EFFECT OF PACKAGING MATERIALS ON STORAGE LIFE OF CHICKPEA GRAIN

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COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

JUNAGADH AGRICULTURAL UNIVERSITY

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EFFECT OF PACKAGING MATERIALS ON STORAGE LIFE OF CHICKPEA GRAIN

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DEDICATION

To my parents and elder sister
The reason for what I become today.
Thanks for your great support and continuous care.

To my true friends
I am really grateful to you.
You have been my inspiration.

To my respected guide
Who is the continuous Source of
Inspiration and constant encouragement for me.



Jay Patel...

Abstract

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING
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Name of student	**Major Guide**
Jay Vallabhbhai Patel	Dr. D. K. Antala

EFFECT OF PACKAGING MATERIALS ON STORAGE LIFE OF CHICKPEA GRAIN

ABSTRACT

***Keywords*:** chickpea grain, packaging materials, storage life, quality evaluation

India is the largest producer of chickpea (*Cicer arietinum* L.) in the world. It is a major and cheap source of protein. Pulses are more difficult to store than cereals and suffer much greater damage from insects and microorganisms. Many synthetic insecticides have been found effective against this pest, but are hazardous, due to their residual effect in the food. This adverse effect of insecticides need diversified efforts for evolving more convenient, safer and alternative methods to minimize the losses of chickpea.

The freshly harvested and fully matured chickpea grain (*GJG-3)* was procured from the Agricultural Research Station, Dhari, Junagadh Agricultural University. The experiment was carried out in the Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh during the year 2017-18. The grain was cleaned, graded and sorted manually to remove extraneous materials. The grain was dried by sun drying to obtain optimum final moisture content 7.5-7.6 % (w.b.) for safe storage. Cleaned and dried grains were packed in different packaging materials *viz*., jute bag (control), polyethylene lined jute bag, polypropylene (PP) woven laminated bag, high density polyethylene (HDPE) bag with vacuum, multilayer coextruded plastic bag with vacuum, polyethylene laminated aluminium foil bag with vacuum, perdue improve crop storage (PICS) bag with 5.0 kg sample size.

The jute bags, polyethylene lined jute bags and PP woven laminated bags were sewed by stitching machine. For PICS bags packaging, the grains were filled and packed in inner double layer HDPE bags of PP bags. HDPE bags, multilayer coextruded plastic bags and polyethylene laminated aluminium foil bags were evacuated at 700 mm Hg vacuum level by vacuum packaging machine. All the bags were stored at room temperature (13.2 °C -38.5 °C, 18.8 -91.1 % RH) for twelve months in the laboratory. The proximate compositions were determined before packaging. The environmental parameters like temperature and relative humidity were recorded daily at room conditions during storage. Entomological parameters viz., insect population and grain damage and physico-chemical properties like moisture content, weight loss and protein content cooking quality in term of cooking time, hydration and swelling properties viz., hydration capacity and hydration index and seed quality such as germination and seed vigour index of chickpea grain were

analysed at two months interval during twelve months of storage. The results were statistically analyzed by Completely Randomized Design with three replications.

The proximate composition of chickpea grain viz., moisture content (w.b.), protein, carbohydrate, fat, crude fibre and total ash of chickpea grain was found to be 7.59 %, 22.39 %, 61.76 %, 3.56 %, 1.26 % and 3.20 %, respectively. Maximum temperature (38.5 °C) was recorded in the month of May while minimum temperature (13.2 °C) was observed in the month of January. Maximum RH was recorded in the month of July (91.1 %) while minimum RH was found in the month of March (18.8 %) at laboratory condition.

The pest population (46 numbers/500 g), grain damage (26.33 %) and weight loss (7.51 %) was found only in chickpea grain stored in jute bag at the end of twelve months of storage period. Moisture content of the grain was recorded maximum in jute bag and minimum was observed in polyethylene laminated aluminium foil bag during entire storage period. Minimum protein content in the grain was found in jute bag (15.32 %) at the end of storage period. Protein content of the grain was found at par with other treatments during entire storage period. Minimum cooking time of the grain was observed in jute bag (47.25 min) and maximum cooking time was recorded in polyethylene laminated aluminium foil bag (74.67 min) on twelve months of storage. Hydration capacity (0.240 g/grain), hydration index (0.986), swelling capacity (0.248 ml/grain), swelling index (1.446), germination (91.33 %), and seed vigour index (1114) was found maximum in PP woven laminated bag at the end of the storage. Hydration and swelling properties and seed quality of the grain was found lower in vacuum packed materials.

Considering the overall aspects of the study, it may be concluded that PP woven laminated bag was observed to be best packaging material amongst all treatments with minimum change in entomological and physico-chemical parameters, cooking quality, hydration and swelling properties and seed quality of chickpea grain for twelve months of storage.

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JUNAGADH

CERTIFICATE – I

This is to certify that the thesis/project work report entitled **"EFFECT OF PACKAGING MATERIALS ON STORAGE LIFE OF CHICKPEA GRAIN"** submitted by **JAY VALLABHBHAI PATEL** (Reg. No. 2050216007) in partial fulfilment of the requirements for the award of the degree of **Master of Technology (Agricultural Engineering)** in the subject of **PROCESSING AND FOOD ENGINEERING** to the Junagadh Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree or other similar title. The candidate had fulfilled all prescribe requirements. The assistance and help received during the course of investigation have been fully acknowledged. He has successfully completed the comprehensive / preliminary examination held on **April 13, 2018** as required under the regulation for Post-graduate studies. He has submitted Kachcha bound thesis on **June 2, 2018.**

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Place: Junagadh **(Jay Vallabhbhai Patel)**
Date: 02/06/2018

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LIST OF ABBREVIATIONS AND NOMENCLATURE

µm	Micrometre
Agri.	Agriculture
Agril.	Agricultural
Anon.	Anonymous
ANOVA	Analysis of variance
B. Tech	Bachelor of Technology
CAET	College of Agricultural Engineering and Technology
CD	Critical Difference
cm	Centimeter
Co.	Cooperative
CO_2	Carbon dioxide
CRD	Completely Randomized Design
CV	Coefficient of variance
e.g.	Exempli gratia
Engg.	Engineering
et al.	et alia (and other)
etc.	Etcetera (and the rest)
FCR	Folin-ciocalteau reagent
Fig.	Figure
g	Gram
G.F.	Graph factor
g/ml	Gram per milliliter
GSM	Grams per square meter
h	Hour
H_2SO_4	Sulfuric acid
HCl	Hydrochloric acid
HDPE	High Density Poly Ethylene
Hg	Mercury
i.e.	That is
ICAR	Indian Council of Agricultural Research

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
JAU	Junagadh Agricultural University
Kg	Kilogram
LDPE	Low Density Poly Ethylene
Ltd.	Limited
m	Meter
M.Tech.	Master of Technology
Max	Maximum
mg	Milligram
mg/100 g	Milligram per hundred grams
min	Minute
Min	Minimum
ml	Milliliter
mm	Millimeter
MT	Metric ton
N	Normal
Na_2CO_3	Sodium carbonate
NaOH	Sodium hydroxide
No.	Number
NS	Non-significant
O.D.	Optical density
PICS	Perdue improve crop storage
PP	Polypropylene
Pvt.	Private
R^2	Regression co-efficient
RH	Relative humidity
rpm	Revolutions per minute
SD	Standard Deviation
SE	Standard error
Sem	Standard error of mean
t	Ton
U.A.E.	United Arab Emirates

Univ.	University
USA	United State of America
UV-VIS	Ultraviolet-Visible
v/v	Volume per volume
viz.,	Namely
w.b.	Wet basis

LIST OF SYMBOLS

@	At the rate
₹	Rupees
%	Per cent
/	Per
-	Minus
±	Plus or minus
^{o}	Degree
^{o}C	Degree Celsius
µg	Micro gram
µg/OD	Microgram per optical density

Introduction

CHAPTER I

INTRODUCTION

The chickpea (*Cicer arietinum* L.) is a legume of the family Fabaceae, subfamily Faboideae. It is one of the most important pulse crop cultivated throughout the world. It is originated in Turkey and Greece in the late Neolithic period around 3500 BC. Chickpea is the premier pulse crop of the Indian subcontinent. India is the largest chickpea producing country accounting for 72% of the global chickpea production. In India, the area under chickpea cultivation was 95.4 lakh ha with an annual production of 90.8 lakh tons during the year 2016-17 (Anon., 2017a). In India, chickpea accounts for about 45% of total pulses produced in the country. Chickpea is mostly grown in the states of Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Andhra Pradesh and Karnataka besides Gujarat in India. The production of chickpea in Gujarat was about 18.3 lakh tons over an area of 16.4 lakh ha during the same year (Anon., 2017b). In Gujarat, the most important chickpea growing districts are Ahmedabad, Bhavnagar, Amreli, Bharuch, Gandhinagar, Junagadh, Kheda, Anand, Mahesana, Panchmahal, Dahod, Surendranagar and Vadodara.

India is exporting chickpea grain to Pakistan (35.60%), Algeria (15.17%), Turkey (8.58%), Sri Lanka (8.07%) and U. A. E. (4.97%). Chickpea contributes the single largest share in India's export basket of pulses registering 85.64% and 84.87% share in the total pulses export during 2014-15 and 2015-16, respectively. However, India imported 10.3 lakh tons chickpea grain from Australia (74.40%), Russia (16.49%), Tanzania (2.79%), Myanmar (0.92%), USA (0.74%) during the year 2015-16 due to the huge gap between production and demand (Anon., 2016).

The domesticated chickpea has been divided into two major distinct chickpeas namely microsperma or desi and macrosperma or kabuli. Desi chickpeas are smaller, angular seeds with thick seed coats and rough surface that range in colour from light tan and speckled to solid black. The splits *(dhal)* and flour (*besan*) are invariably made from desi type. Kabuli chickpeas have larger seeds with paper thin seed coats that range in colour from white to pale cream to tan.

Chickpea is predominantly consumed in the form of whole grain, dhal, flour, sprouted grain, green or matured dry seeds and is used in the preparation of a variety of snacks, sweets and condiments. It is added to many dishes to improve their taste, e.g.

dessert, salads and soup. It is a good source of carbohydrates, important vitamins and minerals. It is a major and cheap source of protein for millions of vegetarians in the developing countries. The protein quality is considered to be better than other pulses. Chickpea is rich in essential amino acids and nutritionally important unsaturated fatty acids like linoleic and oleic acid. Chickpea is a good source of important vitamins such as riboflavin, niacin, thiamin, folate and the vitamin A precursor, β-carotene. Minerals *viz*., calcium, magnesium, phosphorus and especially potassium are present in chickpea seeds. Chickpea has several potential health benefits in combination with other pulses and cereals, it could have beneficial effects on some of the important human diseases like cardiovascular disease, diabetes, digestive diseases and some cancers (Jukanti *et al.*, 2012).

Pulses are more difficult to store than cereals and suffer much greater damage from insects and microorganisms. The post-harvest losses of food grains are estimated to be 10 to 20% in India. India experiences severe losses in the storage of food grains, as per the official records economic loss to the tune of 11,700 tons of food grains was reported to have occurred in the government godowns during 2010 alone (Chahal, 2011). Per capita net availability of pulses in India, however, has reduced from 51.1 g/day in 1971 to 47.2 g/day in 2014 as against World Health Organization recommendation of 80 g/day. This raises questions about the nutritional aspect as pulses are considered to be 'poor man's protein' (Mohanty and Satyasai, 2015).

Safe storage of grains and food products against insect damage is a serious concern. The pulse beetle and bruchids are mostly found during the storage of chickpea and reduce the market value of seed, germination percent and nutrition value. (Modgil and Mehta, 1994). The bruchid is not causing only quantitative losses but also qualitative losses like nutritious and germination loss which make chickpea unfit for marketing as well as human consumption. The milling losses in insect damaged grains are even higher as more breakage and powdering occur with such grain. The pulse industry is greatly suffered due to an infestation of this pest. Thus, the pulse beetle is a serious and destructive pest of chickpea (Singh and Khokhar, 1991).

Phosphine and methyl bromide, two most common fumigants, are used for the control of stored-product insect pests all over the world. Both compounds are highly toxic to man due to their residual effect in the food and strict conditions pertain to their use. With increasing health awareness and tight regulations, food safety has become a

prominent factor in assessing the pulse quality. Consumers prefer and demand safe and healthy food. Molds leading to carcinogenic mycotoxins are a big concern in the grain and food processing industry. There is very low tolerance of mycotoxins in food grain. Pulses should be free from insects and insect damaged pulses, ergot, animal excreta and chemical residues. Insect resistance to phosphine is a global issue now and control failures have been found in some countries. Methyl bromide has been identified as a major contributor to ozone depletion and is, therefore, being phased out completely. This adverse effect of insecticides needs diversified efforts for evolving more convenient, safer and alternative methods which are simple, safe and convenient to minimize the losses of chickpea (Sousa *et al*., 2009; Taylor, 1989).

Disinfestation technologies such as plant materials/essential oils, modified atmosphere with high carbon dioxide concentrations, the application of contact insecticides and biological and physical control methodologies are being increasingly applied in the developed world. Applicability of these disinfestation techniques in a majority of developing countries is, however, limited by cost and socio-economic factors.

Packaging is an important part of product processing and preservation and has a direct influence on the system in respect to physical and chemical changes. Food grains during storage are affected by temperature, relative humidity (RH), moisture, oxygen, respiration and heating besides the biological factors. Moisture is the most important factor among the ones related to the rate of deterioration. Proper packaging and storage methods are essential for good storage stability for food grains. Traditionally, jute has been used for bulk packaging of food grains and pulses. The nature of jute packaging is such that, a lot of food packed therein gets exposed to deteriorating factors and cannot protect the products from moisture ingress. Plastic materials are used very widely for food packaging application because of their obvious advantages of being light in weight, having good productivity, can be manufactured into a number of forms and shape and being recyclable (Narayanan and Dordi, 1998). One of the most important properties of flexible packaging materials is the degree to which they are able to resist the passage of gases and vapour. HDPE and PP woven sacks have replaced jute bags in a number of applications. Multi-layer co-extruded film and triple-layer bag with two inner polyethylene bags and one outer woven polypropylene (PP) bag is also used for food grain storage. Aluminium foil provides an

excellent barrier to moisture, air, odors, light and microorganisms. Lamination of packaging involves the binding of aluminum foil to paper or plastic film to improve barrier properties.

Vacuum packaging is removing air from the product pouch and hermetically sealing it. The product is placed in a pack made from a film of low oxygen permeability. 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.

Practical utility of the research problem

Pulses are more difficult to store than cereals and suffer much greater damage from insects and microorganisms. The pulse beetle and bruchids are mostly found during the storage of chickpea and reduces the market value of seed, germination percent and nutrition value. Many synthetic insecticides have been found effective against this pest, but are hazardous, due to their residual effect in the food. This adverse effect of insecticides need diversified efforts for evolving more convenient, safer and alternative methods which are simple, safe and convenient to minimize the losses of chickpea. Proper packaging and storage methods are essential for good storage stability for food grains. Plastic materials *viz*., HDPE and PP woven sacks, multi-layer co-extruded film, triple-layer bags and aluminium foil are used very widely for food grain and seed storage due to the excellent barrier to moisture, air, odors and microorganisms. Polyethylene lining in jute bag or in PP woven bag are also useful to protect the products from moisture ingress. Vacuum packaging increases storage life of food products by inhibiting the growth of microorganisms and improves hygiene by reducing the danger of cross contamination. Looking to the above facts, the present research work was undertaken with the following objectives.

1. To determine the effect of different packaging materials on insect infestation and damage of chickpea grain.
2. To study physico-chemical and cooking quality of chickpea grain packed in different packaging materials.
3. To evaluate seed quality of chickpea grain packed in different packaging materials.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with the previous findings, new technologies developed and research work carried out by the investigators and researchers on different packaging materials and storage of food grains. The review of research work carried out by the investigators on different quality parameters, effect of different packaging materials and shelf life of food grain in this direction have been reported here under.

2.1 Physico-chemical and cooking qualities of chickpea grain

Williams et al. (1983) determined the relationship between cooking time and some physical characteristics in chickpea. The time required to cook chickpea varies from 55 to over 200 min. Seed weight and volume, swelling index and hydration capacity was found to correlate with cooking time. Correlation coefficients for kabuli-type (large seed) chickpea and desi types (small seed) were found ranges from 0.65 to 0.75 and 0.78 to 0.87 respectively.

