to lesser fluctuation of moisture content and temperature, decreased oxygen and enrichment of carbon dioxide in the containers (Tao, 1989 and Anon, 2009).

5.2 BIOCHEMICAL PARAMETERS

Mineral elements like zinc, copper, iron and manganese are very crucial for plant growth and human health, and play a key role in various physiological and biochemical processes. Results pertaining to mineral contents during study including copper, iron, zinc and manganese showed gradual decrease with an advancement of storage period at all the stages of storage. Among the containers, the decrease in mineral content was very less in vacuum packed bags compared to polythene bags followed by gunny bags and cloth bags throughout the storage period under both ambient (S_1) and cold storage (S_2). Variation in the mineral contents between the packaging materials could be attributed to redistribution of mineral elements in seeds and possible microbial contamination (Bognar *et al.*, 1990). In the polythene bags mineral content values were higher than cloth and gunny bags, but it was lower than vacuum packed bags.

Higher reduction of iron content in cloth and gunny bags may be attributed to its sensitivity to temperature. Kayisoglu and Demirci (2006) reported that copper, iron; zinc and manganese contents in both conventional and vacuum packed bags were affected significantly and decreased with an increased storage period of 10 months (Fig. 12 to 15). In the present study, paddy seeds stored in cold storage recorded higher mineral content values compared to ambient storage throughout the storage period of 18 months. At 18 months of storage, vacuum packed bags recorded significantly higher values of copper, iron, zinc and manganese compared to polythene bags, while significantly lower values were found in gunny bags and cloth bags stored under both ambient (S_1) and cold storage (S_2).

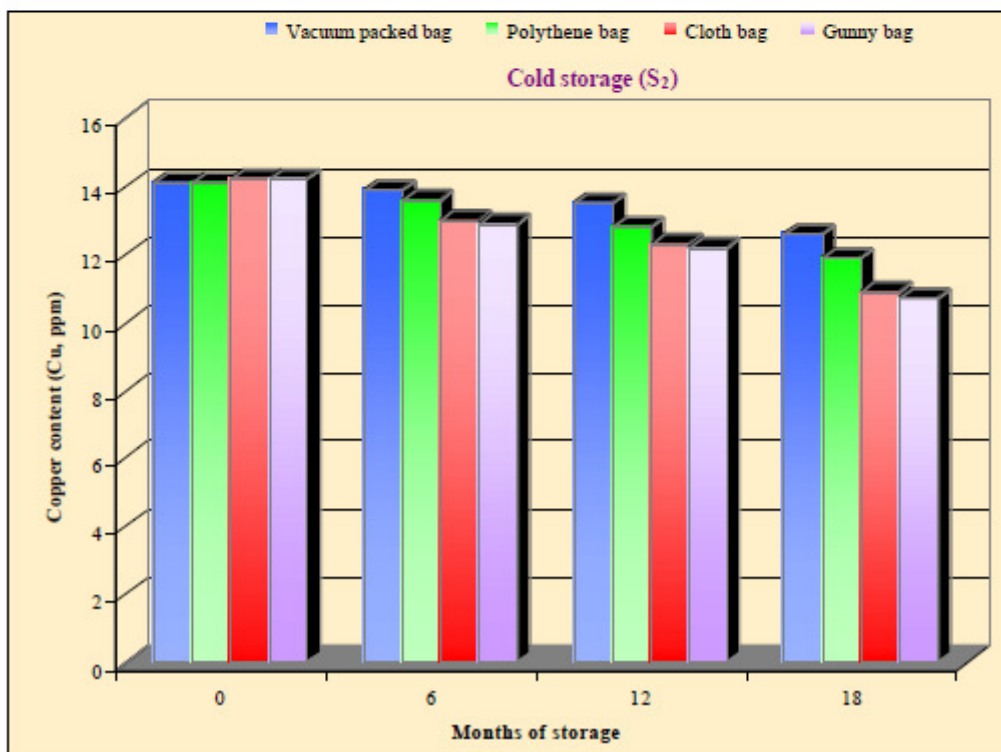
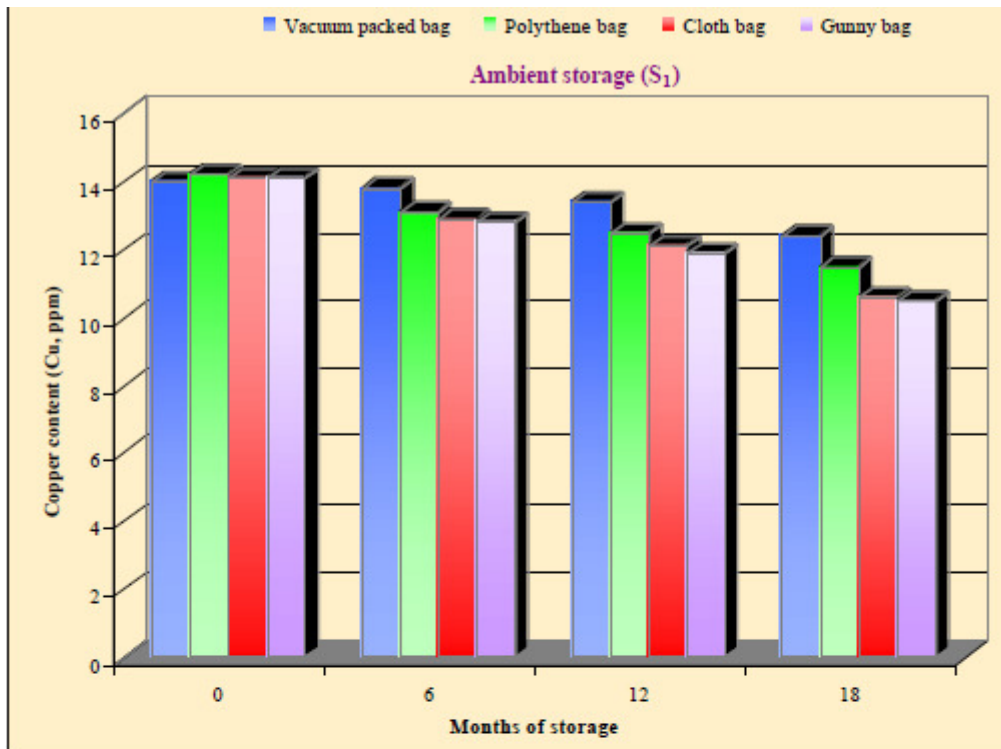


Fig 12: Influence of packaging and storage conditions on copper content (Cu, ppm) at different periods of storage in paddy