Konak et al. (2002) evaluated physical properties of chickpea seeds as functions of moisture content. The average length, width, thickness, the geometric mean diameter, unit mass and volume of seed were 9.342 mm, 7.722 mm, 7.752 mm, 8.358 mm, 0.324 g and 0.238 cm3, respectively, at a moisture content of 5.2% dry basis (d.b.) Studies on rewetted seed showed that as moisture content increased from 5.2 to 16.5% d.b., bulk and kernel density decreased from 800 to 741.4 kg/m3 and from 1428 to 1368 kg/m3, respectively. With increasing moisture content, porosity increased from 43.97 to 45.8%, the projected area from 1.16 to 1.42 cm2, angle of repose from 24.5 to 27.98 and terminal velocity from 8.3 to 9.8 m/s. The rupture strength decreased as the moisture content increased and the highest rupture strength occurred while loading along the Z-axis. The static and dynamic coefficients of friction of chickpea seed against galvanized sheet metal, plywood and rubber surfaces increased with moisture content in the range from 5.2 to 16.5% d.b. The highest coefficient of friction was against a rubber surface, ranging from 0.44 to 0.76.

Kaur et al. (2005) assessed physicochemical, cooking, textural and roasting characteristics of chickpea cultivars viz., five desi (PBG-1, PDG-4, PDG-3, GL-769 and GPF-2) and one kabuli type (L-550). The results showed that cultivars having higher seed weight and volume had higher cooking time, swelling capacity and hydration capacity. Swelling and hydration capacity correlated well with cooking time, springiness and hardness of soaked chickpea seeds. Cooking time had a positive correlation with hardness and gumminess and a negative correlation with springiness. It was also observed that cultivars with high fat and carbohydrate and low fiber content had high soaked-seed hardness.

Jambunathan and Singh (1980) found that chickpea is a good source of carbohydrates and proteins. The seed contain crude protein in the ranges of 17% to 24% while the starch content varies from 41 – 50 %. Thus, proteins and carbohydrates together constitute about 80% of the total dry seed weight. The remaining 20% consists of 0.8-6.4 % fat, 2.1-11.7 % fiber, 0.2 % calcium and 0.3 % phosphorus. Chickpea seed is a good source of the essential amino acids such as tryptophan (0.16 %), methionine (0.52 %), cysteine (1.45 %), lysine (1.45%) and threonine (0.16%).

Tripathi et al. (2012) evaluated genetic variability and inter relationships of phenological, physicochemical and cooking quality traits in chickpea. Eighty-six chickpea genotypes, including 44 kabuli type and 42 desi type, were evaluated during experiment. There were significant differences among genotypes for days to hydration capacity (0.11-0.68 g/seed), hydration index (0.80-1.21), swelling capacity (0.11-0.7 ml/seed), seed volume (0.1-0.52 ml/seed) and cooking time (38-125 min). The desi and kabuli types of chickpea differed significantly from each other for all the traits except for hydration index, swelling index and cooking time.

Gnyandev et al. (2015) determined the influence of seed size on storage potential of chickpea varieties. The study involving three desi (A-1, Bheema and BGD-103) and two kabuli types (ICCV-2 and KAK-2) were sieve graded into small, medium, big and bulk categories and stored in cloth bag under ambient storage condition. The study revealed that seed size group was non-significant. However, the smaller and medium sized seeds in both Kabuli and desi chickpea varieties were found better in storability.

2.2 Post-harvest losses of food grains

Mookherjee et al. (1970) reported that pulse beetle causing on an average 32.6% damage. The pulse beetle mostly found during the storage of chickpea and reduced the market value of seed, germination percent and nutrition value.

Khare et al. (1972) reported that maximum weight loss of food grain due to insect feeding was 4.3% and minimum 1.5% during storage. It was also found that reduction in grain viability and weight loss was due to insect infestation on stored chickpea.

Nag et al. (2000) assessed post-harvest losses of chickpea as perceived by the producers of Sehore District of Madhya Pradesh. Data were obtained from a sample of 100 chickpea farmers at different stages of handling to examine the factors responsible for postharvest losses at the producer level. Results revealed that the overall postharvest losses on sample farms were around 7% and maximum losses occurred during threshing and winnowing. The postharvest losses of chickpea increased with time of storage, while they decreased with improvement in the type of storage and method of storage.

Basavaraja et al. (2007) assessed economic analysis of post-harvest losses in food grains in India. The post-harvest losses were estimated at different stages in two major food grains, viz. rice and wheat. The post-harvest losses were estimated using the survey data collected from 100 farmers, 20 wholesalers, 20 processors and 20 retailers in each crop in Karnataka. Tabular analysis has been used to estimate the post-harvest losses at different stages and functional analysis was used to assess the influence of socio-economic factors on postharvest losses at the farm level. The postharvest losses at the farm level was estimated to be 3.82 kg/q for rice and 3.28 kg/q for wheat. The losses were highest during storage in both the crops.

Shah (2014) estimated pre and post-harvest losses of pigeon pea in Maharashtra. The study showed about 14-18% of the total production of pigeon pea lost on account of pre-harvest, harvest and post-harvest operations. Such high magnitude of loss of crop production is certainly a matter of great concern. Therefore, efforts need to be initiated to curb such losses by adopting appropriate measures. It is expected that measures and programme initiatives such as adoption of improved pre and post-harvest technology and pest control practices do not only increase the productivity of individual crops and

their quality but these are also likely to substantially minimize the post-harvest losses, increase the total crop area cover and generate adequate quality surplus for their conversion into value-added food products.

2.3 Change in food grain/seed quality during storage

Lawal and Fagbohun (2012) studied the nutritive composition and mycoflora of sundried millet seeds during storage and revealed that freshly harvested seeds had crude protein of 11.52% and after six months of storage, the crude protein decreased to 0.86%. The result revealed that the freshly harvested millet seeds decreased fat content from 4.55 to 3.55% after six months of storage.

Sawant et al. (2012) determined effect of temperature, RH and moisture content on germination percentage of wheat stored in different storage structures viz., galvanized iron corrugated silo, godown storage and cover and plinth (CAP) storage. The grain moisture content in the silo increased from 11.20% to 17.08% wet basis (w.b.), in bag storage increased from 11.20% to 17.25% and in CAP storage increased from 11.20% to 17.19% w.b. during the storage period from April to November. The moisture content of the wheat grain then slightly decreased during the storage period from November to April. The initial grain temperature inside godown storage was 29.30℃ and at the end of the storage period, it was 32.31°C. The initial grain temperature inside CAP storage was 29.10°C and it increased to 39.94°C at the end of the storage period. The RH in the silo was 16.1% lower than the ambient RH. The germination percentage of grain inside the silo decreased from 86.70% to 78.60%, in godown storage it decreased from 86.70% to 53.30% and in CAP storage it decreased from 86.70% to 46.60% during the storage period from April to September.

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

with before storage treatment. Seed germination percentage were decreased with increasing period of storage.

Chormule *et al*. (2015) studied the effect of storage periods on quality of chickpea under laboratory conditions. Fresh seeds of three chickpea genotypes; GG1, GJG 3 and GG 4 were sun dried to bring the moisture content to around 10 to 12% and stored in different containers. The observations were recorded on 75, 150 and 225 days of storage periods. It was observed that most of the seed quality parameters *i.e*. weak seedlings, test weight and seed moisture content increased with storage periods, while germination percent, root length and shoot length, seedling length, seed vigour index, strong seedlings decreased with increase in storage periods. However, speed of germination, seedlings fresh and dry weights increased up to 150 days of storage periods then after decreased with further increase in storage periods.

2.4 Effect of environmental parameters on food grain storage

Fonseca *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.

Halder and Gupta (1980) reported that sunflower seeds deteriorated completely within 90 days when seeds were stored at 28 ± 1°C and 95% RH, but seeds were viable for 120 days when stored at 80% RH.

Sharp and Timme (1986) studied effects of storage time, storage temperature and packaging method on shelf life of brown rice. Brown rice was stored either in heat sealed two-ply laminated polyethylene bags sealed in metal cans or in perforated bags in a metal can sealed under vacuum at 3, 22 or 38°C. Storage of brown rice at 3°C resulted in lower levels of free fatty acids and less change in odour and flavor than at high temperatures. The combination of 3°C storage temperature and a sealed polyethylene bag provided the best shelf life of brown rice.

Moreno *et al*. (1994) recorded the maximum germination (74-98%) in pea seeds when stored for six months at 25°C and 75% RH, while the seeds stored at 25°C and 85% RH recorded 10-68% germination after two months of storage.

Mali and Vir (2000) assessed quantitative and qualitative losses in green gram stored in different containers and temperatures. Green gram stored in jute bags, polythene bags and tin containers, at room temperature and at 25 ± 2°C and 5 ± 2°C for 12 months after harvest. The infestation of seeds increased with the storage period and was high on seeds stored in jute bags as compared to those in polythene bags, both at room temperature and at 25°C. The seeds stored at 5°C escaped from bruchids attack in all the three storage materials tested. There was significant increase in crude protein, crude fibre, ash and reducing sugars and decrease in soluble carbohydrate, total soluble sugars, nonreducing sugars and starch with storage time at room temperature and at 25°C. These changes were minimum at 5°C. The maximum adverse effects were observed on storage in jute bags and minimum in polythene bags.

Dejene (2004) reported that sorghum seeds stored in warm temperature with high relative humidity, reduced seed viability due to increase degree of invasion by seed-borne or storage fungi.

Loganathan *et al.* (2011) studied the effect of low and high temperatures for the control of cowpea beetle in chickpea. Eggs, larvae, pupae and adults were held at 42 or 0°C for varying durations. Pupae and adults were equally heat tolerant. The lethal time to reduce survival by 50% (LT50) at 42°C for eggs, larvae, pupae and adults were 18, 57, 78 and 71 h, respectively. Pupa was the most cold-tolerant stage. The LT50 at 0°C for eggs, larvae, pupae and adults were 3, 8, 10 and 4 days, respectively. The LT50 for pupae were 4907, 4262, 336, 36 and 13 min at the grain temperature of 42, 45, 50, 55 and 60°C, respectively. The LT50 of pupae at 0, -5, -10 and -15°C were 274, 122, 7 and 2 h, respectively.

Moses *et al.* (2015) studied the effect of climate change on the major components of stored-grain ecosystems and the system as a whole considering direct or indirect. Direct effects include role of climate change on the growth and developmental cycles of biotic components such as insect pests and indirect effects include the effect of rising global temperatures on grain drying conditions and other post-harvest unit operations that would ultimately affect stored grain quality. The effects on stored grains forecasted in both tropical and temperate regions of the world were summarised. The importance of mathematical modelling and the directions for research that can mitigate the effects of global climate change on stored food grain were also highlighted.

2.5 Effect of moisture content of food grain/seeds on storage life

Sripichitt *et al*. (1989) observed that germinability decreased slightly throughout 18 months storage of soyabean seeds with 6 and 8% moisture content whereas, germinability of seeds stored at 10 and 12% moisture content declined rapidly after 6-8 months of storage in soybean.

Ellis *et al*. (1996) evaluated survival of dry and ultra-dry seeds of carrot, groundnut, lettuce, oilseed rape and onion during five years hermetic storage at two temperatures. Seeds were stored hermetically for five years in four environments (dry or ultra-dry seed storage moisture contents) and estimated at six-monthly intervals. Significant loss in viability occurred at 20°C and was more rapid in dry (5.5-6.8% m.c.) than ultra-dry (2.0-3.7% m.c.) seeds. The results confirmed that storage at 20°C was beneficial to seed survival in hermetic storage. Seeds first dried at 20°C to moisture contents in equilibrium with about 10% RH provided greater longevity than 5.5-6.8% moisture content in these five species.

Shaw (1998) studied the effects on green gram stored under conditions of different initial grain moisture contents, storage periods and storage containers. Green gram seeds at 8, 12 and 16% moisture content were stored for up to 180 days in polythene or jute bags. Moisture contents, insect (*Callosobruchus chinensis*) damage, seed weight increased while protein content and nitrogen solubility index were decreased with storage period. Storage in polythene bags gave better seed preservation than jute bags.

Singh and Gupta (2001) determined influence of packaging materials and pre-treatments on dry matter loss of pigeon pea grain stored under ambient conditions for six months. Pigeon pea grain was packed in three packaging materials and two initial moisture contents *i.e*., 9% and 12%. The dry matter loss in pigeon pea grains ranged from 3.07% to 23.57%. The minimum dry matter loss in grain was observed at 9% initial moisture content for samples stored in jute bags. The pattern of dry matter loss for grain was linear with the period of storage.

Ellis and Hong (2007) studied the effect of hermetic or open storage on the sensitivity of timothy and sesame longevity in relation to moisture content. They concluded that the deleterious effect of oxygen on seed longevity increased as seed

moisture content decreased and confirmed that hermetic packaging is preferable for long term seed storage.

Monira *et al*. (2012) reported that higher moisture enhanced seed deterioration, which ultimately reduced 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 increase was higher in seeds of cloth bags.

2.6 Effect of plant materials/essential oils on storage of chickpea

Sube et al. (1990) evaluated some edible oils as protectants of chickpea seeds, against pulse beetle. The oils of mustard, rapeseed, taramira, groundnut, coconut, sesamum, sunflower, soybean and palm, at 2 and 4 ml/kg, were evaluated as protectants after different storage intervals. Beetles preferred untreated rather than treated seeds for egg laying 30 days and 90 days after treatment. More development of beetle and consequently more weight loss and seed damage, was recorded in untreated than treated seeds. Similarly, irrespective of these oils, the 2 ml/kg dose was less effective in reducing development, weight loss and seed damage than 4 ml/kg. At 4 ml/kg dose of palm, mustard, rapeseed, taramira, groundnut and coconut oils provided almost complete protection after 30 days as well as 90 days of treatment. Whereas after 150 days of treatment none of the oil was able to provide complete protection at any dose.

Choudhary et al. (2014) investigated efficacy of some plant extracts against C. chinensis on chickpea during storage. The treatments comprised neem leaf powder (10 and 20 g), custard apple leaf powder (10 and 20 g), mustard oil (4, 8 and 12 ml), groundnut oil (4, 8 and 12 ml), sesame oil (4, 8 and 12 ml) and a control. After 90 days of storage, groundnut oil at 12 ml/kg recorded the lowest grain damage of 4.8%, followed by groundnut oil at 4 and 8 ml/kg and sesame oil at 4, 8 and 12 ml/kg (with 17.7, 10.2 and 5.1% grain damage, respectively).

Haile (2015) carried out an experiment on eco-friendly management of chickpea storage pest under laboratory conditions (25-27°C and 61% RH). The treatments used were: control (with no treatment), mixture of sand, taff, ash, malathox 1% and sesame oil. The highest mean grain damage was recorded in treatments of control, mixture of sand and taff with a mean count of 16.97, 15.37 and 8.02 g, respectively. The corresponding weight grain damage for mixtures of taff, sand and control were 5.46,

14.53 and 20.07 g, respectively. The most effective treatments were malathox, sesame oil and ash with a mean grain damage loss of 0.93, 0.11 and 0.21 g, respectively. The germination percentage of the damaged grains decreased with the increase population of the pest and period of storage.

2.7 Effect of packaging materials on storage of food grains/seeds

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

Saxena *et al*. (1985) stored the seeds of onion, cabbage, radish, cauliflower, okra and peas in impervious and pervious container at room temperature for 24 months. It was concluded that germination, root length, shoot length and vigour index decreased with an increase in storage period and the decrease was greater in the seeds stored in cloth bags and least in polythene bags.

Kulkarni *et al*. (1988) studied the effect of different storage containers on the storage of legumes seed and concluded that bruchid infestation was less in plastic bags than cloth bags.

Dwivedi and Shukla (1990) concluded that seeds of gram should be stored in polythene bags in preference to other containers such as cloth bag, earthen pot, gunny bag and paper bag to preserve greater seed viability.

Verma *et al*. (1993) determined the effect of containers on germinability of mustard seeds. They concluded that for long time storage of mustard seeds, seed should be packed in 700 guage polythene bags or polylined jute canvas bags with 8% moisture content.

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 and mud-pot maintained the seed germinability of 80% 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.

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.

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.

Bhardwaj *et al*. (2001) reported that polythene bags proved to be the best for maintaining longevity of royle seed upto 9 months during storage. It was also reported that maximum germination was recorded in seeds of royle stored in sealed plastic bins followed by polythene bags. However, the rate of germination percentage was least when seed stored in polythene bag over storage period.

Biradar (2001) reported that significantly higher seedling vigour and germination (1508 and 83.9%) in green gram seeds was found in polythene bags compared to those stored in cloth bags (1428 and 79.8%) at the end of 12 months 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.

Ankaiah *et al.* (2006) stated that germination and seedling vigour were significantly higher in sunflower 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% germination up to 18 months, while the seed stored in paper bags and poly pouch retained viability up to one year in sunflower.

Chuansin *et al*. (2006) studied the effect of packaging materials for soybean seed storage. Soybean seeds were processed and dried to 9.06% moisture content. Soybean seeds were stored in different kinds of plastic bags *i.e*. metallized film, aluminum foil, polypropylene and woven polypropylene for a period of 4 months under controlled temperature (16°C) and RH (65%). It was found that seed moisture content increased in time and showed positive correlation with water activity value and negative correlation with seed germination and seed vigour showed in terms of low percentage standard germination. Oxygen level showed positive correlation with storage fungi. From this experiment, soybean seeds were stored in metallized film bags and aluminum foil bags observed highly standard germination and seed vigor and keep water activity and seed moisture content in low level could delay seed quality deterioration followed by polypropylene bags and woven bag.

Jagtap (2006) found that the polylined jute canvas bag was relatively better for sorghum seed storage than gunny bag and cloth bag. The seed stored in polylined jute canvas bag possessed longer storability. The germination percentage and vigour index were significantly higher in seed stored in polylined jute canvas bag.

Sharma and Swarn (2006) reported that polylined bag followed by high density polythene packing was significantly superior over cloth bag to retain germination and field emergence up to next season in soybean.

Pham and Rame (2007) observed that hybrid rice germination and seedling vigour 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.

Sharma *et al*. (2007) determined the effect of different storage conditions on the infestation of pulse beetle in chickpea grain. The plastic container was the most suitable for keeping the chickpea grain, providing the minimum oviposited grains (15.66%), the maximum developmental period (27.33 days), the least number of adult emergence (12.66) and 17.33% minimum grain damage, having 81.43% reduction, 14 days increased developmental period, 69.36% reduced emergence and 80.88% reduction in grain damage over the control.

Ramanadane and Rettinassababady (2008) evaluated different packaging materials for safe storage of paddy seeds. The seed moisture content increased with an advancement of storage period in cloth bags (9.5 to 13.5%) compared to high density polyethylene (HDPE) bags (9.5 to 13.3%) and super grain bags (9.5 to 11.9%). 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. However, the rate of infestation increase was significantly higher in cloth bags followed by HDPE bags than in polylined cloth bags and super bags.

Alam et al. (2009) studied the performance of alternate storage devices on seed quality of boro rice and found that germination per cent of 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%).

Biradarpatil and Shekhargouda (2010) 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.

Naguib et al. (2011) determined the effect of storage period and packaging material on wheat seed viability and quality. The seed samples (12%, m.c.) were stored in different packages (clothes, plastic, aluminum and polyethylene) for 18 months at room temperature. Results revealed that there was a high reduction in seed germination and seedling vigor as the storage period increased, however, the poor vital seeds were recorded after 18 months from storage. The seed germination percentage after 12 and 18 months of storage was less than the recommended level of standard germination of wheat seed (85%). Wheat seed stored in aluminum and polyester bags showed high seed germination, seedling vigor and kept nutrient contents, and therefore they could delay seed quality deterioration compared with plastic and clothes bags.

Raikar *et al*. (2011) reported that storability of 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.

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%). The initial root and shoot length of soybean 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.

Baributsa *et al*. (2014) studied the effect of triple-layer plastic bags (PICS) for cowpea storage. A survey was conducted to assess the reuse and recycling of PICS bags. Respondents reported that PICS bags performed well in storing cowpea grain during consecutive years of use 100% (year one), 97.3% (year two), 79.0% (year three), and 15.4% (year four). It was concluded that for grain storage purposes, PICS bags may have to be replaced after three or four years of use. There was no evidence that PICS bags are discarded into the environment; rather, they are used for other purposes when they are no longer fit to hermetically store cowpea grain.

Chattah *et al*. (2014) investigated the effect of packing materials *viz*., metal bin, earthen bin, plastic bag, cloth bag as well as gunny bag and grain moisture content at packing (10% and 16%) on quality of wheat grain for ten months of storage in the laboratory. They reported that 1000-grain weight, protein and starch contents decreased and insect-pest infestation increased with the increase of storage period of wheat grain when gunny, cloth and plastic bags were used as the packing material. Wheat grain stored in metal and earthen bins with initial moisture content of 10% showed satisfactory qualitative characters throughout the storage period than those packed with 16% moisture. Higher the moisture content of grain at packing higher was the rapidity of quality loss and shorter the time of storage of wheat grain in metal and earthen bins.

Salimath *et al.* (2014) determined the effect of storage conditions and containers on seed quality of green gram. The well dried green gram seeds packed in cloth bag, poly lined gunny bag and high density polythene bag and stored under two different

storage conditions *viz*., ambient and commercial cold storage condition with initial 7.4% moisture content. The result revealed that the seeds stored in commercial cold storage and packed in polylined gunny bag recorded higher seed germination (91.25%), seedling length (24.33 cm) and seedling vigour index-II (2219) after ten months of storage.

Kumar *et al.* (2015) evaluated seed quality traits and storage methods used in the legume crops (green gram, black gram, chickpea and pea) by the house hold farmers in Jhansi district of Uttar Pradesh. Seventy-nine seed samples were collected for crops representing the routine cropping pattern practiced by the farmers. The commonly used methods and containers are polythene lined urea bag, jute bag, room storage, bunnda, metal container, plastic container and mud pot. Maximum damage was estimated 6% due to insect pests. The current evidence on farmer's seed samples indicated that storage methods and seed quality parameters need to be improved to increase yield.

Martin *et al*. (2015) assessed Purdue Improved Crop (PICS) bags for protection of wheat grain against common stored grain pest. Storing rice weevil infested wheat in PICS bags arrested weevil population growth and preserved the grain well. The air surrounding infested wheat held in PICS bags had lower oxygen and higher carbon dioxide levels compared to the ambient atmosphere. Seed germination declined over time in infested PICS bags, but it was less than grain held woven bags.

Sudini *et al*. (2015) evaluated Purdue Improved Crop Storage (PICS) bags for safe storage of Groundnuts. Custom made triple-layer bags were used and pods were placed @ 2 kg/bag. Over four months of storage under ambient conditions, triple-layer bags supported retention of seed weight, germinability and oil content significantly better than cloth bags. Further, under both natural and artificial infestations with A. flavus, seed aflatoxins levels were lower in PICS bags compared to cloth bags. Bruchid damage to pods was less in PICS bags versus cloth bags in all cases. The results suggested the superiority of triple-layer PICS bags was over cloth bags in protecting seed viability, seed weight and oil content while safeguarding the groundnuts from bruchids and retarding toxin accumulation.

Divekar and Sharma (2016) reviewed on hermetic storage system for food material. India is amongst the leading countries as far as food wastage is concerned.

Food grains worth ₹ 58,000 crore are wasted per annum due to the inferior condition of godowns. The storability of the food grain is affected by different factors like, moisture content of the grain, oxygen, carbon dioxide content of the storage environment. As the moisture content affects food grains storability severely, the storage structures must be provided with sufficient protection from moisture migration to the grain from the environment. The insect and pests grow at a faster rate in the presence of oxygen and moisture in the storage environment. To avoid infestation, the storage environment can be manipulated or a chemical treatment can be given to the grain. Among the new gaseous application technologies that have successfully replaced fumigants are the manipulation of modified atmosphere (MA) through the use of bio generated MA, for insect control and for quality preservation of grains. The sealed structures keep moisture levels of the grain constant which prevents mould growth. This technology is also termed as sealed storage, airtight storage, or assisted hermetic storage, bio-generated MA, etc.

Garg *et al.* (2016) reported that moisture content of the hermetic bags was constant after three months but in case of steel bins and gunny bags, the moisture content responded to changes in ambient conditions. It was suggested that hermetic bags can be a solution for preventing storage losses in India and an additional benefit is that no chemical fumigants are required which makes them environmentally acceptable.

Kumar *et al.* (2016) reported that the variation in grain moisture content (0.15% w.b.), water activity (0.083) and colour index (2.77) was the least in hermetic super bag, while variations were the maximum in case of wheat treated with neem and stored in jute bags (0.37, 0.175 and 5.42, respectively). The germination percentage was the maximum for wheat stored in hermetic super bags (76%) and the least for jute bags (16%) after 6 months storage. No visible damage due to insect/pest infestation was observed in wheat samples stored in super bags, while all samples stored in other bags were found heavily infested (25 ± 8%).

Tubbs *et al*. (2016) determined impact of opening hermetic storage bags on maize grain quality, fungal growth and aflatoxin accumulation. Maize with moisture contents high enough to support fungal growth (15%, 16%, 18% and 20%) was stored in PICS bags, which were opened weekly and exposed to humid conditions (85% RH)

for 30 min over a period of 8 weeks and 24 weeks. Monitors indicated that oxygen defused into the open bags but did not reach equilibrium with the bottom layers of grain during the 30 min exposure period. Fungal colony forming units obtained from the grain surface increased 3-fold (at 15% mc) to 10,000-fold (at 20% mc) after 8 weeks. At both 8 weeks and 24 weeks, aflatoxin was detected in at least one bag at each grain moisture.

Baributsa *et al*. (2017) assessed PICS bags for safely storage of unshelled and shelled groundnuts in Niger. Naturally-infested groundnut was stored in PICS bags and woven bags for 6 months. After storage, the average oxygen level in the PICS bags fell from 21% to 18% (v/v) and 21% to 15% (v/v) for unshelled and shelled groundnut, respectively. After 6 months of storage, in the woven bag, there was a large increase in the pest population accompanied by a weight loss of 8.2% for unshelled groundnuts and 28.7% for shelled groundnut. In PICS bags for both shelled and unshelled groundnuts, by contrast, the density of insect pests did not increase, there was no weight loss, and the germination rate was the same compared to that recorded at the beginning of the experiment.

Williams *et al*. (2017) reported that grain moisture content declined in woven bags, but remained high in PICS bags. Seed germination was not significantly affected over the first six months in all treatments, but declined after eight months of storage when infested grain was held in woven bags. Relative damage was low across treatments and not significantly different between treatments. Overall, maize showed no signs of deterioration in PICS bags versus the woven bags and PICS bags were superior to woven bags in terms of specific metrics of grain quality.

2.8 Effect of vacuum and modified atmosphere packaging on storage of food grains

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.

Rouziere (1986) conducted storage trials on shelled groundnut seeds using high vacuum or nitrogen compensated vacuum packaging for 18 months at 6°C and at room

temperature. No changes was found in physico-chemical properties under nitrogen compensated vacuum storage at room temperature.

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%, which declined to 40% inside after 6 months of storage and to 40% outside after 8 months storage.

Rao and Sastry (2002) stored sorghum and bajra seeds of 6, 10 and 14% 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. Pearl millet seeds survived longer than sorghum under similar conditions of storage. Seeds dried to 6% moisture content retained viability longer than those stored at 10 and 14%. Vacuum packing further enhanced seed longevity at 6% moisture content but not at 10 or 14% moisture content.

Chadda *et al.* (2004) developed a new method of phosphine and carbon dioxide application and its optimization. A "Fumigation Machine" was designed and fabricated to generate phosphine, mixed with carbon dioxide at the required proportion and deliver the mixture into the bag stack under gas proof cover. Rice stacks (> 90 t each) having infestations were fumigated with various proportions of phosphine and carbon dioxide. Additionally, test cages with 10 adults each of T. *Castaneum* and *Cryptolestes* spp. as well as full grown larvae of T. *granarium* were kept in the stacks at different levels. It was observed that a combination of 1.35 g phosphine and 35 g carbon dioxide per cubic meter was most effective in controlling all the species of stored grain insects tested.

Navarro (2006) studied on new global challenges to the use of gaseous treatments in stored products. Concerns over the adverse effects of fumigant residues in food and the environment have led regulatory agencies to take actions by imposing

strict limitations on fumigant registration. Among the new gaseous application technologies that have successfully replaced fumigants are the manipulation of MA alone or at high temperatures and high pressure carbon dioxide that needs to be further explored for specific applications. A recent development is the use of MA in a low-pressure environment. These niche applications of MA that have resulted in very promising application treatments with market acceptability, should serve as models for global challenges for new application methods.

Villers *et al.* (2006) reviewed on development and applications of the hermetic storage technology. Use of hermetic storage has resulted in safe, pesticide-free and sustainable storage suitable for many commodities and seeds, particularly in hot, humid climates. An increasingly popular transportable form of hermetic storage, super grain bag, provides capacities ranging from 10 to 1,000 kg, with 50 – 60 kg capacity being the most common. Field and laboratory data on long-term hermetic storage of coffee, peanuts, cocoa, rice, corn, and rice seeds, shows very significant quality and quantity preservation in the stored commodities.

Asha (2012) stated 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. The moisture content differed significantly from fourth month to the end of storage period due to containers. The moisture content was significantly lowest (8.26%) in vacuum sealed container followed by polythene bags (8.29%) 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.

Adler *et al.* (2016) reported that the reduced pressure and resulting oxygen content interfered with insect movement, feeding and respiration. Vacuum storage in flexible bags could be a suitable method for pest prevention of sufficiently dry stored products even if a moderate infestation had already occurred.

Meena *et al*. (2017a) determined the influence of vacuum packaging and storage conditions on the seed quality of cotton. Cotton seeds were stored in different packaging materials *viz*., cloth, aluminium and vacuum packed bags stored at room temperature (25 ± 2ºC) and cold storage (4 ± 1ºC) for a period of 18 months. The seed quality parameters on germination per cent, root length, shoot length, total seedling length and seedling vigour index decreased with an advancement of storage period, but electrical conductivity increased with an increase in storage period. It was observed that the samples stored in vacuum packed bags maintained the seed quality with least deterioration in all the quality parameters compared to samples stored in aluminum and cloth bags.

Meena *et al*. (2017b) determined influence of different packaging materials and storage conditions on the seed quality parameters of groundnut. Groundnut seeds were stored in different packaging materials *viz*., gunny bags, high density polythene bags and vacuum packed bags and stored at room temperature (25 ± 2ºC) and cold storage (4 ± 1ºC) for a period of 18 months. More fluctuation was observed in moisture content values throughout storage period but it was constant for vacuum packaging. It was also observed that the seeds stored in vacuum packed bags maintained the seed quality with least deterioration with respect to all the seed quality parameters compared to seeds stored in gunny bags and high density polythene bags.

2.9 Effect of combination treatments on storage life of food grains

Singh and Gupta (2002) determined the effect of packaging materials and pre-treatments on infestation of arhar dhal stored for eight months under various storage conditions. Untreated, $NaHCO_3$ treated and oil treated pigeon pea dhal samples were stored in different packaging materials (polythene, polylined and jute bags) at 9% and 12% initial moisture content. Effect of fumigation (ethylene-di-bromide) was also investigated. For dhal samples, polythene bags had the lower level of infestation as compared to polylined and jute bags. $NaHCO_3$ treatment and fumigation could reduce the level of infestation up to some extent. For dhal samples, rice moth and weevils were the main infesting insects.

Malaker *et al*. (2008) reported 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 the 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.

Choudhury and Rajanna (2011) studied the influence of packaging materials and seed treatments on physiological attributes during storage of rice. Freshly harvested seeds of rice were dried to a safe level of moisture (<13%), graded to uniform size and treated with Thiram + Bavistin, Malathion (10% dust) and bioneem at recommended dosages and packed in either a cloth bag, polylined cloth bag or polythene bag (700 gauge) and maintained for 10 months under ambient conditions. The results clearly revealed that seeds stored in polythene bags and treated with Thiram + Bavitin (1 g/kg seed) had higher seed quality parameters namely germination (81.50%), mean seedling length (20.92 and 19.62 cm), seedling vigour (1609 and 1704) and lower infection (10.27 and 9.44%), respectively.

Regmi and Dhoj (2013) carried out an experiment on eco-friendly management of pulse beetle. The experiment consisted storage structure (aluminium sheet bin and jute bag with plastic lining) was considered as one factor and pesticidal materials was as another factor. Among six pesticidal materials tested, mortality of adult bruchids was obtained significantly higher in chickpea treated by *C. camphora* balls (25.17) followed by *A. calamus* rizome dust (24.83) and sesamum oil (24.50). Grain damage and weight loss was nil in chickpea treated by these three materials. While comparing two storage structures, jute bag with plastic lining was better in terms of maintaining lower moisture (14.64%), higher germination (65.14%) and lesser grain damage (39.95%). The jute bag with plastic lining was found as a better storage structure and botanical materials such as *A. calamus* rhizome dust, Sesamum oil and *C. camphora* balls have been found as effective safe alternatives for the management of *C. chinensis* L. in the storage of chickpea.

Basavegowda and Arunkumar (2013) studied the effect of commercial cold storage conditions and packaging materials on seed quality of chickpea. The graded

seeds were packed in three containers *viz.*, gunny bag, polylined gunny bag and high density polythene bag (HDPE) and stored under two different storage conditions *viz*., ambient and commercial cold storage condition (temperature of 5-7°C and 65-70% RH) with initial seed moisture content less than 8% and seeds were treated with thiram @ 2g/kg seed before storage. The results revealed that the seeds stored in commercial cold storage (5-70°C and 65-70% RH) and packed in polylined gunny bag recorded higher seed germination (88.7%), vigour index (2799), seedling dry weight (430 mg), lower insect damage (1.7%), seed infection (4.5%), after 22 months of storage.