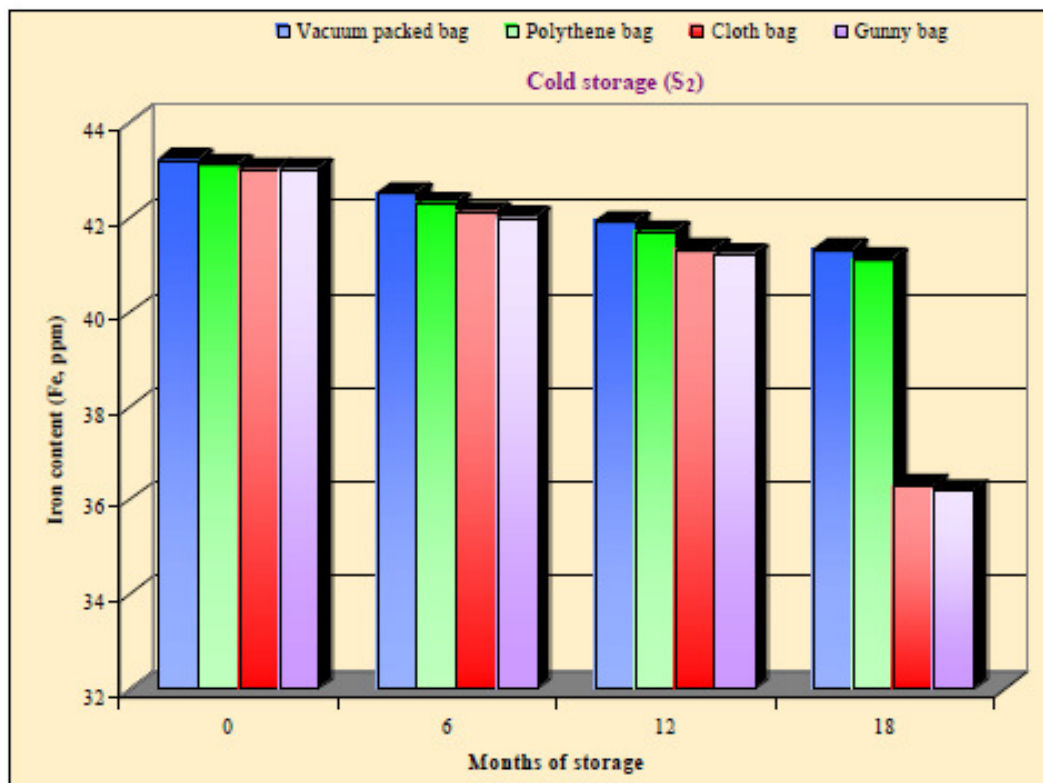
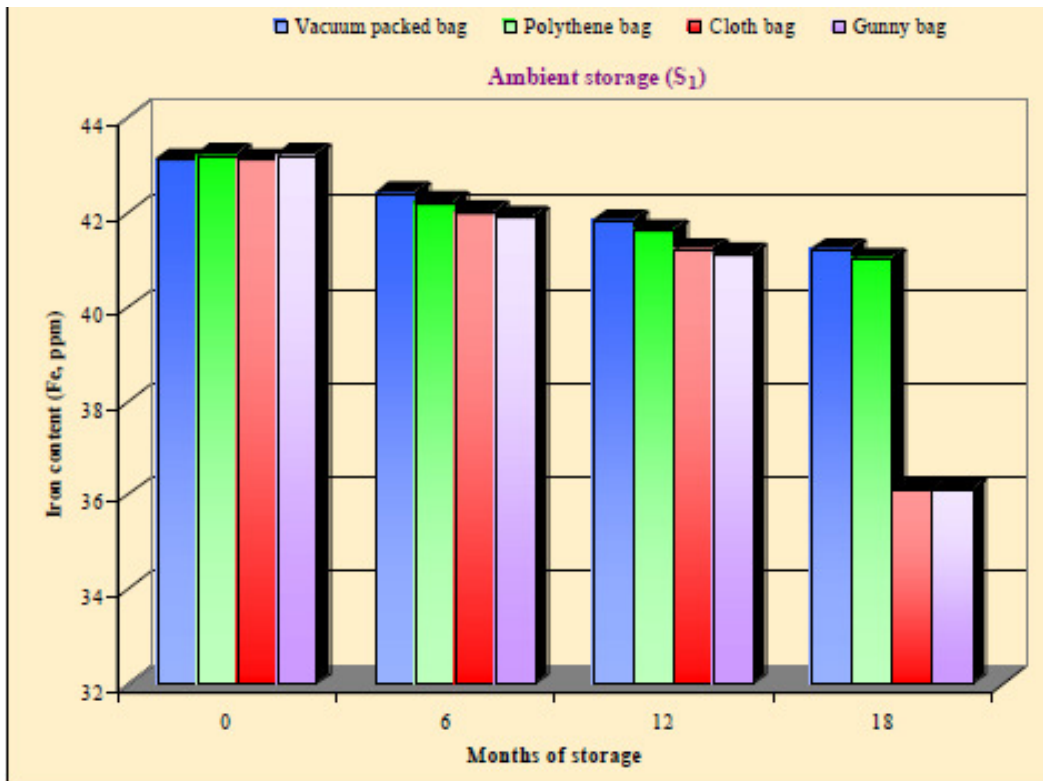


Fig 13: Influence of packaging and storage conditions on iron content (Fe, ppm) at different periods of storage in paddy

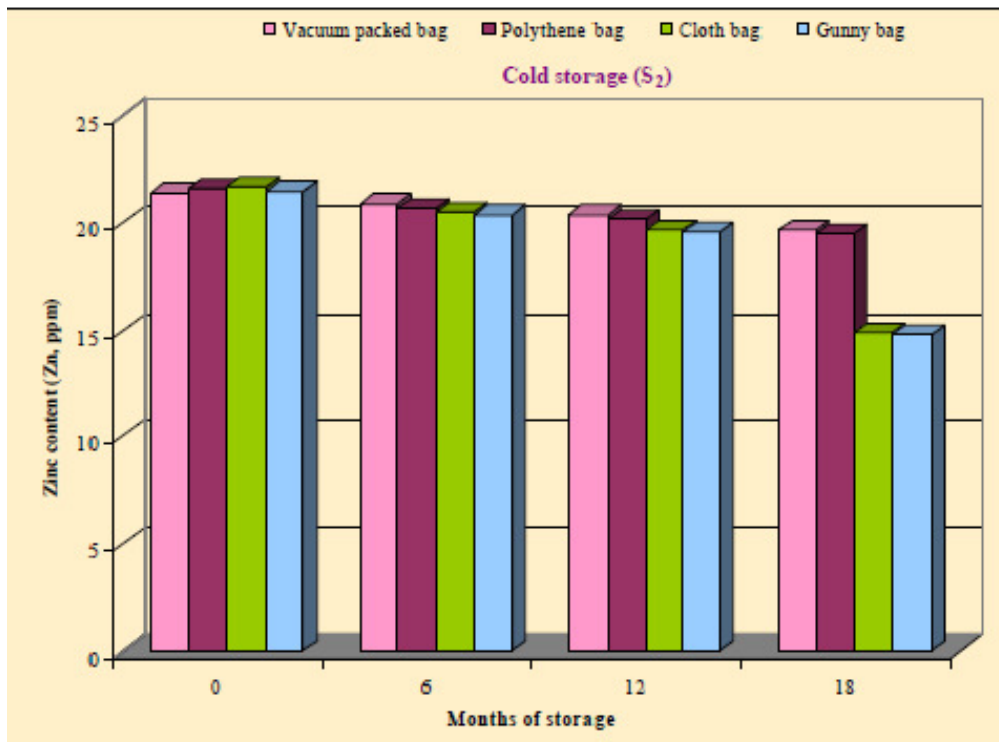
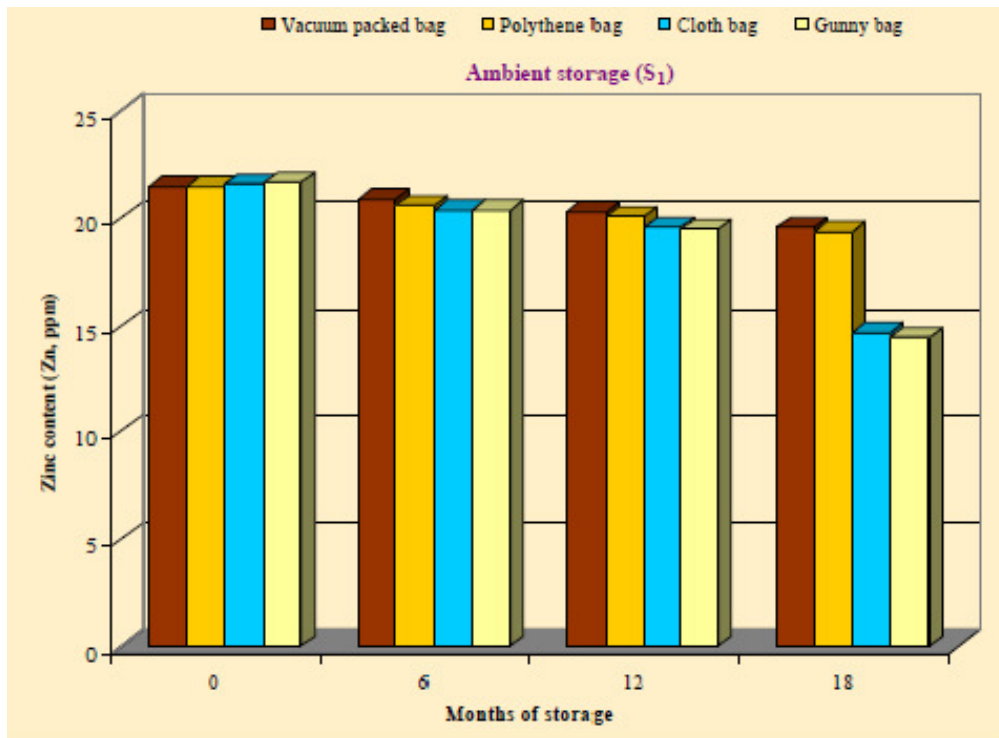