Kamara *et al*. (2014) determined the effects of packaging material and seed treatment on weevil infestation and quality of cowpea seeds. The study was conducted for seed treatments using neem leaf powder, pepper fruit powder, camphor, groundnut oil and wood ash in combination with five different packaging materials (cloth bag, paper bag, glass bottle, polythene bags and plastic container) on the viability and germination vigor of cowpea seeds. One kg of dried cowpea seeds with a uniform moisture content of 11% were stored for 6 months at room storage temperature (25.3-30.7°C) and RH (61- 82%). Results obtained from the study showed that packaging material and seed treatment had high significant effect on the vigour and germination percentage of cowpea seeds. Germination of seeds treated with powdered pepper (73%) and neem leaf powder (72.5%) were significantly higher than other treatments. Seeds stored in plastic containers had the highest vigour (61.1%) and germination (77.1%) after 6 months storage period. It was concluded that for better storage of cowpea seeds for a period not exceeding 6 months, plastic containers was preferable in combination with dry powdered pepper or neem leaf powder to maintain seed vigor and viability.

Said and Pradhan (2014) reviewed on food grain storage practices. They reported that now-a-days, the grains are stored using the improved methods such as in bags, silos, warehouses, containers and even in piles on the ground. These systems can be managed as man-made ecosystems, where deterioration of the stored grain is a result of interactions among physical, chemical and biological factors. Stored grain insects and pests normally cause as much loss of grains in storage. A new approach to the use of pheromones is the monitoring of insects based on remote sensing electronic transmitters that are progressively integrated into control programs. An integrated pest management program that might integrate insect monitoring, aeration, refrigerated

storage, modified or controlled atmosphere for insect control and for quality preservation of grain. The future requirement is to synthesize the status of knowledge and to provide directions in order to minimize the post-harvest losses of grains in different regions of the world.

2.10 Hazardous effect of fumigation/pesticides during storage

Garry *et al.* (1989) carried out a status survey on human genotoxicity pesticide applicators and phosphine. Twenty-four fumigant applicators were evaluated and compared to control subjects who had no exposure to pesticides. Phosphine was the main pesticide studied. The applicators sprayed pellets of phosphide onto the grain; the solids quickly converted to highly toxic phosphine gas if temperature and humidity were favorable. Results of blood tests showed that applicators exposed to phosphine and other pesticides had 3.58 time more total chromosome abnormalities compared to control subjects. For one specific type of chromosome rearrangement, applicators had five times the number of changes compared with controls. Workers who spent over 20 minutes fumigating in an enclosed area had more abnormalities than workers who completed a job in under 15 minutes, suggesting that the toxic effect is time-dependent. The workers again had blood tests six to twelve weeks after the application season. Some types of abnormalities remained while others had disappeared and were apparently transient. Long-term health risks, which may include a type of cancer called non-Hodgkins lymphoma, deserve further scrutiny.

Taylor (1989) reported that insect resistance to phosphine is a global issue now and control failures have been reported in field situations in some countries. Fumigation plays a major role in insect pest elimination in stored products. Currently, phosphine (from metal phosphide preparations, cylinderized formulations and on-site generators) and methyl bromide (available in cylinders and metal cans) are the two common fumigants used for stored-product protection world over.

Bell (2000) reported that methyl bromide, the fumigant with the widest range of applications is scheduled for worldwide withdrawal from routine use as a fumigant in 2015 under the directive of the Montreal Protocol on ozone-depleting substances. Phosphine, the only other commodity fumigant available worldwide, used principally on bulk grain but also on dried fruit, nuts, cocoa, coffee and bagged rice, is currently

under regulatory review in the USA and Europe. The prospects for the continued use of fumigants are discussed atmospheric emission controls, fears on safety or health grounds, the incidence of resistance and the need to achieve increasingly high standards of pest control in international trade. Some recent research results relating to fumigant toxicity and gas application technology are presented which indicate ways in which the use of some of the few remaining fumigants can be extended in the 21st century.

Methyl bromide, a broad-spectrum fumigant, has been declared an ozone-depleting substance and therefore, is being phased out completely. In view of the problems with the current fumigants, there is a global interest in alternative strategies including development of chemical substitutes, exploitation of controlled atmospheres and integration of physical methods. (Anon., 2002)

Fields and White (2002) studied alternatives to methyl bromide treatments for stored-product and quarantine insects. Methyl bromide is used to control insects as a space fumigant in flour and feed mills and ship holds, as a product fumigant for some fruit and cereals, and for general quarantine purposes. Methyl bromide acts rapidly, controlling insects in less than 48 h in space fumigations, and it has a wide spectrum of activity, controlling not only insects but also nematodes and plant-pathogenic microbes. This chemical was banned in developed countries, except for exceptional quarantine purposes, because it depletes ozone in the atmosphere. Many alternatives have been tested as replacements for methyl bromide but the most promising include integrated pest management tactics and combinations of treatments such as phosphine, carbon dioxide, and heat.

Collins (2006) reviewed on resistance to chemical treatments in insect pests of stored grain and its management. Chemical insecticides, including fumigants, disinfectants and grain protectants, are essential components of grain insect pest management systems. This is particularly the case in warmer climates where insect infestation pressure is high. Because of health, safety, environmental and economic considerations, only a very limited number of chemicals is available for application to grain. A serious threat to the continued availability of these materials is the development of resistance in target pests. Worldwide, the fumigant phosphine is by far the most important insect control treatment for stored grain. There are no practical alternatives to this unique material. However, resistance to this fumigant has developed

in major pest species in many regions threatening its continued viability. In some regions, the situation is precarious with insect populations containing multiple resistances leaving no effective protectant options available. Development of effective strategies requires an understanding of the grain storage system, the ecology of the pest insects, the response of insects to various chemicals and other treatments, and some insight into resistance genetics.

Riudavets *et al.* (2006) carried out an experiment on the response of eleven stored product pest species to modified atmosphere with high carbon dioxide concentrations. Modified atmosphere with high carbon dioxide concentrations have been used as an alternative treatment to methyl bromide for the control of stored product pests. In this study, two different methods were chosen to apply carbon dioxide (CO_2) modified atmosphere packaging and high-pressure treatments. Eggs, larvae, pupae and adults were exposed to two sub-lethal dosages of each method (packaging: 50% and 90% CO_2 for 4 days and high pressure: 15 and 20 atm. of pressure for 15 minutes) and the resulting mortality was recorded. For modified atmosphere packaging, pupae of Coleoptera and Lepidoptera were the least sensitive stages and could, therefore, be used to further fine-tune optimal dosages for controlling all their developmental stages.

Rajashekar *et al*. (2012) reported that prevention of food losses during postharvest storage is of paramount economic importance. Integrated pest management is now a widely accepted strategy in pest control including postharvest infestation control which involves the use of chemical (contact/residual) insecticides along with fumigants. The use of synthetic chemical insecticides is either not permitted or used restrictively because of the residue problem and health risks to consumers. There is a growing demand to develop newer eco-friendly and safer control approach for stored pest management due to the problem of resistance to insecticides.

Mada *et al.* (2014) studied toxicity of pesticide on storage of cereal, legume and oil seed with regard to storage structures. Food contamination with pesticide is a serious hazard that poses a great threat to farmers', grain merchants and stake holders of pesticides. The hazardous nature of pesticides inherent toxicity and ability to cause harm makes it mandatory in this study to ensure the safety of human and livestock consumption. In this background, the toxicity of pesticide residue dissipation on cereal, legumes and oilseed made simulated storage condition was investigated. Poor storage

structures investigated in the study zone had led to farmers, grain merchant and stakeholder of pesticides to used banned, overdosed and wrongly approved pesticides. The effect of using toxic pesticide on seed and grain include germination ability, seeding viability and dietary risk. Available information raised from long term exposure to the pesticide in the study zone had led to 164 contracted disease, 103 poison, 101 hospitalized and 28 untimely deaths.

Singh and Sharma (2015) reported that out of a total about 10% post-harvest loss of grains, a significant 6% are damaged during their storage. Methyl bromide, a cheap, broad spectrum fumigant, has to be phased out honouring 'Montreal Protocol'. Phosphine widely used worldwide, is the only fumigant currently used in India, because of its low cost, availability and residue-free treatment. But one serious limitation of use of phosphine is the development of resistance in the major stored grain insect pests. There are several other fumigants which have been found promising but cost remains a serious factor, especially for a country like that of India. Besides fumigants, use of Modified Atmosphere (MA) seems to be the best bet for pesticide free organic storage. However, the technology of MA can be well adapted where cheap sources of nitrogen or carbon dioxide are available and the storage structure is well sealed. Ozone, a strong oxidant, has also been successfully tried for control of stored grain insect pests, but its corrosive property towards most of the metals, is a concern.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the procedure adopted for packaging and storage of chickpea grain in different packaging materials. Methodologies adopted for selection and processing of raw material, determination of proximate compositions of chickpea grain, packaging and storage, determination of environmental parameters, entomological parameters, quality of chickpea grain during storage are reported here in details. The particulars of machineries, instruments and materials used in the experiments are discussed in the following sub-heads.

3.1 Experimental details

The experiment was carried out in the Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. during the year 2017-18. The experiment was mainly consisting of selection of raw material, cleaning, grading and sorting, drying, packaging and storage of chickpea grain in the different packaging materials for the period of twelve months.

3.1.1 Selection and procurement

Desi and kabuli chickpea varieties are cultivated in Saurashtra region. Amongst different desi varieties *viz*., *GG-1*, *GG-2*, *GJG-3*, *GG-4*, *GG-5* and *GJG-5* of chickpea, *GJG-3* is most commonly grown in Saurashtra region due to high-yielding variety. The freshly harvest and uniformly matured chickpea grain was procured from the Agricultural Research Station, Dhari, Junagadh Agricultural University. In view of this, *GJG-3* variety of chickpea grain was selected for the present investigation.

3.1.2 Cleaning, grading and sorting

The chickpea grain was cleaned and graded by cleaner-cum-grader machine at Dhari Research Station. The grain was then cleaned and sorted manually to remove extraneous materials such as dust, dirt, stones, chaff, immature grains, insect infested and damaged grains for two times (Plate 3.1-3.3).



Plate 3.1 First cleaning and sorting of chickpea grain



Plate 3.2 Second cleaning and sorting of chickpea grain



Plate 3.3 Clean and damaged chickpea grains

3.1.3 Drying

Initial moisture content of chickpea grain was found 8.9 – 9.0 % (w.b.). The grain was dried for 6 h in open yard for sun drying as shown in Plate 3.4 to obtain optimum final moisture content 7.5 - 7.6 % (w.b.) for safe storage.



Plate 3.4 Sundrying of chickpea grain

3.1.4 Packaging of chickpea grain

Cleaned and dried grains were packed in different packaging materials *viz*., polyethylene lined jute bag, polypropylene (PP) woven laminated bag, high density polyethylene (HDPE) bag, multilayer coextruded plastic bag, polyethylene laminated aluminium foil bag, perdue improve crop storage (PICS) bag with 5.0 kg sample size. The jute bag was considered as a control for packaging of the grain (Plate 3.5). The jute bags, polyethylene lined jute bags, HDPE bags and polyethylene laminated aluminium foil bags were procured from local market. Multilayer coextruded plastic bags were obtained from Essen Multipack Pvt. Ltd., Rajkot and PICS bags were procured from ICRISAT, Hyderabad. The jute bags, polyethylene lined jute bags and PP woven laminated bags were packed and sewed by portable stitching machine (Revo bag closer, Surat) after filling the grain (Plate 3.7). For PICS bags packaging, the grains were filled first inner HDPE bags and sealed with heat sealing machine (Plate 3.6). The inner HDPE bags were placed in outer HDPE bags and sealed the same way. The grains with double layer HDPE bags were packed in outer PP bags and sewed by portable stitching machine. The vacuum packaging machine (Packmech Engineers, Ahmedabad) was used for vacuum packaging (700 mm Hg) and sealing of the grain of HDPE bags, multilayer coextruded plastic bags and polyethylene laminated aluminium foil bags. The technical specification of vacuum packaging machine is presented in Appendix A-1. The sample bags with the grain were put into the chamber of vacuum packaging machine and lid was closed. The vacuum was created in the chamber of the vacuum packing machine as well as in the sample bags. The bags were collapsed and sealed and the lid was automatically opened (Plate 3.8). The vacuum packed bags were taken out from the chamber of the machine for subsequent storage.

3.1.4.1 Specification of bags

Jute bag:

The size of jute bag was 45 cm × 32 cm. The bag had 10 × 10 mesh size.

Polyethylene lined jute bag:

The jute bag had 25 µm thick of polyethylene film lining inside. The size of the bag was 47 cm × 27 cm. Jute bag had 10 × 10 mesh size.

PP woven laminated bag:

The bag had 50 cm × 32 cm size. The bag was anti-slip weaving dust proof bag having 12 × 12 mesh size and 100 GSM with 25 µm lamination.



Jute bag



Polyethylene lined jute bag



PP woven laminated bag



HDPE bag



Multilayer coextruded plastic bag



Polyethylene laminated aluminium foil bag



PICS bag (Perdue improve crop storage bag)

Plate 3.5 Different packaging materials

HDPE bag (150 µm):

HDPE bag had 150 µm thickness having stress crack resistance in addition to chemical and corrosion resistance. The size of the bag was 52 cm × 35 cm.

Multi-layer co-extruded plastic bag (150 µm):

The bag had 150 µm thickness having excellent resistance to puncturing, heat sealability and gas barrier. The film is the simultaneous extrusion of LDPE and nylon polymers. The bag had 50 cm × 34 cm size.

Polyethylene laminated aluminium foil bag (150 µm):

Aluminium foil had 125 µm thickness with laying of 25 µm polyethylene film. The size of the bag was 42 cm × 30 cm. The bag comprises the features of high durability, moisture proof, gas proof, light proof, temperature resistant, light weight, good for sealing by heat and induction, corrosion resistant.

Perdue improve crop storage bag:

The size of the bag was 48 cm × 35 cm. The purdue improved crop storage (PICS) bag is a triple-layer bag which comprises of two inner high density polyethylene bags (HDPE, 80 µm each) and one outer woven polypropylene (PP) bag. The PP bag had 10 × 10 mesh size.

3.1.5 Storage

All the bags were stored at room temperature (13.2 - 38.5 °C, 18.8 - 91.1 % RH) for twelve months on large sheet placing on table platform forming L shape having collar projected from all the sides in the laboratory for rat control (Plate 3.9-3.10).



Plate 3.6 Sealing of plastic bags



Plate 3.7 Stitching of bags



Plate 3.8 Vacuum packaging

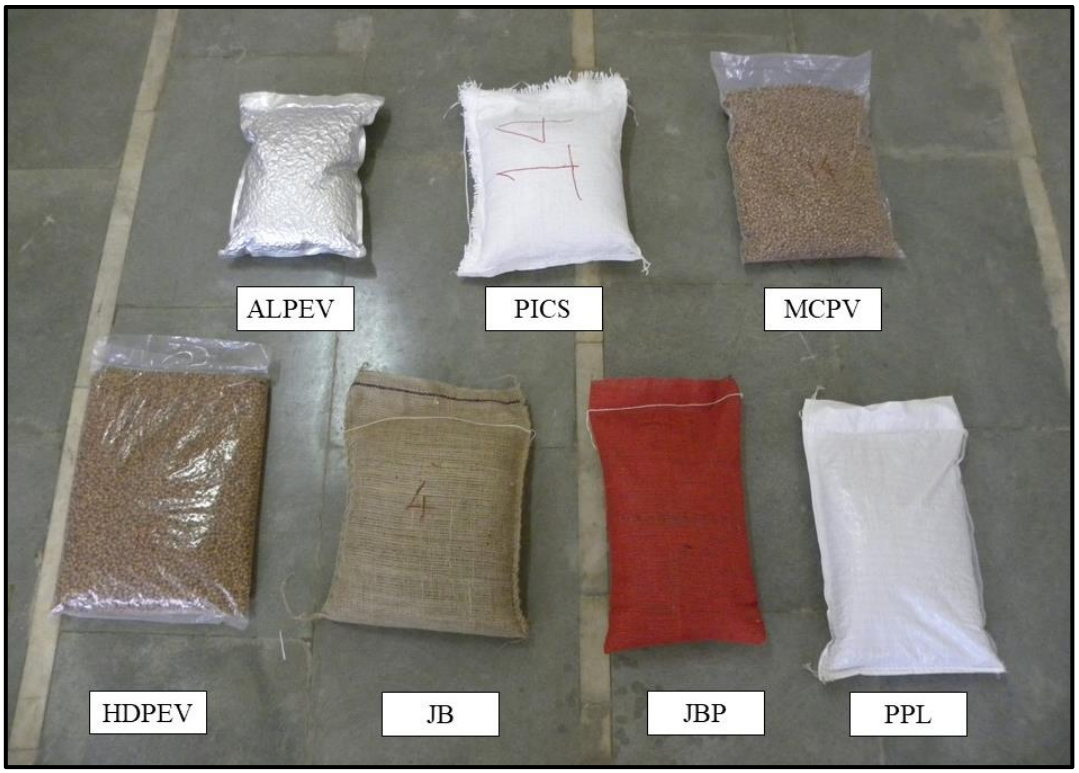


Plate 3.9 Chickpea grain packed in different bags



Plate 3.10 Storage of chickpea grains in different packaging materials

3.2 Proximate composition of chickpea Grain

The proximate composition of ten samples of chickpea grains *viz.*, carbohydrate, protein, crude fiber, fat and ash content were determined at 7.59 %, (w.b.) moisture content before packaging as described in the subsequent sections here under.