Fig 14: Influence of packaging and storage conditions on zinc content (Zn, ppm) at different periods of storage in paddy

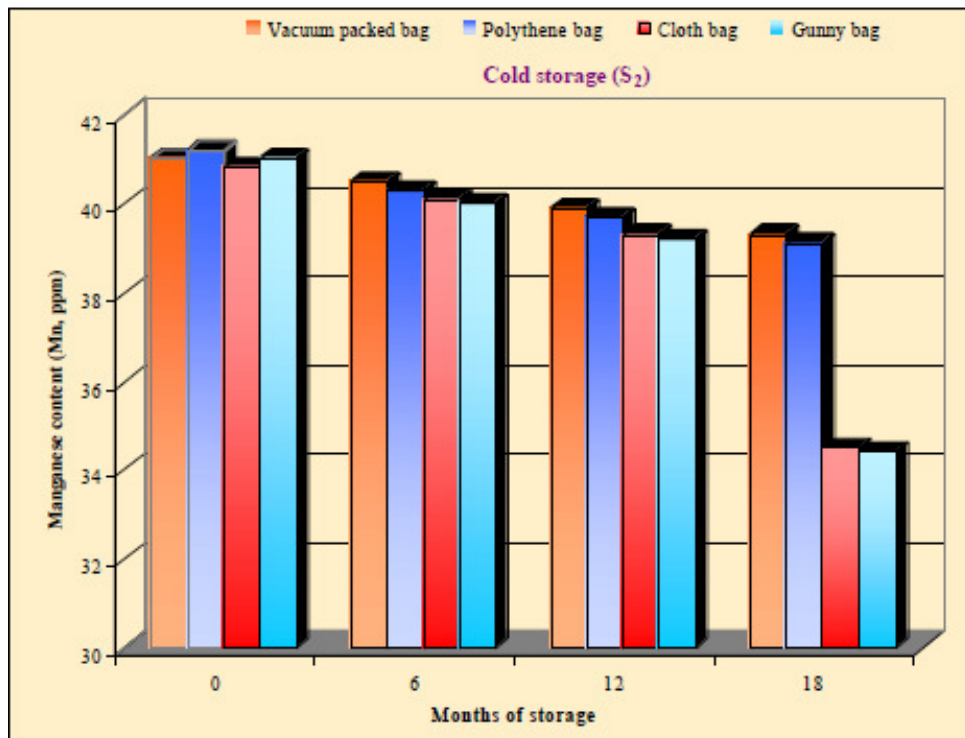
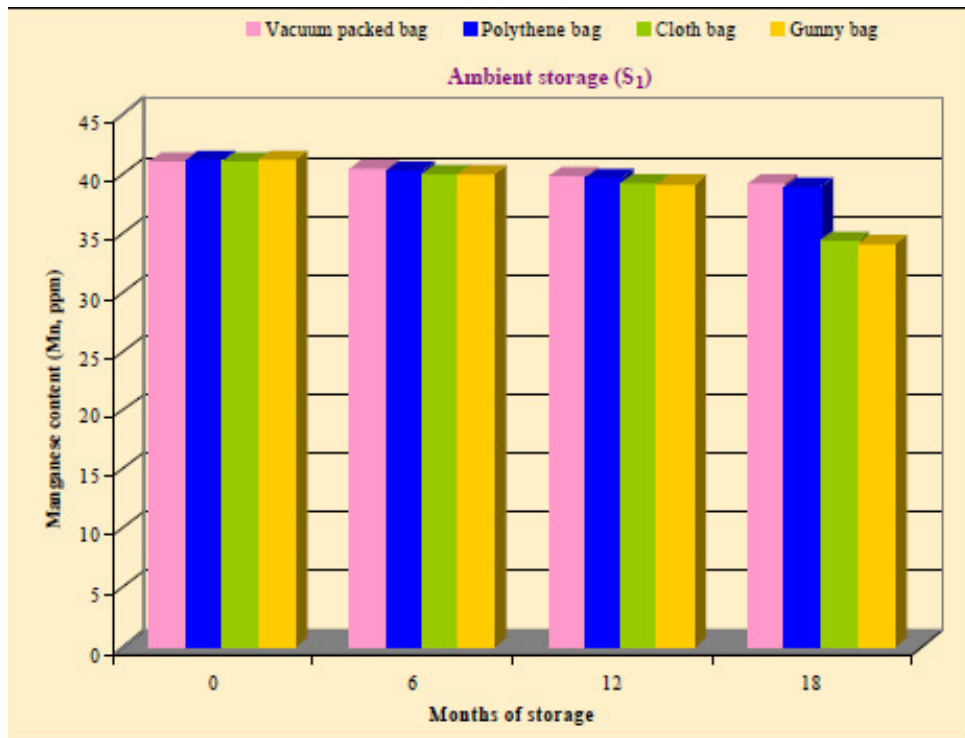


Fig 15: Influence of packaging and storage conditions on manganese content (Mn, ppm) at different periods of storage in paddy

Higher mineral contents during cold storage compared to ambient storage could be attributed due to lower internal physiological and biochemical processes in the seed there by prolonging the shelf life of seeds during storage. Higher micro nutrients in vacuum packed bags compared to gunny bags, may be due to decrease in ash content (Kayisoglu and Demirci, 2006). Similar findings were also reported in shelled melon seeds (Fagbohun *et al.*, 2011), in millet seeds (Lawal and Fagbohun, 2012), cocoyam chips (Echendu *et al.*, 2009) and okra (Fagbohun *et al.*, 2011).

5.2.1 Enzymes

In cereal seeds, the development of amylase activity constitutes an important event in germination. During germination of seeds, a massive breakdown of the reserve substances begin with the help of amylolytic, proteolytic and lipolytic enzymes and the products are transported to the growing seedlings for their development. The remaining small amount of protein represents enzymes concerned in metabolic processes during seed development and germination (Millerd and Thomson, 1975). In the present investigation α -amylase enzyme decreased with an increased storage period (Fig. 16). Gunny bag stored seeds recorded higher amylase activity compared to vacuum packed seeds followed by cloth bags. Decreased α -amylase activity with an increase in storage period may due to reduction of free sugars and amino acids. Similar observations were also reported in wheat seeds (Chauhan *et al.*, 2011) and in naturally aged gram, chickpea and wheat seeds (Agarwal and Kharlukhi, 1987).

Lipase and protease activity was found to be slightly less in vacuum packed bags compared to gunny bags. There was higher lipase activity in gunny bags followed by cloth bags (Fig. 17 to 18). There was increase in the activity of these enzymes with an advancement in storage period. Our results are in agreement with results of Dhaliwal *et al.* (1991) and Chaitanya *et al.* (2000). Increase in protease activity during storage may be due to decline in protein content (Chaitanya *et al.*, 2000). The peroxidase activity was higher in gunny bags followed by cloth bags and lower in vacuum packed bags and polythene bags (Fig. 19). Peroxides activity decreases substantially with ageing, due to which seeds become more sensitive to the effects of oxygen and free radicals in membrane unsaturated fatty acids and produce lipid peroxidation products such as monaldehyde and lipid conjugants. Similar results were observed by Chauhan *et al.* (2011) in wheat, Scialabba *et al.* (2002) in radish, Pallavi *et al.* (2003) in sunflower. Among the storage conditions, ambient storage recorded higher enzyme activities compared to cold storage. This may be due to higher temperature and higher metabolic activity under ambient storage.

Chauhan *et al.* (2011) studied the level of various enzymes and found that reason might be cause of seed deterioration under natural ageing is decrease in enzyme activity in seeds lowers its respiratory potential, which in turn lowers both the energy (ATP) and food supply to the germinating seed. Several changes in the enzyme macromolecular structure may contribute to their lower effectiveness. They may undergo compositional changes by losing or gaining certain functional groups, by oxidation of sulf-hydral groups or by conversion of amino acids within the protein structure.

5.3 PROXIMATE COMPOSITION

Ellis and Hong (2007) hypothesized that O₂ and reactive oxygen species (ROS) cause deleterious effect by damaging protein, lipid and starch constituents, there by damage lipid bilayer membrane, enhance lipid peroxidation and exhaustion of antioxidants resulting in more rapid seed deterioration and opined that hermetic packaging is preferable for long term seed storage than cloth bags in maintaining various seed quality parameters (Hong and Kim, 2004).

The results of proximate composition showed the decreased trend with an increased storage period. The nutrients are lost due to changes in carbohydrate, protein, lipids and vitamins (Abaka and Norman, 2000). Among the containers, vacuum packed bags recorded higher protein, fat, ash and carbohydrate content compared to polythene bags followed by gunny bags and cloth bags, respectively. This may be either due to extensive damage of protein synthesizing system, synthesis or activation of large quantities of proteolytic enzymes during seed deterioration (Bewley and Black, 1982). The fat content was less in gunny bags and cloth bags, while higher in vacuum packed bags and poly thene bags. Fat content decreased as storage progressed which may be due to the fact that lipase act on hydrolysis of fat over a prolonged period which is the main cause for seed deterioration. Similar results were reported by Lawal (2012), Fagbohun *et al.* (2011), Fagbohun and Faleye (2012).

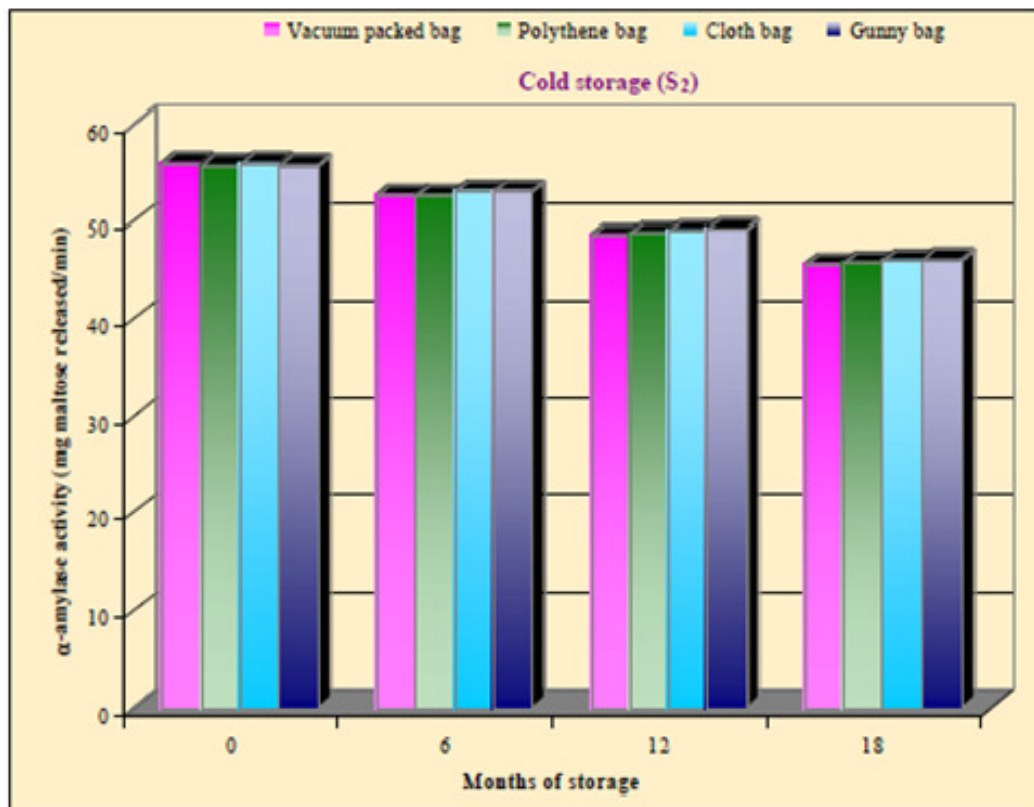
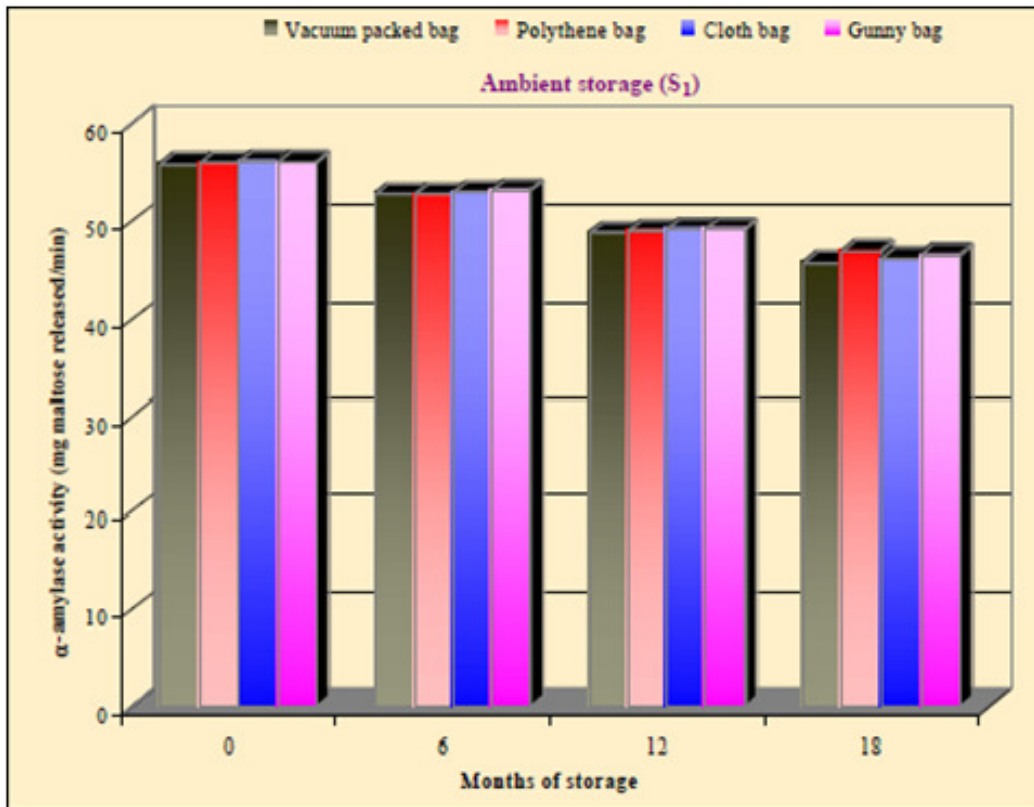


Fig 16: Influence of packaging and storage conditions on α -amylase activity (mg maltose released/min) at different periods of storage in paddy