3.2.1 Carbohydrate (%)

Carbohydrate was determined by using phenol sulphuric acid method (Sadasivam and Manickam, 1992). Chickpea powder (0.1 g) was hydrolysed by keeping in water bath for three hours with 5 ml of 2.5 N HCl and cooled to room temperature. Working standard was then taken out by pipette into 0.2, 0.4, 0.6, 0.8 and 1 ml in series of test tubes and made up to 1 ml. Sample was analysed in duplicate for 0.1 and 0.2 ml in separate tubes. Blank was set by 1 ml of water. Phenol (1 ml) and 5 ml of sulphuric acid (96 %) was then added to each tube, shaken well and colour was read at 490 nm by using absorption type UV-VIS spectrophotometer (Systronics Model: UV-VTS 108). Standard graph was then used for calculating amount of carbohydrate.

$$\text{Total carbohydrate (\%)} = \frac{\text{G. F.}\times\ \text{O. D.}\times \text{Total volume} \times 10^{-6}}{\text{Aliquot taken}} \times 100 \qquad \ldots (3.1)$$

3.2.2 Protein content (%)

Reagents for lowry method:

Solution A was prepared by adding 2 % sodium carbonate (Na_2CO_3) in 0.1N NaOH solution. Solution B was prepared by in proportion of 0.5% copper sulphate in 1% potassium sodium tartarate solution. Alkaline copper sulphate solution (solution C) was prepared by mixing 50 ml solution A and 1 ml of solution B just prior to use. Folin-ciocalteau reagent (FCR) solution (1N) was made by dilute commercial grade reagent (2N) to 1:1 (v/v) with distilled water.

Stock standard protein solution was prepared by weighing accurately 100 mg of bovine serum albumin and dissolved in distilled water and made up to 100 ml in a standard flask. Working standard was prepared by dilution of 10 ml of the stock solution to 50 ml with distilled water in a standard flask.

Sample extraction

Protein was extracted by weighing known quantity (0.1 to 0.5 g) sample. The assay material was extracted with 10-50 ml of 0.1N NaOH and put it in water bath for 6 h at 65°C. After cooling, the extract was centrifuged at 6000 rpm for 15 min. Supernatant was collected and centrifuged repeatedly with 0.1N NaOH and recollected the supernatant. Final volume was made 10/50 ml with adding distilled water. The supernatant was used for the estimation of total protein content (Lowry *et al*., 1951).

Estimation of protein

Supernatant (0.1 ml) was taken and added 0.8 ml distilled water for making up to 1 ml. The solution C (5.0 ml) was added and mixed. After 10 min, 0.5 ml of FCR was added and mixed well and incubated for 30 min. The absorbance of the solution was recorded at 660 nm against a reagent blank using spectrophotometer (Plate 3.11-12). A standard graph was prepared with BSA as a standard in the range of 20 to 120 µg.

$$\text{Protein content (\%)} = \frac{\text{G. F.}\times\ \text{O. D.}\times\ \text{Total vol. of buffer (ml)}}{\text{Vol. taken from extracts (ml)}\times\ \text{wt. of sample (gm)}} \times 100 \quad \ldots (3.2)$$

3.2.3 Fat content (%)

Fat content was determined by soxhlet method (Socs plus, Model: SCS 06 AS DLS). Chickpea grain powder (2 g) was transferred to the cellulose thimble (Fig 3.13). The initial weight of the beaker was recorded, where the fat or oil was extracted. The thimble was fixed to the thimble holder and placed into the beaker. Eighty ml of solvent (petroleum ether, boiling point temperature 40-60 °C) was added and inserted the beaker with solvent in the extraction system. The water inlet was connected and started the water flow through the system. The power was switched on and set 80 °C temperature for first step of one hour boiling and 120 °C for second step of half hour evaporation of solvent. When the complete evaporation of solvent was done, the beaker was taken out from the system. The thimble was also taken out from the beaker. The beaker was kept inside the hot air oven for few mins to remove solvent vapours. The

final weight of the beaker was taken and calculated the fat content of sample taken in thimble using following equation.

$$\text{Fat content (\%)} = \frac{(\text{Weight of flask} + \text{oil}) - \text{Weight of flask (g)}}{\text{Weight of sample (g)}} \times 100 \quad \ldots (3.3)$$

3.2.4 Crude fibre (%)

Fibretherm Gerhardth plus instrument was used for estimation of crude fibre content (Plate 3.14). chickpea sample was treated with 1.25 % H_2SO_4 followed by 1.25 % NaOH and washed thoroughly with distilled water after each treatment. Neutral residue left over was dried, weighed and then ignited into muffle furnace. From the loss in weight of residue, the percentage of crude fibre was calculated using following formula given by Ranganna (1986).

$$\text{Crude Fibre, \%} = \frac{W_2 - W_3}{W_1} \times 100 \quad \ldots (3.4)$$

Where,

W_1 = Initial sample weight, g

W_2 = Weight of digested sample, g

W_3 = Weight of ash, g

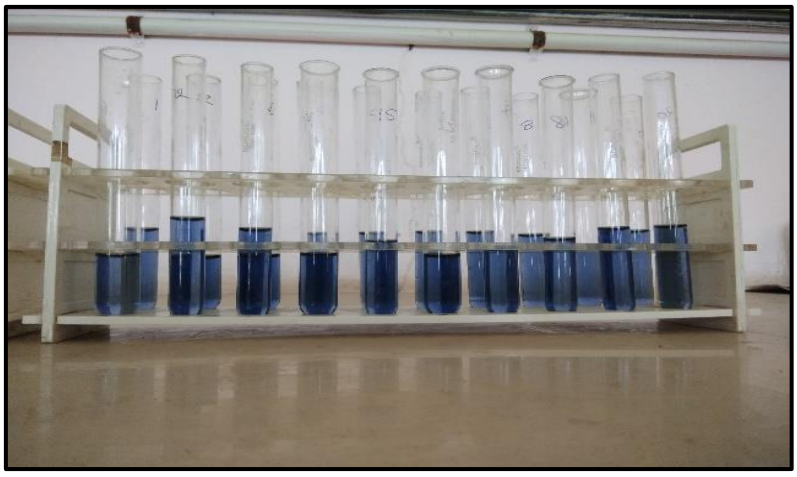


Plate 3.11 Protein content determination of chickpea grain



Plate 3.12 Spectrophotometer for protein measurement



Plate 3.13 Fat content determination



Plate 3.14 Fibertherm for fibre content measurement



Plate 3.15 Measurement of ash content

3.2.5 Ash content (%)

Ash content was determined by keeping 5 g of sample placed in silica dish in muffle furnace (Meta Instruments, Mumbai) at 600 °C until grey coloured ash was occurred to a constant weight (Fig 3.15). The ash was weighed after short time of cooling. The ash content was calculated by

$$\text{Ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100 \qquad \ldots (3.5)$$

3.3 Treatment details

The details of treatments in terms of independent and dependent parameters are given below.

3.3.1 Independent parameters

1. Jute bag (JB) (control)
2. Polyethylene lined jute bag (JBP)
3. PP woven laminated bag (PPL)
4. HDPE bag with vacuum (HDPEV)
5. Multilayer coextruded plastic bag with vacuum (MCPV)
6. Polyethylene laminated aluminium foil bag with vacuum (ALPEV)
7. Perdue improve crop storage bag (PICS)
8. No. of Replications: 3 (Three)
9. Statistical Design: Completely Randomized Design (CRD)

3.3.2 Dependent parameters

Environmental parameters

Temperature (°C)

Relative humidity (%)

Entomological parameters

Insect population (number/500g)

Grain damage (%)

Physico-chemical parameters

Moisture content (w.b., %)

Weight loss (%)

Protein content (%)

Cooking quality

Cooking time (min)

Hydration and swelling Properties

Hydration capacity (g/grain)

Hydration index

Swelling capacity (ml/grain)

Swelling index

Seed quality

Germination (%)

Seed vigour index

3.4 Details of observations taken

The environmental parameters were recorded daily at room conditions in the laboratory during storage. Entomological and physico-chemical parameters, cooking quality, hydration and swelling properties and seed quality of chickpea grain were analysed at two months interval during storage.

3.4.1 Environmental parameters

The environmental parameters like temperature and relative humidity were recorded daily with using data logger at room conditions during storage by using following methods.

3.4.1.1 Temperature (°C)

The room temperature was recorded at 2 h interval daily with using data logger during storage (May, 2017 to April, 2018). The maximum and minimum room temperature data were extracted and monthly mean data are presented.

3.4.1.2 Relative humidity (%)

The relative humidity was recorded at 2 h interval daily with using data logger during storage (May, 2017 to April, 2018). The maximum and minimum relative humidity data were extracted and monthly mean data are presented.

3.4.2 Entomological parameters

Entomological parameters *viz.*, insect population and grain damage were recorded at two months interval during storage by using following methods.

3.4.2.1 Insect population (number/500 g)

The grain samples were taken out randomly at bottom, middle and top portion from each bag of the treatments. The samples were thoroughly mixed and 500 g of sample was used for recording insect population like pulse beetle and bruchid. The total number of adults obtained from each sample were counted and recorded.

3.4.2.2 Grain damage (%)

The grain samples were taken out randomly at bottom, middle and top portion from each bag of the treatments. The samples were thoroughly mixed and a sample of 200 chickpea grains was used for counting damaged grains from the sample. Care was taken to avoid recount of damage grain. The grain damage was determined using following formula.

$$\text{Grain damage (\%)} = \frac{\text{Number of damaged grains}}{\text{Number of grains in sample}} \times 100 \qquad \ldots (3.6)$$

3.4.3 Physico-chemical parameters

The physico-chemical parameters *viz.*, moisture content, weight loss and protein content were recorded at two months interval during storage by using following methods.

3.4.3.1 Moisture content (%)

The initial and final moisture contents of the samples were determined by using hot air oven method as suggested by Sadasivam and Manickam (1996). In this method about ten grams of grain sample was taken at random from each sample, ground and placed in petri dish. The samples in a petri dish were placed inside the hot air oven (Scientronic-universal oven) at 130 ± 1°C till it got constant weight (about 2-3 h). The samples were cooled and weighed (Plate 3.16). The difference in the initial and the final weights of the sample was taken as the moisture content (w.b.) using following formula.

$$\text{M.C.}(\text{w.b.},\%) = \frac{\text{Initial weight of sample} - \text{Final weight of sample}}{\text{Initial weight of sample}} \times 100 \quad \ldots (3.7)$$



Plate 3.16 Hot air oven for moisture content determination

3.4.3.2 Weight loss (%)

The weight loss was calculated using weight of un-infested grains and weight of infested grains as well as number of un-infested grains and number of infested grains at two months interval as reported by Adams and Schulton (1978).

$$\text{Weight loss (\%)} = \frac{\{(\text{U})(\text{ND})\} - \{(\text{D})(\text{NU})\}}{\text{U (ND + NU)}} \times 100 \qquad \ldots (3.8)$$

Where,

U = Weight of un-infested grains (g)

NU = Number of un-infested grains

D = Weight of infested grains (g)

ND = Number of infested grains

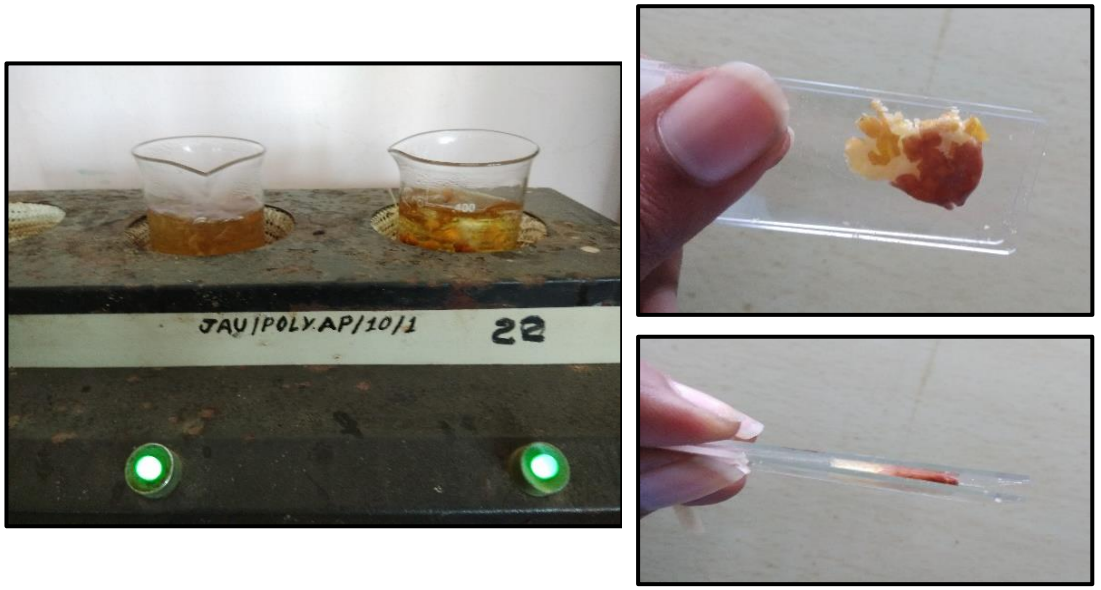
3.4.3.3 Protein content (%)

Protein content of the grain was measured as discussed in 3.3.2.

3.4.4 Cooking quality

3.4.4.1 Cooking time (min)

Chickpea grain samples were cooked in a beaker on heating mortal (EIE Instrument, Model: EIE 070318) having a ratio of the grain : distilled water as 1 : 10. For determination of cooking time, distilled water was heated to boiling point in a 500 ml beaker and then 50 g grain was added. During boiling, the level of water was maintained by regular addition of boiling water. Boiling was continued and samples were drawn at 2 min interval to check the level of cooking by pressing between two glass slides till no hard core was left (Plate 3.17). Full cooking time was recorded as the time when 90 % of the grain were soft enough to masticate (Williams *et al.*, 1983).



Cooking of chickpea grains **Checking the softness of the grain**

Plate 3.17 Estimation of cooking time of chickpea grain

3.4.5 Hydration and swelling properties

Hydration and swelling properties of the grains were determined using the procedure reported by Williams *et al.* (1983).

3.4.5.1 Hydration capacity and hydration index

A weighed amount of the grain sample was poured into a measuring jar containing 100 ml distilled water and left to soak for 24 h at room temperature (30 ± 5 °C). The water was drained afterwards and the soaked grains were blotted on tissue paper to remove adhered water and the grains were weighed again. Hydration capacity and index were calculated according to the expressions below:

$$\text{Hydration capacity, g/grain} = \frac{\text{Weight after soaking} - \text{Weight before soaking}}{\text{Number of grains}} \quad \ldots (3.9)$$

$$\text{Hydration index} = \frac{\text{Hydration capacity of grain}}{\text{Weight of one grain}} \quad \ldots (3.10)$$

3.4.5.2 Swelling capacity and swelling index

One hundred kernels were randomly selected and the initial volume of kernels was determined by volume displacement method. The selected kernels were soaked for 24 h at room temperature (30 ± 5 °C) in distilled water and the volume of the soaked kernels was measured in a graduated cylinder. The swelling capacity and swelling index were calculated as follows:

$$\text{Swelling capacity, ml/grain} = \frac{\text{Volume after soaking} - \text{Volume before soaking}}{\text{Number of grains}} \quad \ldots (3.11)$$

$$\text{Swelling index} = \frac{\text{Swelling capacity of grains}}{\text{Volume of one grain}} \quad \ldots (3.12)$$

3.4.6 Seed quality

Seed quality *viz.*, germination and seed vigour index were recorded at two months interval during storage by using following methods.

3.4.6.1 Germination (%)

Germination percentage was calculated by using the method given by International Seed Testing Association (ISTA). Hundred seeds taken from each treatment were kept for germination test at 25 ± 1°C temperature and 80 % RH by using paper towel method with three repetitions (ISTA, 1996) (Plate 3.18). The germinated seedlings were evaluated on 8th day and germination percentage were calculated by the following formula,

$$\text{Germination (\%)} = \frac{\text{Number of germinated grains}}{\text{Total number of grains}} \times 100 \quad \ldots (3.13)$$

3.4.6.2 Seed vigour index

Ten normal seedlings were selected randomly on 8th day from each replication among the germinating seedlings. The shoot length was measured from the base of primary leaf to the base of hypocotyl. Similarly, the root length was measured from the base of the hypocotyl to the tip of the primary root. The mean seedling length was computed by adding both shoot and root lengths of ten seedlings (Plate 3.19). Seed vigour index was determined as reported by ISTA (1996) by using following formula:

Seed vigour index = Average seedling length (root + shoot) (cm) × Germination (%) … (3.14)

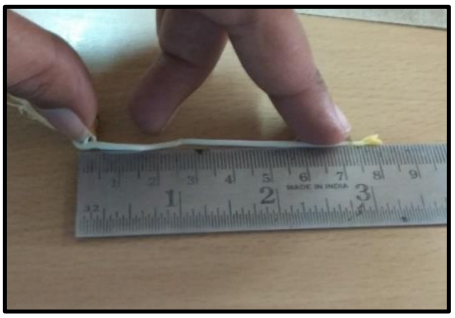




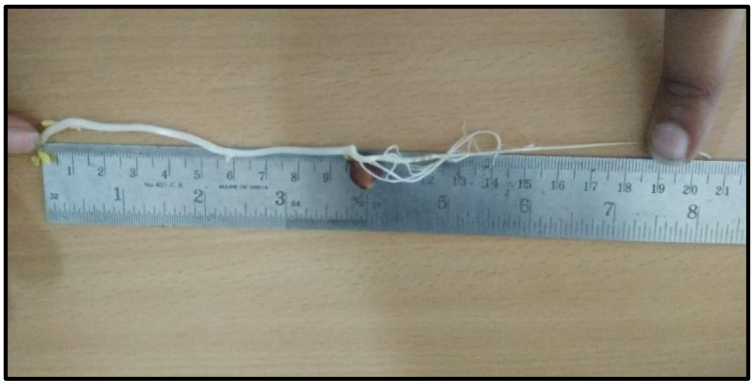
Seed germinator **Germination paper rolls**

Plate 3.18 Estimation of germination of chickpea grain





Measurement of root length **Measurement of shoot length**



Measurement of seedling length

Plate 3.19 Estimation of seed vigour index of chickpea grain

3.5 Statistical analysis

Statistical analysis was carried out by Completely Randomized Design with three replications. All the treatments were compared at 5% level of significance using the critical difference test. The analysis of variance (ANOVA), standard error of mean (SEm), critical difference (CD), coefficient of variance (CV) and mean values for dependent parameters were tabulated and the level of significance was reported. (Panse and Sukhatme, 1967).

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the results obtained from different packaging materials on storage life of chickpea grain. The effect of different packaging materials on entomological parameters, physico-chemical parameters, cooking quality and seed quality of chickpea grain were carried out at room condition to study storage life of chickpea grain. The results are presented and discussed in subsequent sections.

4.1 Proximate composition, cooking time, hydration and swelling properties, seed quality of chickpea grain before storage

The data obtained for the proximate composition of ten samples of chickpea grain, *i.e*., moisture content, protein, carbohydrate, fat, crude fibre and total ash are presented in Table 4.1. The moisture content (w.b.), protein, carbohydrate, fat, crude fibre and total ash of chickpea grain was found to be 7.59 %, 22.39 %, 61.76 %, 3.56 %, 1.26 %, 3.20 %, respectively. These results of proximate composition of chickpea grain were observed in agreement with the results reported by Jambunathan and Singh, 1980; William and Singh, 1987.

Table 4.1 Proximate composition of chickpea grain

Constituent	**Mean value (%)**
Moisture content (w.b.)	7.59 ± 0.04
Protein	22.39 ± 1.26
Carbohydrate	61.76 ± 1.51
Fat	3.56 ± 0.05
Crude fibre	1.26 ± 0.07
Total ash	3.20 ± 0.20

The cooking time, hydration and swelling properties and seed quality of five samples of chickpea grain before storage are presented in the Table 4.2. The mean cooking time of the grain was recorded 30.46 min. The mean values of hydration and swelling properties *viz.*, hydration capacity, hydration index, swelling capacity and swelling index of chickpea grain before storage were observed 0.256 g/grain, 1.191, 0.292 ml/grain and 1.680, respectively. These results are in agreement with Tripathi *et al*., 2012. Seed quality parameters like mean values of germination and seed vigour index were recorded 97.33 % and 1458, respectively.

Table 4.2 Cooking time, hydration and swelling properties and seed quality of chickpea grain before storage

Parameters	**Mean value**
Cooking time, min	30.46 ± 0.56
Hydration capacity, g/grain	0.256 ± 0.006
Hydration index	1.191 ± 0.020
Swelling capacity, ml/grain	0.292 ± 0.014
Swelling index	1.680 ± 0.129
Germination, %	97.33 ± 1.15
Seed vigour index	1458 ± 395

4.2 Environmental parameters during storage of chickpea grain

The observations in respect of environmental parameters *viz.*, temperature and RH at room condition was recorded daily during storage period (2017-18). The mean monthly minimum and maximum data of temperature and RH are presented in Table 4.3. Maximum temperature (38.5 °C) was recorded in the month of May while minimum temperature (13.2 °C) was observed in the month of January. Maximum RH was recorded in the month of July (91.1 %) while minimum RH was found in the month of March (18.8 %).

Table 4.3 Environmental parameters at room condition during storage of chickpea grain

Months	Temperature, °C		Relative humidity, %	
	Min	**Max**	**Min**	**Max**
May	24.7	38.5	33.1	77.7
June	26.6	35.0	56.6	81.4
July	25.4	28.9	78.9	91.1
August	24.6	29.3	77.2	90.8
September	24.5	30.4	70.1	87.4
October	22.9	34.5	33.6	68.3
November	16.7	31.1	26.6	66.7
December	14.8	27.1	38.1	69.1
January	13.2	28.0	28.4	72.6
February	16.2	31.0	23.1	61.9
March	20.2	35.6	18.8	60.9
April	23.7	38.3	20.4	72.5

4.3 Effect of different packaging materials on quality of chickpea grain

4.3.1 Entomological parameters

The observations in respect of various entomological parameters *viz.*, insect population and grain damage were recorded at an interval of two months during storage up to twelve months.

4.3.1.1 Insect population

Insect was not observed up to two months of storage period in the chickpea grain. From the Table 4.4, it can be observed that the effect of different packaging materials on insect population was found significant during entire storage period except two months. JB resulted significantly highest insect population during entire storage period except two months. However, JBP, PPL, HDPEV, MCPV, ALPEV and PICS were found at par with each other during entire storage period.

Table 4.4 Effect of different packaging materials on insect population (number/500g) of chickpea grain during storage

Treatment	Storage period, Months				
	4	**6**	**8**	**10**	**12**
JB	1.64* (2.3)	2.32* (5.0)	4.01* (15.7)	4.91* (23.7)	6.81* (46.0)
JBP	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
PPL	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
HDPEV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
MCPV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
ALPEV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
PICS	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
S.Em.±	0.099	0.095	0.082	0.079	0.106
C.D. at 5 %	0.299	0.288	0.249	0.238	0.322
C.V. %	20.290	17.520	12.060	10.410	11.630

* Data subjected to square root transformation

Figures in parentheses are original values

The data regarding effect of different packaging materials on insect infestation during storage is shown graphically in Fig. 4.1. The insect population of pulse beetle (*Callosobruchus chinensis* L.) was only found in jute bag. The data depicted in Fig. 4.1 indicate that population of pulse beetle in chickpea greatly affected when stored in JB. However, it started in JB on four months of storage and the insect population increased cumulative as storage progressed. *i.e.*, 46 numbers/500 g of sample at the end of twelve months of storage period. The increase in insect population in the grain might due to higher moisture content and aeration which enhanced grain deterioration (Monira *et al*. 2012). JBP, PPL, HDPEV, MCPV, ALPEV and PICS treatments were observed free from insect infestation throughout the storage period. It might be due to reduced pressure and resulting oxygen content interfered with insect movement, feeding and respiration (Adler *et al*., 2016).

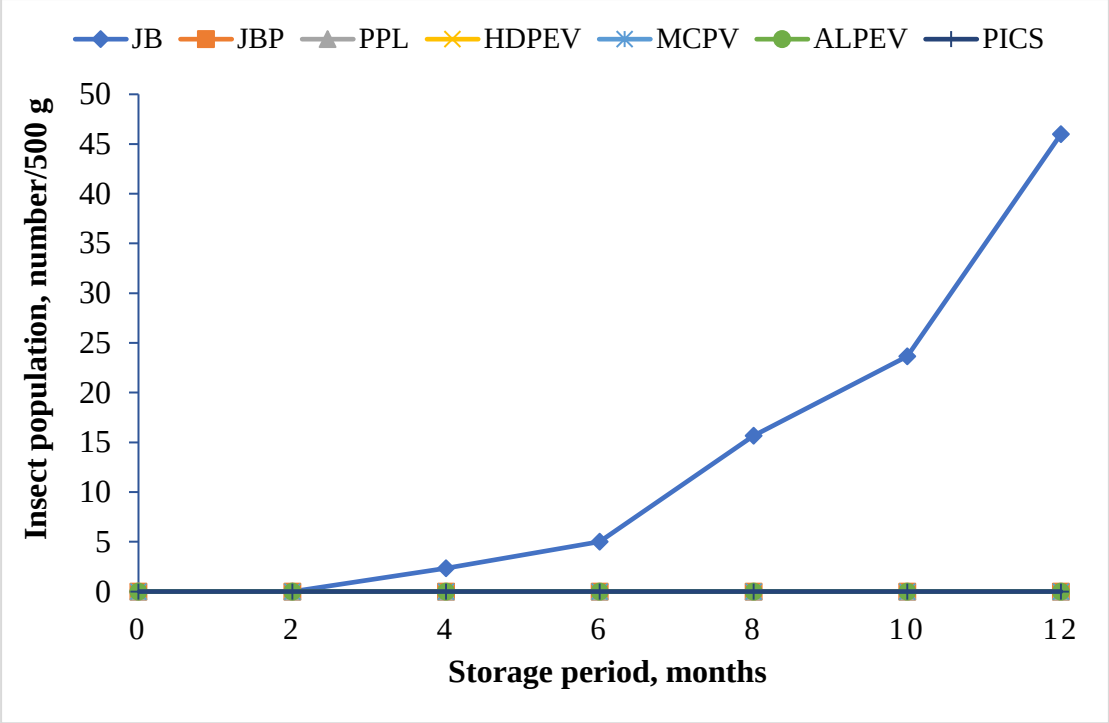


Fig. 4.1 Effect of different packaging materials on insect population of chickpea grain

Similar findings for increase in insect population were also reported by Haile (2015) in chickpea, Martin *et al*. (2015) in wheat and Baributsa *et al*. (2017) in chickpea grain.

4.3.1.2 Grain damage

Grain damage was not observed up to two months of storage period in the chickpea grain. The data regarding effect of various packaging materials on the grain at two months interval are presented in Table 4.5. The data revealed that all the treatments were found significantly superior over JB in terms of grain damage. However, JBP, PPL, HDPEV, MCPV, ALPEV and PICS were found at par with each other during entire storage period.

Table 4.5 Effect of different packaging materials on grain damage (%) of chickpea grain during storage

Treatment	Storage period, Months				
	4	**6**	**8**	**10**	**12**
JB	1.27* (1.2)	1.98* (3.5)	2.96* (7.5)	3.53* (12.0)	5.38* (26.3)
JBP	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
PPL	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
HDPEV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
MCPV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
ALPEV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
PICS	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
S.Em.±	0.064	0.084	0.050	0.057	0.044
C.D. at 5 %	0.194	0.253	0.152	0.172	0.134
C.V. %	14.07	16.28	8.61	8.82	5.7

* Data subjected to square root transformation

Figures in parentheses are original values

It is clearly indicated in Fig. 4.2 that the grain damage in JB increased with increase in storage period. Grain damage increased in the grain might be due to the insect infestation increased during storage. The JB was recorded the highest grain damage (26.33 %) at the end of storage period and thus found susceptible to pulse beetle (Plate 4.1). JBP, PPL, HDPEV, MCPV, ALPEV and PICS treatments were observed free from grain damage during entire storage period.

Similar results were also reported by Sharma *et al*. (2007) in chickpea, Shaw (1998) in green gram Regmi and Dhoj (2013) in chickpea and Basavegowda and Arunkumar (2013) in chickpea.

From the results, it may be concluded that JBP, PPL, HDPEV, MCPV, ALPEV and PICS were found to be the best amongst all treatments which did not contain insect population and grain damage during entire storage period.

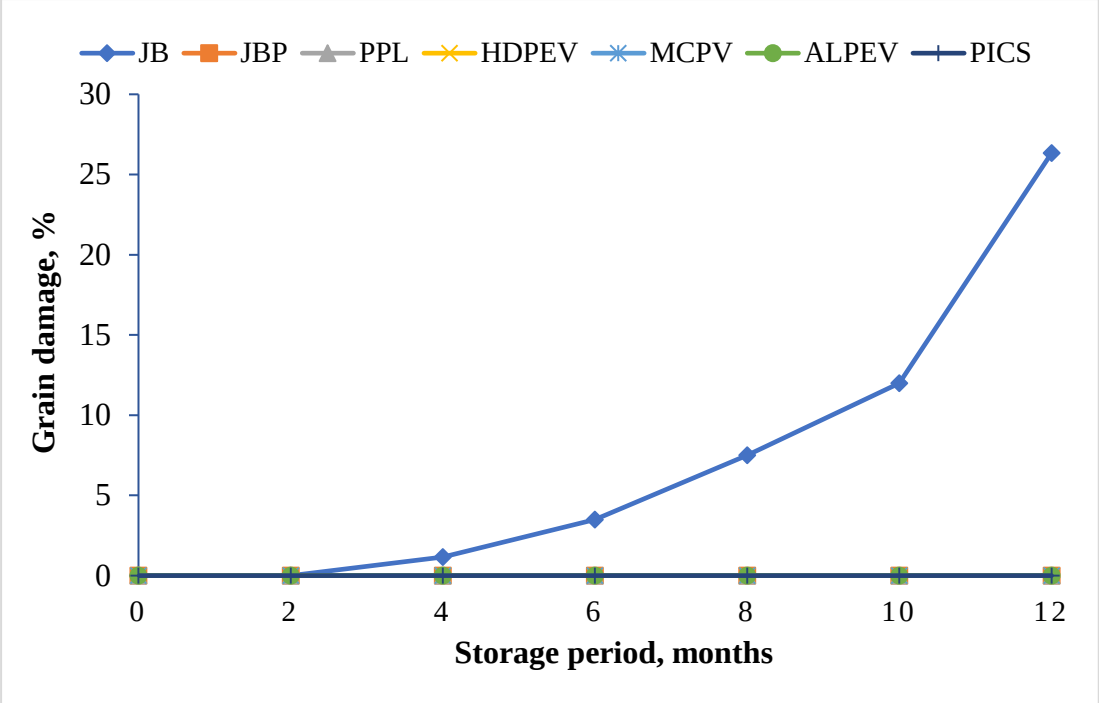


Fig. 4.2 Effect of different packaging materials on grain damage of chickpea grain



Plate 4.1 Insects and damaged chickpea grain

4.3.2 Physico-chemical parameters

The variation in observations of various physico-chemical parameters such as moisture content, weight loss and protein content are presented in following subheads.

4.3.2.1 Moisture content

From the Table 4.6, it can be observed that the effect of different packaging materials on moisture content was found significant during entire storage period. JB resulted significantly highest moisture content up to eight months of storage period. However, it was found at par with JBP on ten and twelve months of storage period. ALPEV was found at par with MCPV, HDPEV and PICS during entire storage period.