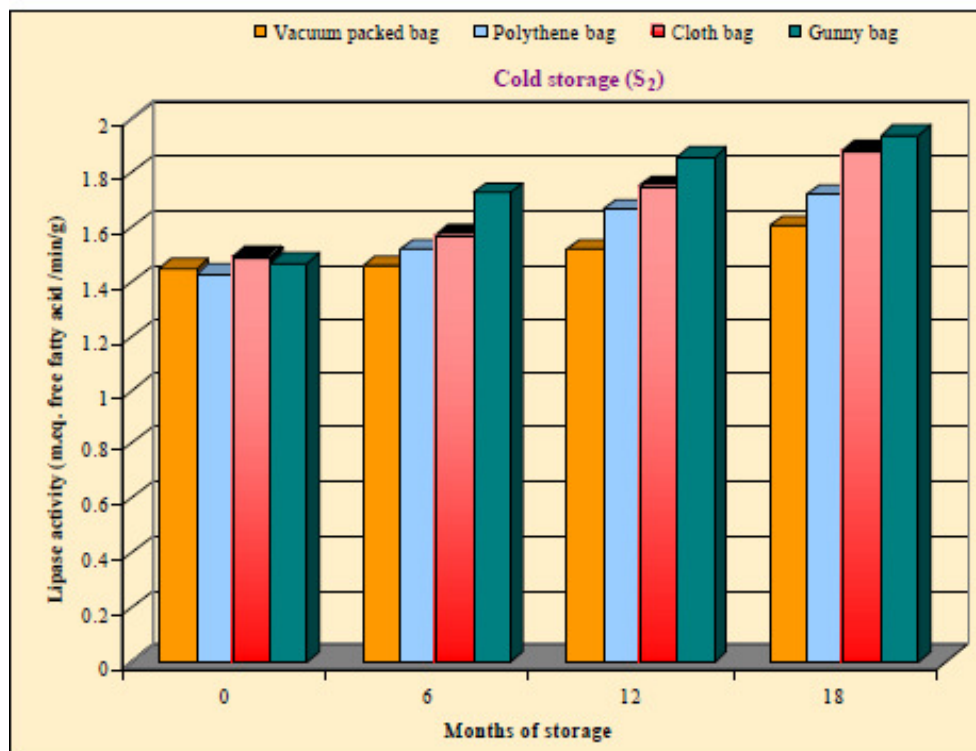
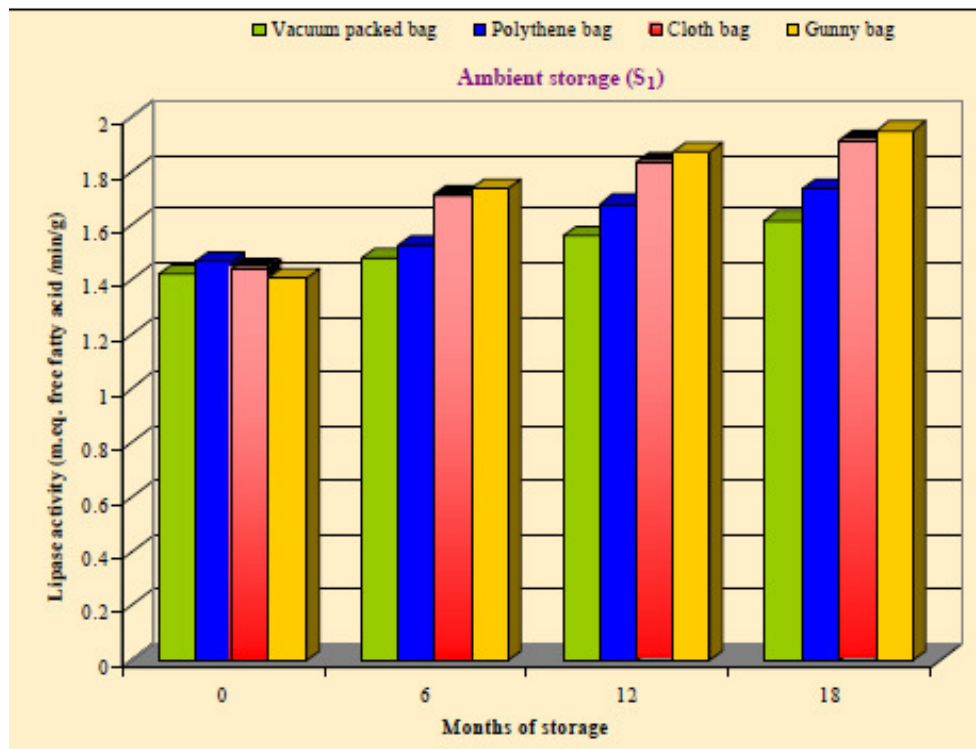


Fig 17: Influence of packaging and storage conditions on lipase activity (m.eq. free fatty acid /min/g) at different periods of storage in paddy

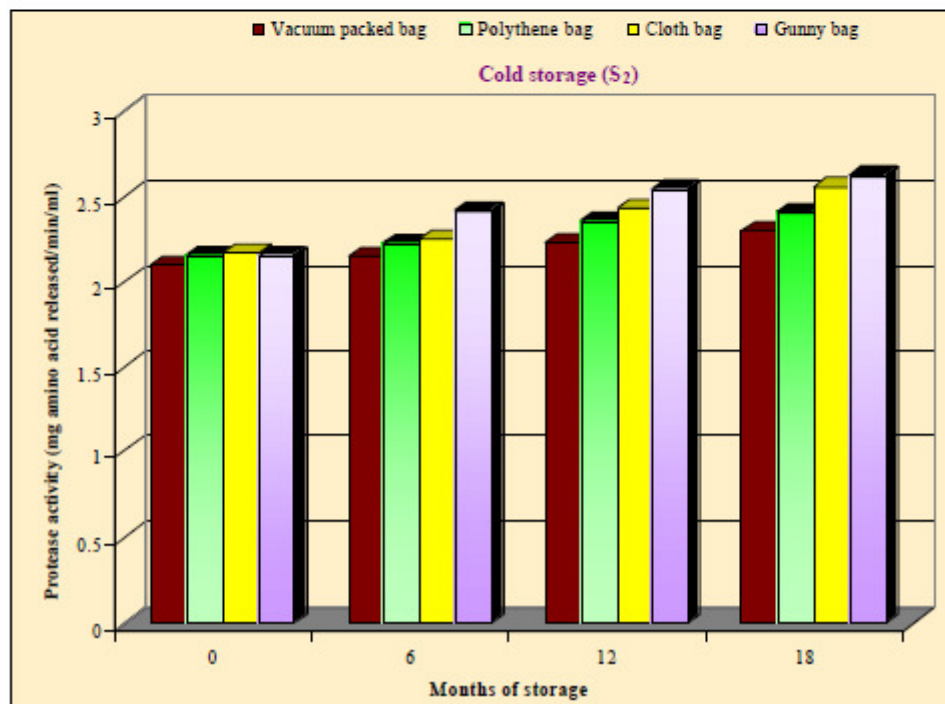
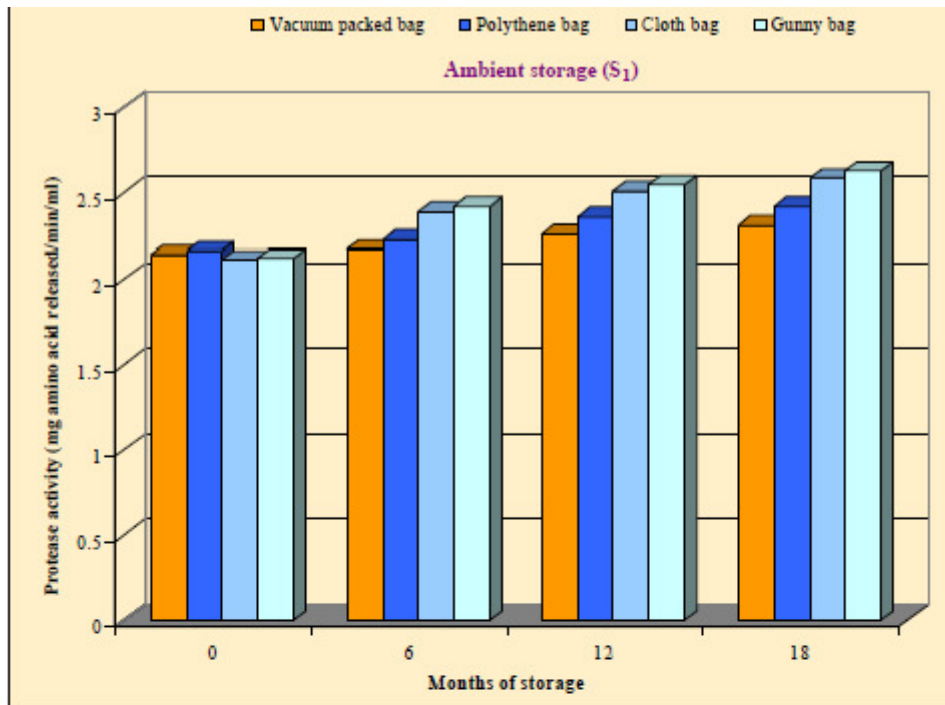


Fig 18: Influence of packaging and storage conditions on protease activity (mg amino acid released/min/ml) at different periods of storage in paddy

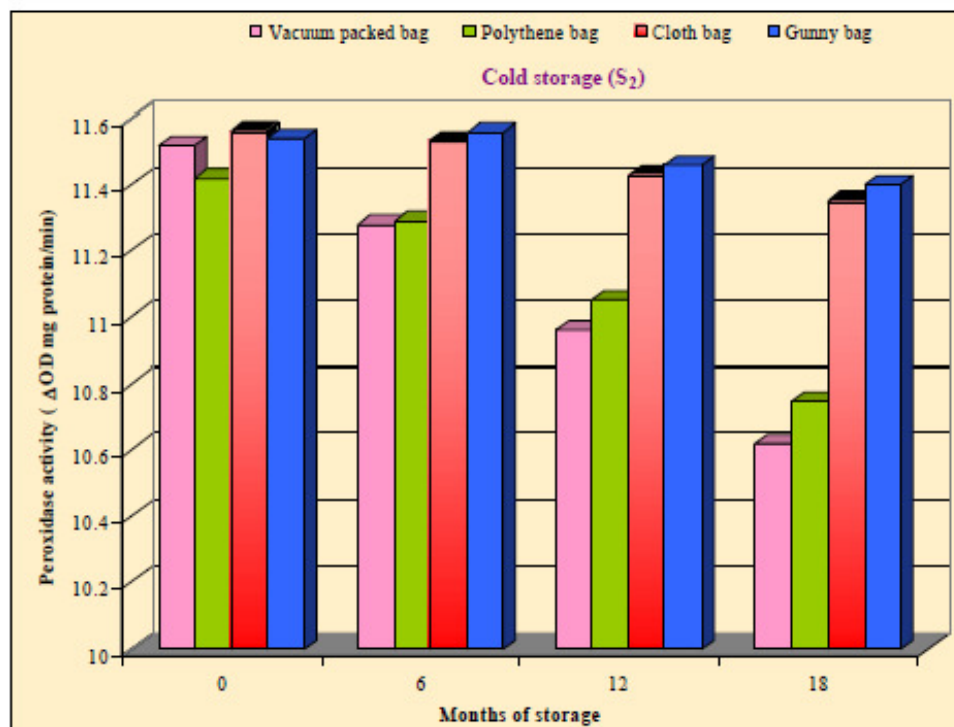
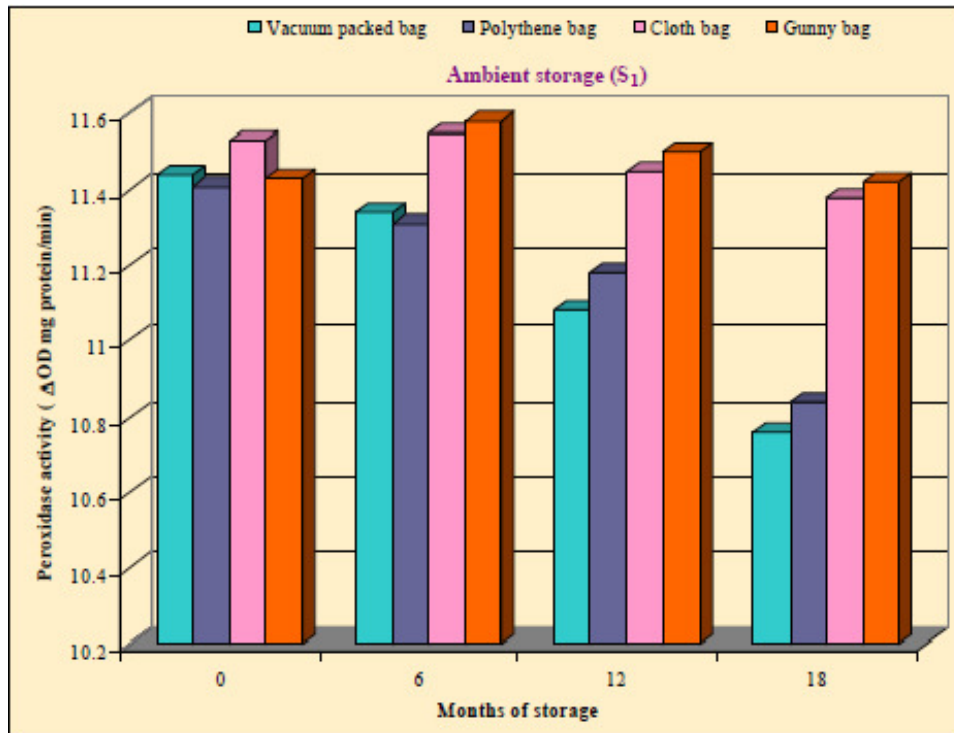


Fig 19: Influence of packaging and storage conditions on peroxidase activity (Δ OD mg protein/min) at different periods of storage in paddy