Table 4.6 Effect of different packaging materials on moisture content (% w.b.) of chickpea grain during storage

Treatment	Storage period, Months					
	2	4	6	8	10	12
JB	10.75	12.38	10.48	9.69	8.96	8.37
JBP	8.70	10.39	9.31	9.27	8.74	8.23
PPL	8.58	10.12	9.08	8.82	8.52	8.10
HDPEV	7.77	7.84	7.81	7.75	7.70	7.68
MCPV	7.65	7.77	7.74	7.67	7.66	7.64
ALPEV	7.64	7.72	7.71	7.65	7.64	7.62
PICS	7.66	7.80	7.77	7.70	7.67	7.65
S.Em.±	0.103	0.124	0.135	0.067	0.124	0.085
C.D. at 5 %	0.312	0.377	0.408	0.204	0.376	0.257
C.V. %	2.12	2.36	2.72	1.39	2.64	1.86

It is evident from the Fig. 4.3 that moisture content of the grain increased drastically for JB, JBL and PPL up to four months of storage period. However, little variation was observed in other treatments. The increase in moisture content of the grain up to four months of storage period might be due to hygroscopic nature of the grain and increase in RH during monsoon season (Harrington, 1972; Roberts, 1986). Maximum moisture content found in JB on four months of storage might be due to moisture exchange took place in a previous material (Malarkodi, 1997). The moisture content of the grain deceased after four months of storage period for all the treatments. The initial moisture content of chickpea grain was 7.59 % at the time of storage. The maximum moisture content of the chickpea stored in JB, JBL and PPL was found 12.38 %, 10.39 %, and 10.12 %, respectively on four months of storage. Minimum moisture content

was observed in ALPEV followed by MCPV, HDPEV and PICS *i.e.* vacuum packaging and triple layer PICS bags during entire storage. In case of ALPEV, MCPV, HDPEV and PICS, the increase in moisture content of the grain was found little due to their lesser permeability in plastic packaging materials as well as vacuum packaging (Sumathi, 2010). The regression equation of PPL was fitted to a fourth order polynomial. The predicted values were fairly matched with the experimental values.

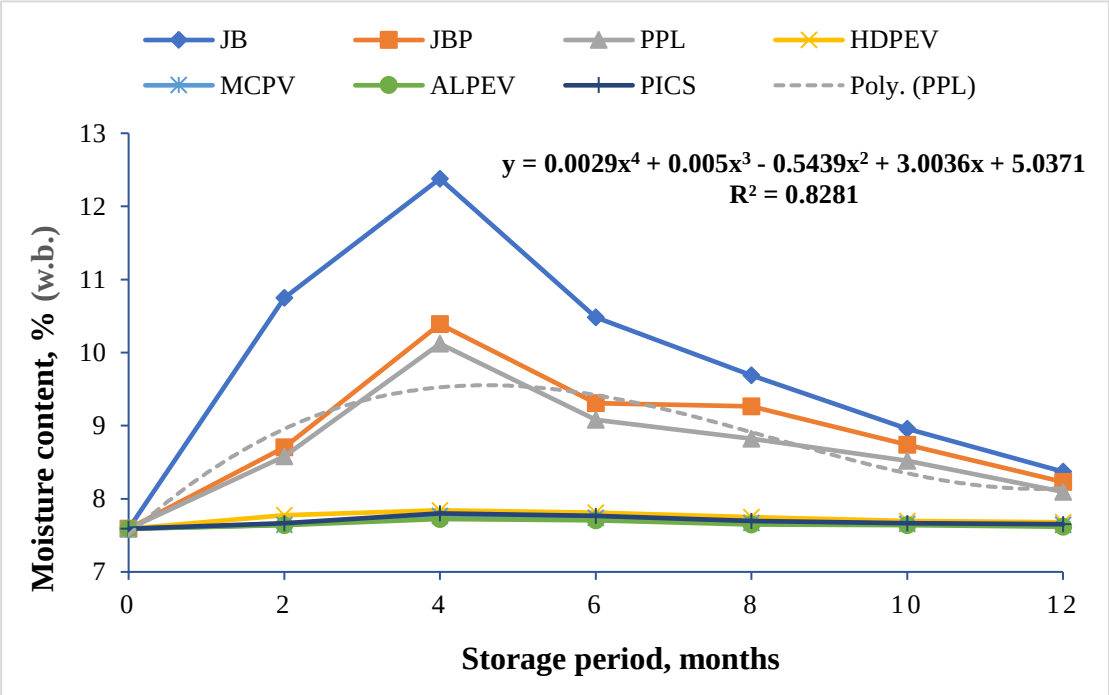


Fig. 4.3 Effect of different packaging materials on moisture content of chickpea grain

The similar results for moisture content were also reported by Asha (2012) in maize, Kurdikeri *et al*. (1995) in maize and Shaw (1998) in green gram during storage.

4.3.2.2 Weight loss

Weight loss was not observed up to two months of storage period in the chickpea grain. The result presented in Table 4.7 shows that JB had significantly highest weight loss. Grain damage in chickpea grain started from four months of storage. However, JBP, PPL, HDPEV, MCPV, ALPEV and PICS were found at par with each other during entire storage period.

Table 4.7 Effect of different packaging materials on weight loss (%) of chickpea grain during storage

Treatment	Storage period, Months				
	4	**6**	**8**	**10**	**12**
JB	0.81* (0.16)	0.99* (0.48)	1.73* (2.49)	2.21* (4.39)	2.83* (7.51)
JBP	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
PPL	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
HDPEV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
MCPV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
ALPEV	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
PICS	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)	0.71* (0.0)
S.Em. ±	0.019	0.016	0.022	0.039	0.017
C.D. at 5 %	0.056	0.049	0.066	0.120	0.050
C.V. %	4.43	3.78	4.44	7.4	2.82

* Data subjected to square root transformation

Figures in parentheses are original values

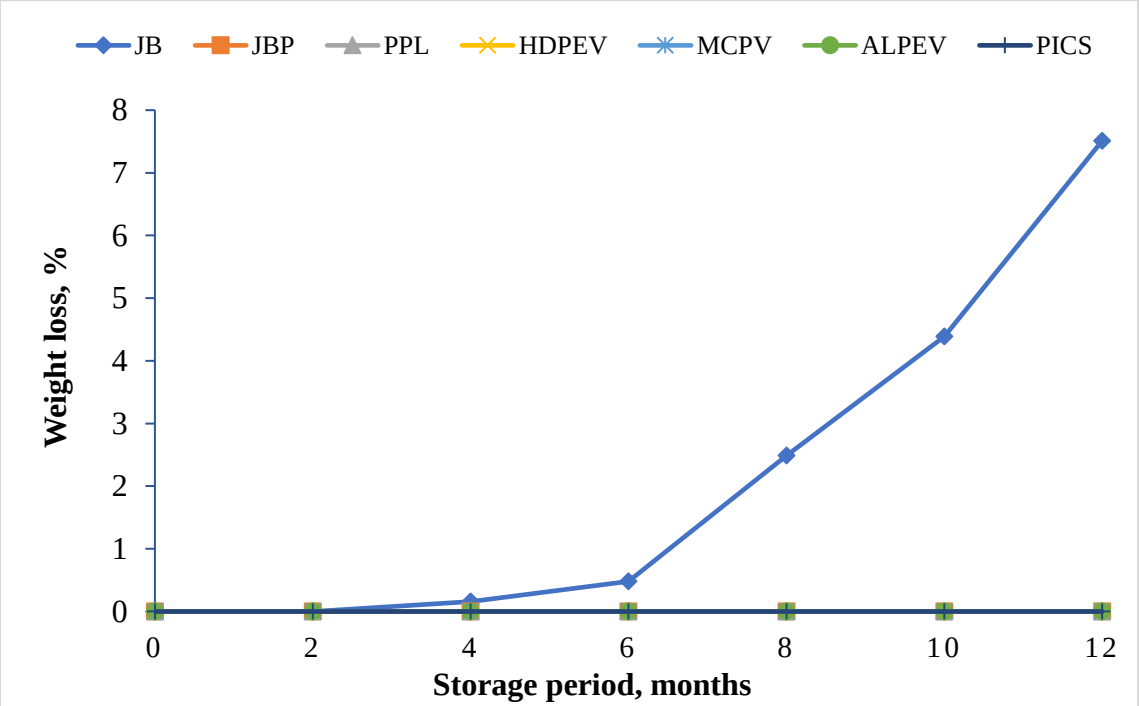


Fig. 4.4 Effect of different packaging materials on weight loss of chickpea grain

It is clearly depicted in Fig. 4.4 that weight loss increased with increase in storage period. It might be due to insect infestation developed in JB. The maximum weight loss was recorded in JB (7.51 %) at the end of storage period. However, pulse beetle restricted by other packaging materials hence no weight loss was observed. These findings are fairly matched with Sudini *et al*. (2015) in groundnut and Khare *et al*. (1972) in chickpea during storage.

4.3.2.3 Protein content

The effect of different packaging materials on protein content of chickpea grain was found non-significant up to eight months of storage period (Table 4.8). JB resulted significantly highest loss in protein content on ten and twelve months of storage period. However, HDPEV was found at par with JBP, PPL, MCPV, ALPEV and PICS during entire storage period.

Table 4.8 Effect of different packaging materials on protein content (%) of chickpea grain during storage

Treatment	Storage period, Months					
	2	**4**	**6**	**8**	**10**	**12**
JB	21.06	20.34	19.01	18.11	17.01	15.32
JBP	21.27	20.42	19.80	18.43	18.26	18.21
PPL	21.47	20.62	19.98	19.06	18.84	18.76
HDPEV	21.89	21.49	20.85	19.46	19.17	19.09
MCPV	21.68	20.82	20.39	19.32	19.07	18.98
ALPEV	21.52	20.73	20.32	19.12	18.92	18.84
PICS	21.35	20.54	19.87	18.71	18.54	18.45
S.Em.±	0.440	0.437	0.494	0.902	0.369	0.602
C.D. at 5 %	NS	NS	NS	NS	1.118	1.826
C.V. %	3.55	3.66	4.26	8.27	3.44	5.72

It is apparent from the Fig. 4.5 that protein content of the chickpea decreased with increase in storage period. The reduction in the protein content might be attributed to oxidation of the amino acids, increase in the respiratory activity and moisture content as a result of deterioration process of the stored seeds (Veraja *et al.*, 2015). The reduction in protein content as insect-pest infestation increased with the increase of

storage period (Chattah *et al*., 2014). The initial protein content was 22.39 % at the time of storage of chickpea grain. Maximum protein content was recorded in HDPEV (19.09 %) followed by MCPV (18.98 %), ALPEV (18.84 %), PPL (18.76 %), PICS (18.45 %) and JBP (18.21 %) at the end of storage period. It was also observed protein content of the grain was found higher in vacuum packed bags than other treatments. Minimum protein content was recorded in JB (15.32 %) at the end of storage period. Vastly decrease in protein content in JB might be due to grain damage by pulse beetle which resulted the loss of chickpea endosperm. The regression equation of HDPEV and PPL were fitted to a first order polynomial. The predicted values were fairly matched with the experimental values.

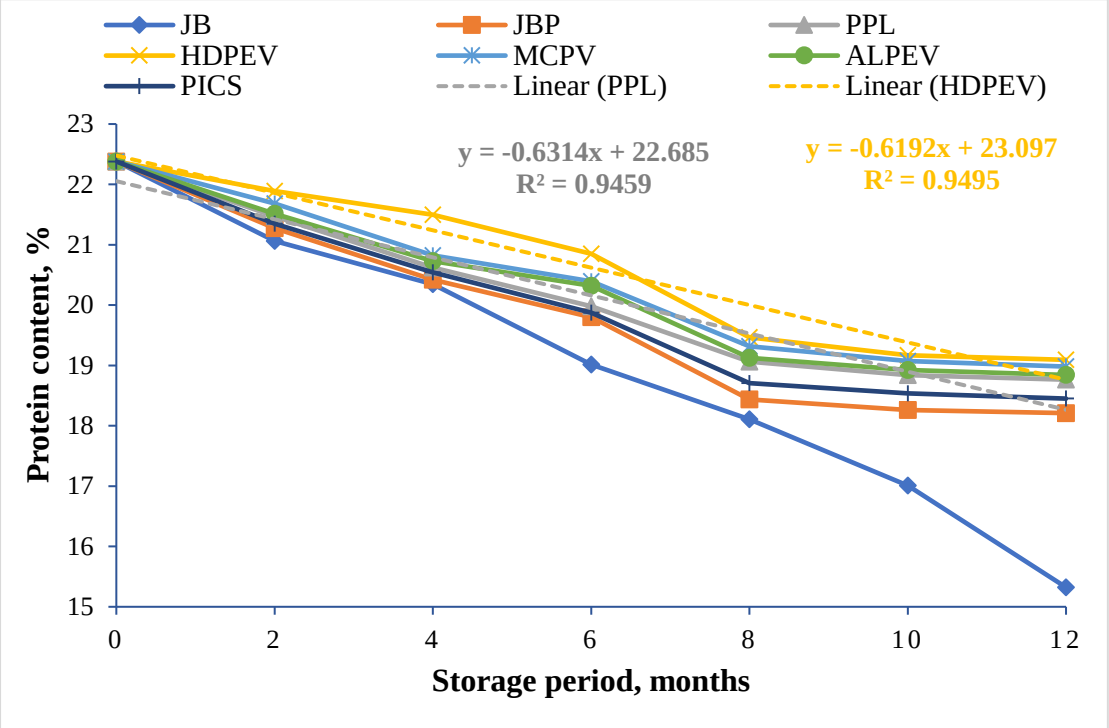


Fig. 4.5 Effect of different packaging materials on protein content of chickpea grain

These results for decrease in protein in the grain are in agreement with those reported by Lawal and Fagbohun (2012) in millet, Shaw (1998) in green gram and Chattah *et al*. (2014) in wheat.

From the results, it may be concluded that JBP, PPL, HDPEV, MCPV, ALPEV and PICS were found to be the best amongst all treatments in terms of weight loss and

protein content. ALPEV, MCPV, HDPEV and PICS were found to be the best amongst all treatments in terms of moisture content.

4.3.4 Cooking quality

4.3.4.1 Cooking time

It is obvious from the Table 4.9 that the effect of different packaging materials on cooking time of chickpea grain was found significant during entire storage period. JB resulted significantly lowest cooking time throughout storage period. However, significantly highest cooking time was found in ALPEV during entire storage period.

Table 4.9 Effect of different packaging materials on cooking time (min) of chickpea grain during storage

Treatment	Storage period, Months					
	2	**4**	**6**	**8**	**10**	**12**
JB	32.00	37.67	39.50	40.17	43.17	47.25
JBP	32.17	38.33	42.17	44.25	49.08	56.17
PPL	32.67	39.08	45.00	49.42	54.00	61.00
HDPEV	33.67	47.50	50.17	55.00	61.33	69.17
MCPV	32.83	48.33	52.00	60.00	65.08	70.83
ALPEV	34.67	50.17	55.17	63.00	72.00	74.67
PICS	32.67	41.83	48.00	53.00	58.33	65.08
S.Em.±	0.244	0.332	0.393	0.570	0.717	0.723
C.D. at 5 %	0.740	1.007	1.193	1.728	2.175	2.194
C.V. %	1.28	1.33	1.44	1.89	2.16	1.97

The effect of different packaging materials on cooking time during storage is shown graphically in Fig. 4.6. The cooking time of the chickpea grain increased with increase in storage period. It might be due to the susceptibility of chickpea grain to develop the hard to cook condition related to both seed coat tannin content and phytic acid level in the cotyledon (Reyes *et al.*, 2000). Reduction in phytic acid levels is related to the reduction in cookability and the development of the hard to cook phenomena in legumes (Bhatty, 1990). The initial cooking time was 30.46 min at the time of storage

of chickpea grain. Minimum cooking time of the grain was observed in JB (47.25 min) at the end of storage period. Maximum cooking time of the grain was recorded in vacuum packed packaging materials *i.e.*, ALPEV (74.67 min) followed by MCPV and HDPEV bags on twelve months of storage. Maximum cooking time was recorded in ALPEV (74.67 min) on twelve months of storage. The regression equation of JB and PPL were fitted to a first order polynomial. The predicted values were fairly matched with the experimental values.