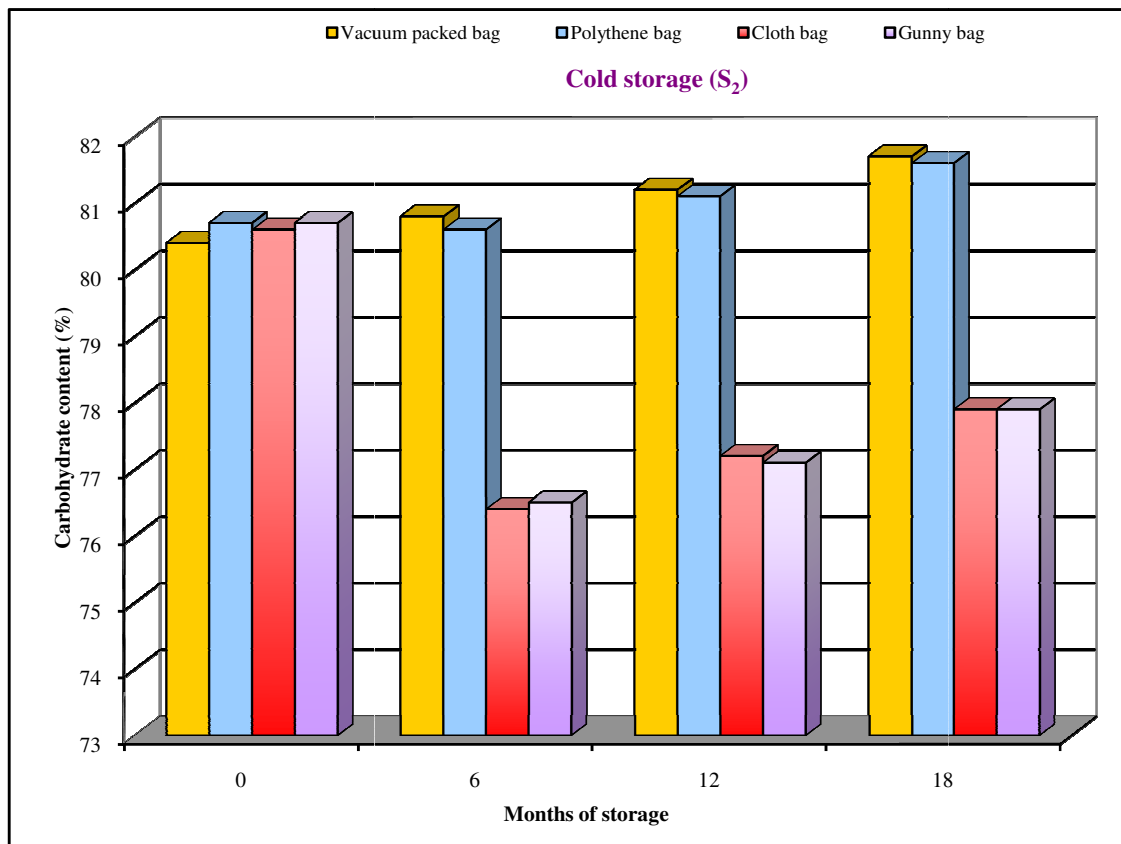
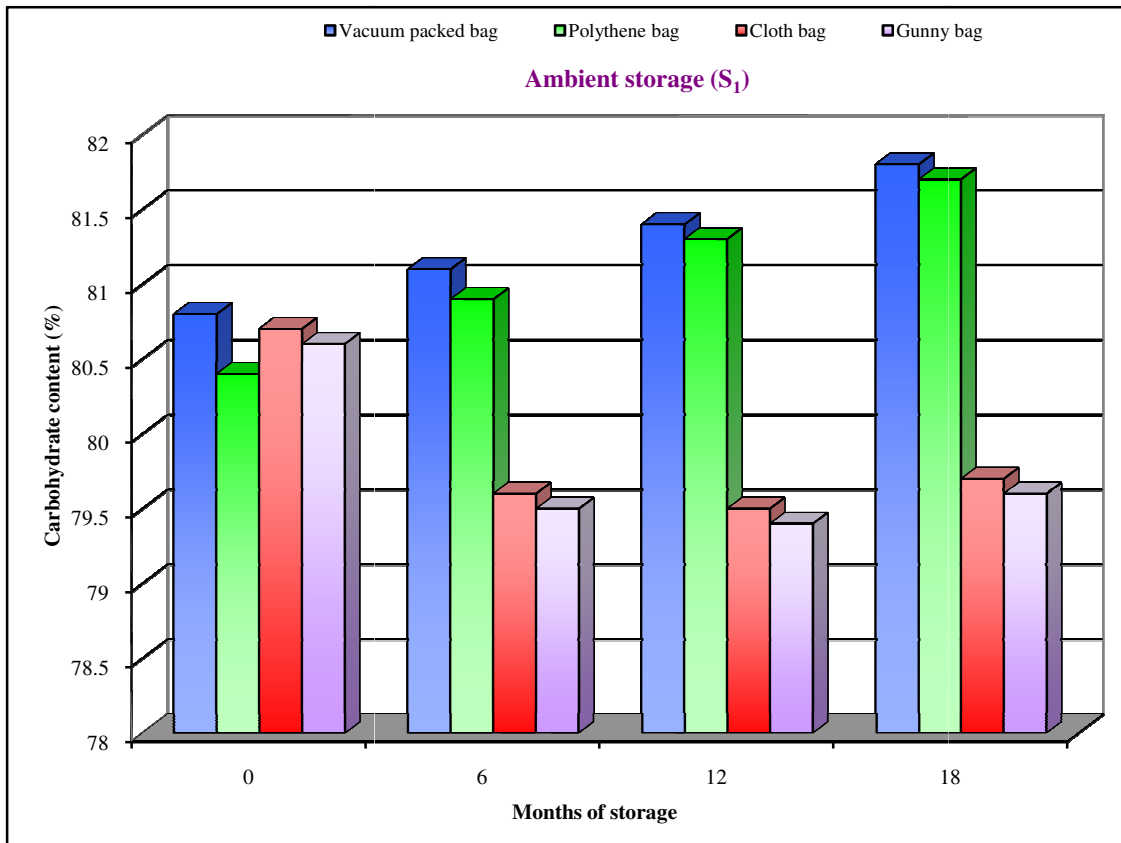


Fig 20: Influence of packaging and storage conditions on carbohydrate content (%) at different periods of storage in paddy

The soluble protein content decreased with increased storage period. This indicates that the protein content in the seeds is also subjected for deterioration depending on the storage conditions indicating sensitivity to moisture, light, temperature and oxygen (Vertucci and Roos, 1990). Loss of protein content was maximum in gunny bags stored at room temperature which could be mainly attributed to property of protein chains forming loose mesh when the moisture content is more. With loss in moisture content, they become disorganized resulting in nutrients loss. In addition, the reaction between simple sugars and amino acids leads to breakdown of protein molecules (Sandhya and Singh, 2004). The reduction of protein, rehydration ratio and increase in moisture content was comparatively higher in ordinary heat sealed storage against vacuum packaging, which was attributed to the lower activity of proteinase (Kumar and Sreenarayanam, 2000).

The ash content constitutes inorganic part of the solid matter. It was lowest in the gunny and cloth bags stored under room temperature followed by cold storage. While, no appreciable changes were observed in the samples stored under vacuum packed bags, irrespective of storage conditions. It could be mainly attributed to increased respiration as a result of higher moisture content in the gunny and cloth bags, while, there was no exchange of gases in vacuum packed bags. Similar results were observed in cheese by Abdulla and Nusr (2009).

Carbohydrate content decreased significantly (63.5%) in gunny bags under ambient condition at the end of the storage period compared to initial value (Fig. 20). While, vacuum packed bags recorded carbohydrate content of 81.8 per cent. It clearly indicates the influence of storage conditions on the stability of sugars. These changes could be attributed to the balance between anabolic and catabolic processes. Inter conversions between the carbohydrates during the storage are greatly influenced by O₂, temperature, CO₂ and light. Sanchez Mata *et al.* (2003a & b) opined that respiration involves a high consumption of simple sugars and both respiration and degradation processes are intensified during later stages of storage. At 18 months of storage, vacuum packed bags recorded significantly higher per cent of crude protein, fat content, ash content and carbohydrate content compared to polythene bags.

5.4 SENSORY EVALUATION

Physical and chemical changes occur during storage. The eating and cooking properties are affected by the starch, protein and protein interaction, only structural changes occur rather than the change in the starch and protein interactions in rice grains. These structural changes affect the flavor, texture, taste and colour. Short term as well as long term storage has effect on rice pasting as well as cooking and eating characteristics, but the long term storage has the significant effect (Perdon *et al.*, 1997).

Sensory evaluation of rice grains revealed that as the storage period increased score for appearance, texture, colour and overall acceptability decreased, except the taste. Among the containers, vacuum packed bags recorded higher score for appearance, texture, colour, taste and overall acceptability compared to polythene bags, while gunny bags followed by cloth bags recorded lower score. This may be due to moisture pervious nature of gunny bags. The degradation was also related to the moisture content of the samples during storage. Samples with higher levels of moisture content degrade more rapidly than the lower levels of moisture content due to oxidation (Chiu *et al.*, 2003).

When storage period increased, it affected the texture which may be due to physiochemical changes of rice during storage. Vacuum packaging reduced oxygen level in the packs compared to gunny bags and the anaerobic environment thus created prevents the growth of spoilage microorganism's especially aerobic ones which are responsible for off odor, slime and texture changes. Similar observations were reported by Nunez *et al.*, (1986), Indhudhara Swamy *et al.* (1978) and Chrastil *et al.* (1992). The score for taste was decreased with an increased storage period. Vacuum packed seeds recorded higher score for taste compared to polythene bags, while lower score for gunny bags and cloth bags. Enhanced storage period increases the taste which is more acceptable than fresh rice (Meuellenet *et al.*, 1999). In the present investigation aroma, flavour and colour for cooked rice decreased with an advancement in storage period. The scores for aroma, flavour and colour were higher in vacuum packed bags, while lower in gunny bags followed by cloth bags. Similar observations were made by Sidik (2000).

5.5 FUTURE LINE OF WORK

Based on the results of the present investigation, it is suggested to conduct future research on the following aspects.

1. The storage studies can be further extended beyond 18 months to know the influence of packaging and storage conditions on paddy and rice under both ambient and cold storage.
2. There is a scope for evaluating some more storage containers, which are domestically available in rural areas such as earthen pots, polythene lined gunny bags and also similar storage studies may be conducted on other field and vegetable crops.
3. Vacuum packaging could be useful to farmers from the point of preserving the viability of seeds. Future studies may be undertaken on germination in pot culture experiments.
4. Vacuum packaging technology has huge potential and therefore it needs to be explored for different dehydrated products, food grains and other dry spices and food products, so that post harvest losses can be minimized to a greater extent and food hygiene can be maintained.
5. Further studies should also focus on the influence of packaging and storage conditions on macro elements under both ambient and cold storage.
6. Studies can also be directed towards the use of oxygen scavenger films while packing and its influence on long term storage in different food commodities

SUMMARY AND CONCLUSIONS

Investigations were undertaken to study the physiological and biochemical changes during long term storage (February, 2011 to August, 2013) of paddy and rice under different packaging materials and storage conditions at the Department of Crop Physiology, College of Agriculture, University of Agricultural Sciences, Dharwad. The research study consisted of two experiments with eight treatments in each experiment. Treatments involved packing of seeds with different packaging materials (vacuum packed bags, gunny, polythene and cloth bags) stored under both room temperature and cold storage. The salient findings of the investigations are summarized here under.

- Vacuum packaging has been found to be highly useful in storing paddy seeds as well as rice grains compared to polythene bags.
- Among the containers, various seed quality parameters *viz.*, germination per cent, root length, shoot length, total seedling length, seedling dry weight, seedling vigour index, mean daily germination and mobilization efficiency were very high in vacuum packed bags compared to gunny bags throughout the storage period of 18 months under both ambient and cold storage. At the end of storage the germination per cent in vacuum packed bags was very high, which was much more than minimum seed certification standards. This is also a good indication that vacuum packaging can extend the shelf life of agricultural produce.
- The activities of enzymes *viz.*; amylase, lipase, protease and peroxidase activity slightly less in vacuum packed bags compared to gunny bags and cloth bags, irrespective of paddy and rice grains. All the enzymes decreased with an increased storage period.
- Mineral contents such as copper, zinc, iron and manganese were higher in vacuum packed seeds over all other treatments, irrespective of paddy and rice grains. Lower values were recorded in the seeds of gunny bags followed by cloth bags. All the mineral contents decreased with an advancement in storage period.
- Among the storage conditions, cold storage recorded better seed quality, physiological and biochemical parameters over room temperature, irrespective the storage containers throughout the storage period of 18 months.
- Original moisture content was maintained in the vacuum packed bags up to 18 months of storage, while the moisture content fluctuated greatly in the gunny bags and cloth bags stored at room temperature depending on the ambient relative humidity and temperature. The moisture content was maximum in the gunny bags stored in cold storage compared to room temperature throughout the storage period.
- The electrical conductivity values were lowest in vacuum packed bags compared to polythene bags, gunny and cloth bags. Among the storage conditions, cold storage recorded less electrical conductivity values compared to ambient storage at all the stages of storage.
- The samples stored in vacuum packed bags recorded very less microbial contamination and all the parameters were well within the permissible limits; while, the samples stored in gunny bags had higher fungal load followed by cloth bags, which was much above the permissible limit throughout the storage period.
- Among the containers, vacuum packed bags recorded higher protein, fat, ash and carbohydrate contents compared to polythene bags followed by gunny bags and cloth bags under both ambient and cold storage throughout the storage period of 18 months. Proximate composition in paddy as well as rice grains decreased with an increased storage period.
- The vacuum packed bags showed higher soluble protein content compared to polythene bags. Loss of protein content was maximum in gunny bags stored at room temperature.
- Sensory evaluation of rice grains revealed that appearance, texture, colour and overall acceptability values decreased with an increase in storage period, except the taste. Among the containers, vacuum packed bags recorded higher score for appearance, texture, colour, taste and overall acceptability compared to polythene bags; while gunny bags recorded lower score followed by cloth bags.

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**Appendix I: Monthly meteorological data during the research period 2011-12
observed at Main Agricultural Research Station, Dharwad**

Months	Temperature (⁰ C)		Relative humidity (%)	Rainfall (mm)	No. of rainy days
	Maximum	Minimum			
January	29.8	13.9	62	000.0	-
February	32.8	16.1	44	000.0	-
March	35.8	18.5	43	Trace	-
April	35.7	21.2	57	056.6	7
May	35.7	21.5	57	003.8	-
June	30.2	21.2	76	043.4	4
July	27.3	20.8	83	111.6	10
August	27.0	20.5	85	092.4	11
September	37.1	19.6	80	087.0	9
October	29.7	18.2	65	89.2	4
November	29.2	17.0	63	35.7	1
December	30.0	14.4	58	19.6	1
Total				539.3	47

**Appendix II: Monthly meteorological data during the research period 2012-13
observed at Main Agricultural Research Station, Dharwad**

Months	Temperature (⁰ C)		Relative humidity (%)	Rainfall (mm)	No. of rainy days
	Maximum	Minimum			
January	31.2	14.5	47	0.0	-
February	32.6	16.8	51	02.2	-
March	35.3	19.2	48	42.0	1
April	36.9	20.2	51	10.0	1
May	35.5	21.8	61	124.6	6
June	28.0	20.8	82	75.4	10
July	25.4	20.3	89	177.8	17
August	26.7	19.9	85	97.2	10
September				14.8	3
October					
November					
December					
Total				544.0	48

STUDIES ON PHYSIOLOGICAL AND BIOCHEMICAL CHANGES DURING LONG TERM STORAGE OF PADDY AND RICE UNDER DIFFERENT PACKAGING MATERIALS

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ABSTRACT

Investigations were undertaken to study the physiological and biochemical changes during long term storage of paddy and rice under different packaging materials at the Department of Crop Physiology, College of Agriculture, University of Agricultural Sciences, Dharwad over a period of 18 months from February, 2011 to August, 2013. The research study consisted of two experiments with eight treatments comprising packing of seeds with different packaging materials viz., vacuum packed, polythene, cloth and gunny bags stored at room temperature ($25\pm 2^{\circ}\text{C}$) and cold storage ($4\pm 1^{\circ}\text{C}$) for a period of 18 months.

The observations recorded at bi-monthly intervals revealed that the seeds stored in vacuum packed bags maintained the quality with least deterioration compared to gunny and cloth bags. The seed quality parameters viz., germination per cent, root length, shoot length, total seedling length, seedling dry weight, seedling vigour index, mean daily germination and mobilization efficiency were very high in vacuum packed bags compared to gunny bags throughout the storage period of 18 months under both ambient and cold storage. Electrical conductivity values were lowest in vacuum packed bags compared to polythene, gunny and cloth bags.

The rate of absorbance of moisture content was more in gunny and cloth bags, while vacuum packed bags maintained constant moisture content. The activities of enzymes viz., α -amylase, lipase, protease and peroxidase were slightly less in vacuum packed bags compared to gunny and cloth bags in both paddy and rice grains. Mineral contents viz., copper, zinc, iron and manganese decreased with advancement in storage period and higher in vacuum packed seeds over all other treatments in both paddy and rice grains. Among the storage conditions, cold storage recorded better seed quality, physiological and biochemical parameters over room temperature, irrespective of the storage containers throughout the storage period of 18 months.