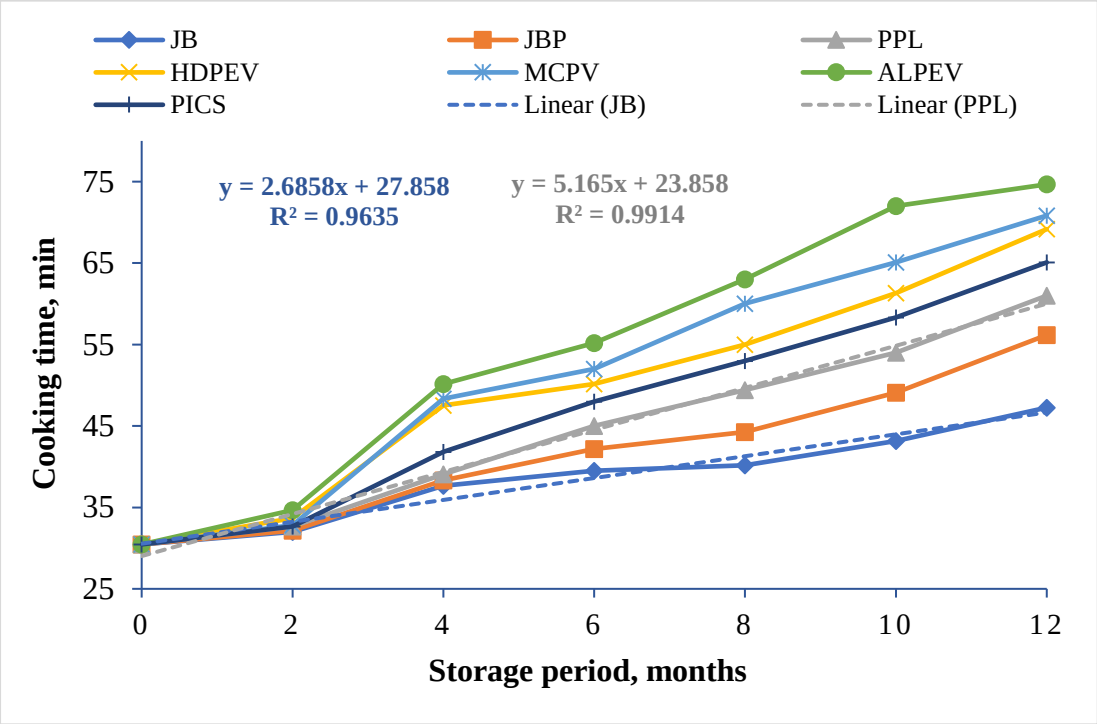


Fig. 4.6 Effect of different packaging materials on cooking time of chickpea grain

From the above study, it may be concluded that JB was found better than other treatments in terms of cooking time of the grain.

4.3.5 Hydration and swelling properties of chickpea grain

The contrast in observations of various hydration and swelling properties *viz.* hydration capacity, hydration index, swelling capacity and swelling index of chickpea grain are presented in following subheads (Plate 4.2).

4.3.5.1 Hydration capacity

The effect of different packaging materials on hydration capacity is presented in Table 4.10. From the table, it can be observed that the effect of different packaging materials on hydration capacity of the chickpea was found significant during entire storage period. PPL resulted significantly highest hydration capacity throughout storage period. However, PPL was found at par with JBP and JB during entire storage period. ALPEV resulted significantly lowest hydration capacity and was found at par with MCPV during entire storage period.

Table 4.10 Effect of different packaging materials on hydration capacity (g/grain) of chickpea grain during storage

Treatment	Storage period, Months					
	2	**4**	**6**	**8**	**10**	**12**
JB	0.248	0.248	0.247	0.244	0.242	0.239
JBP	0.250	0.249	0.247	0.245	0.243	0.239
PPL	0.251	0.250	0.248	0.246	0.244	0.240
HDPEV	0.204	0.180	0.157	0.148	0.142	0.133
MCPV	0.191	0.174	0.145	0.139	0.125	0.120
ALPEV	0.189	0.171	0.142	0.119	0.114	0.110
PICS	0.236	0.201	0.188	0.180	0.176	0.149
S.Em.±	0.004	0.005	0.006	0.008	0.009	0.007
C.D. at 5 %	0.012	0.016	0.019	0.023	0.027	0.021
C.V. %	3.02	4.35	5.48	7.02	8.31	6.7

It is evident from the Fig. 4.7 that hydration capacity of the chickpea decreased with increase in storage period. The initial hydration capacity was 0.256 at the time of storage of chickpea grain. Maximum hydration capacity was observed in PPL (0.240 g/grain) followed by JBP (0.239 g/grain) and JB (0.239 g/grain) at the end of storage period. Hydration capacity in the chickpea stored in PICS and HDPEV was found 0.149 g/grain and 0.133 g/grain, respectively. Minimum hydration capacity was recorded in ALPEV (0.110 g/grain) followed by MCPV (0.120 g/grain) on twelve months of storage period. The regression equation of PPL was fitted to a first order polynomial. The predicted values were fairly matched with the experimental values.

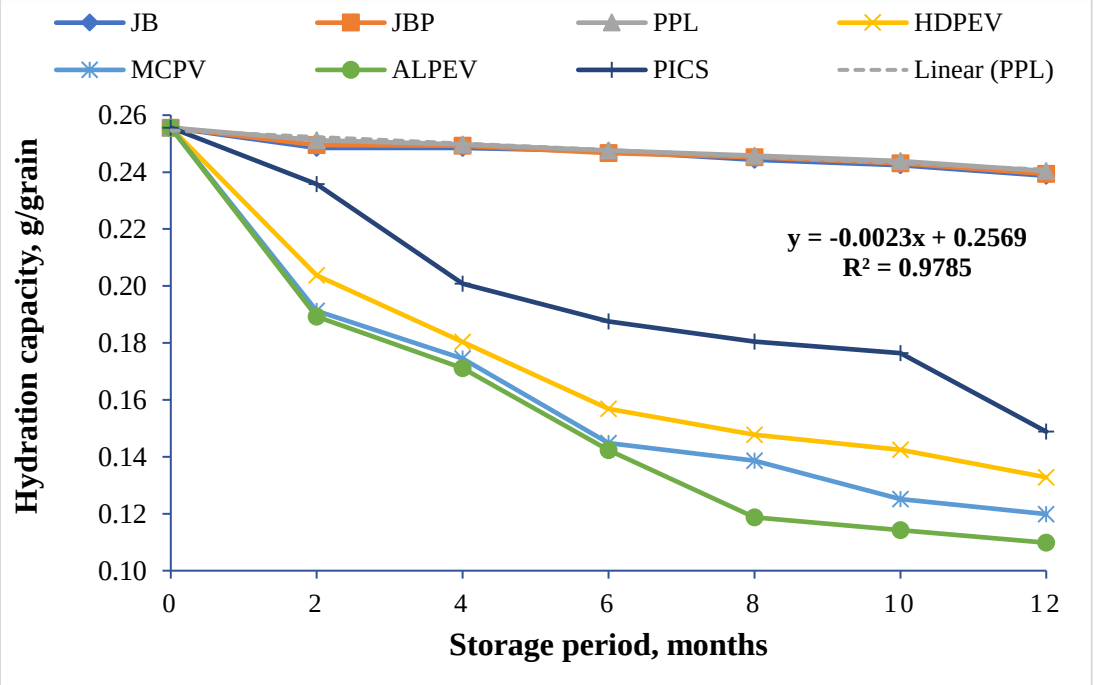


Fig. 4.7 Effect of different packaging materials on hydration capacity of chickpea grain

4.3.5.2 Hydration index

The effect of different packaging materials on hydration index of the chickpea was found significant during entire the storage period (Table 4.11). PPL resulted significantly highest hydration index during entire storage period. However, JBP and JB was found at par with PPL during entire storage period. ALPEV resulted significantly lowermost and it was at par with MCPV during whole storage study.

It is obvious from the Fig. 4.8 that hydration index of chickpea grain declined with advancement of storage period. The initial hydration index was 1.191 at the time of storage of chickpea grain. Maximum hydration index was observed in PPL (0.986) followed by JBP (0.957) and JB (0.945) at the end of storage period. Hydration index of chickpea grain packed in PICS and HDPEV was found 0.667 and 0.593, respectively. Minimum hydration index of the grain was recorded in ALPEV (0.457) followed by MCPV (0.533) on accomplishment of storage period. The regression equation of PPL was fitted to a first order polynomial. The predicted values were fairly matched with the experimental values.

Table 4.11 Effect of different packaging materials on hydration index of chickpea grain during storage

Treatment	Storage period, Months					
	2	**4**	**6**	**8**	**10**	**12**
JB	1.060	1.056	1.040	1.015	0.990	0.945
JBP	1.093	1.069	1.050	1.027	1.001	0.957
PPL	1.127	1.075	1.054	1.039	1.005	0.986
HDPEV	0.863	0.800	0.733	0.655	0.622	0.593
MCPV	0.847	0.788	0.662	0.633	0.611	0.533
ALPEV	0.820	0.778	0.598	0.573	0.508	0.457
PICS	1.052	0.876	0.814	0.776	0.765	0.667
S.Em.±	0.019	0.026	0.022	0.034	0.039	0.029
C.D. at 5 %	0.059	0.077	0.067	0.103	0.119	0.089
C.V. %	3.42	4.80	4.5	7.2	8.64	6.88

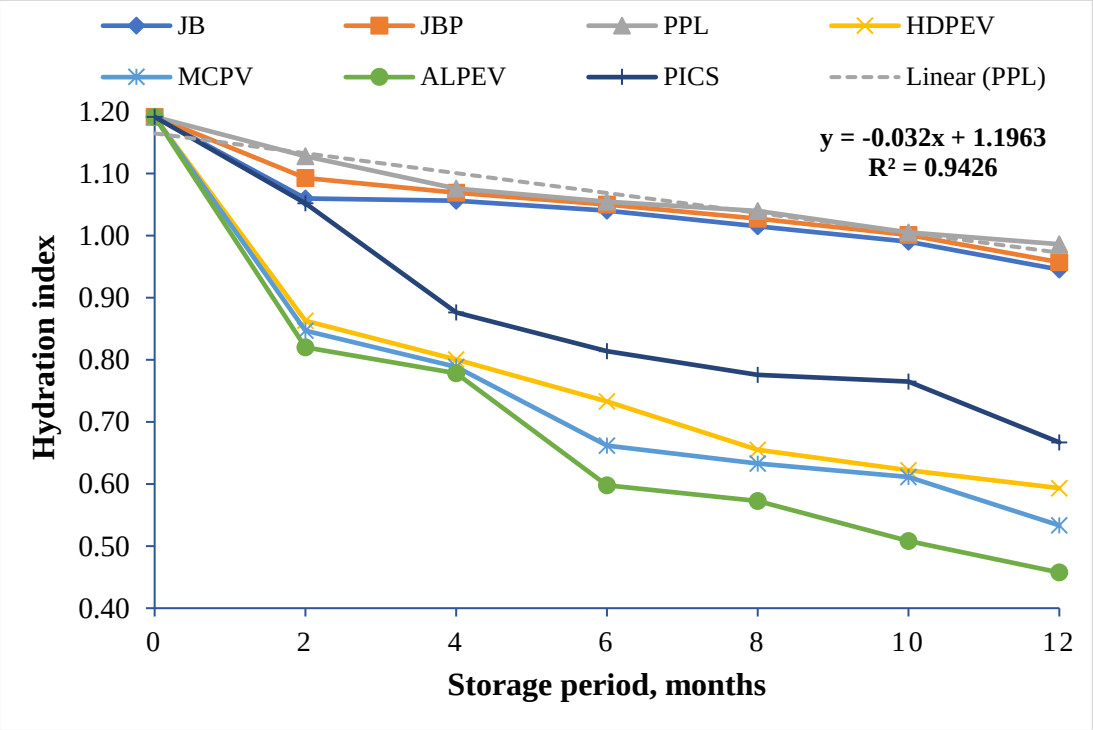


Fig. 4.8 Effect of different packaging materials on hydration index of chickpea grain

4.3.5.3 Swelling capacity

The effect of different packaging materials on swelling capacity of the grain during storage is presented in Table 4.12. It is apparent from the table that effect of different packaging materials on swelling capacity was found significant during entire storage period. PPL resulted significantly highest swelling capacity during entire storage period. However, JBP and JB were found at par with PPL during entire storage study. Swelling capacity of the grain was found minimum for ALPEV and it was at par with MCPV throughout storage period.

Table 4.12 Effect of different packaging materials on swelling capacity (ml/grain) of chickpea grain during storage

Treatment	Storage period, Months					
	2	**4**	**6**	**8**	**10**	**12**
JB	0.270	0.267	0.262	0.258	0.252	0.244
JBP	0.281	0.271	0.265	0.262	0.254	0.246
PPL	0.290	0.277	0.269	0.263	0.256	0.248
HDPEV	0.242	0.198	0.187	0.173	0.157	0.152
MCPV	0.218	0.194	0.183	0.163	0.124	0.119
ALPEV	0.205	0.188	0.172	0.160	0.119	0.117
PICS	0.245	0.222	0.220	0.208	0.183	0.182
S.Em.±	0.009	0.008	0.010	0.009	0.005	0.003
C.D. at 5 %	0.026	0.023	0.030	0.026	0.014	0.009
C.V. %	6.08	5.67	7.66	6.93	4.22	2.79

The effect of different packaging materials on swelling capacity of the grain during storage is shown graphically in Fig. 4.9. It can be observed that swelling capacity of chickpea grain decreased with increase in storage period. The initial swelling capacity was 0.292 ml/grain at the time of storage of chickpea grain. The swelling capacity of chickpea was observed maximum in PPL (0.248 ml/grain) followed by JBP (0.246 ml/grain) and JB (0.244 ml/grain) during storage study of twelve months. Swelling capacity for PICS and HDPEV was found 0.182 ml/grain and 0.152 ml/grain, respectively. The swelling capacity was recorded minimum in ALPEV (0.117 ml/grain) followed by MCPV (0.119 ml/grain) during entire storage study. The regression

equation of PPL was fitted to a first order polynomial. The predicted values were fairly matched with the experimental values.

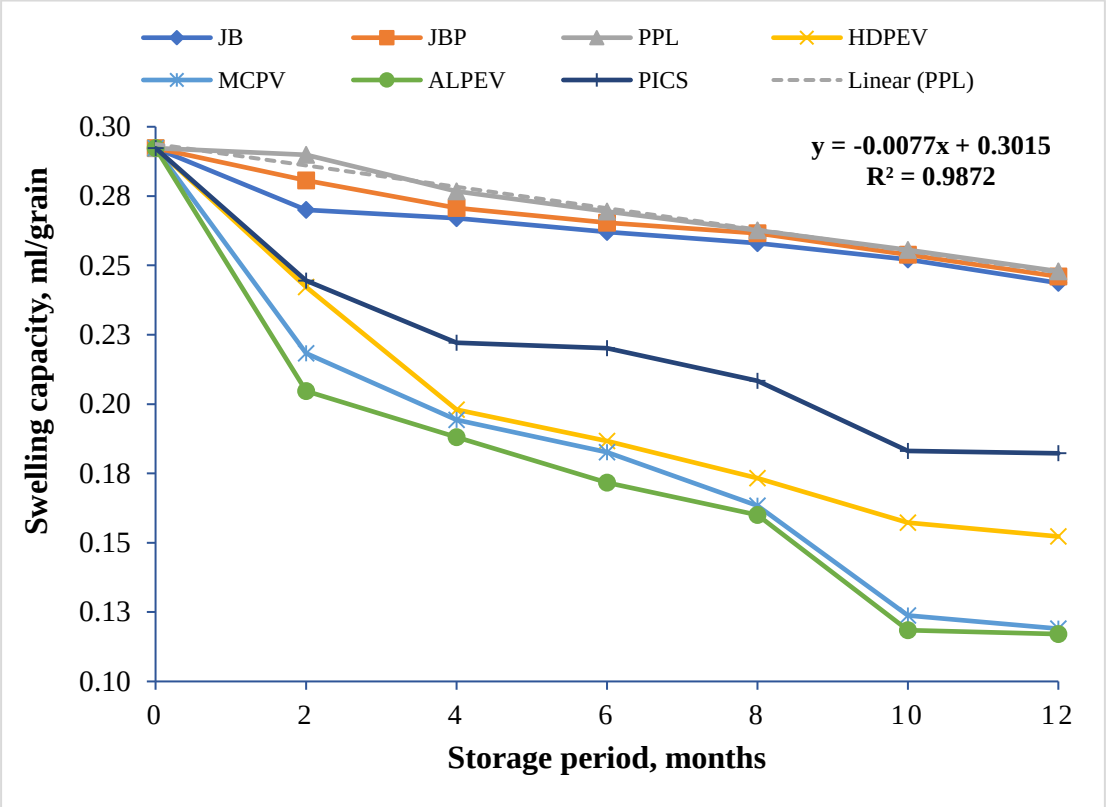


Fig. 4.9 Effect of different packaging materials on swelling capacity of chickpea grain

4.3.5.4 Swelling index

The effect of different packaging materials on swelling index of chickpea during storage is presented in Table 4.13. From the table, it can be observed that the effect of different packaging materials on swelling index of the chickpea was found significant during entire storage period. PPL resulted significantly highest swelling index throughout storage period. JBP and JB was found at par with PPL during entire storage period. However, ALPEV resulted significantly lowermost and it was found at par with MCPV during whole storage study.

Table 4.13 Effect of different packaging materials on swelling index of chickpea grain during storage

Treatment	Storage period, Months					
	2	**4**	**6**	**8**	**10**	**12**
JB	1.525	1.500	1.485	1.428	1.417	1.340
JBP	1.576	1.537	1.514	1.468	1.449	1.386
PPL	1.636	1.569	1.539	1.485	1.460	1.446
HDPEV	1.375	1.245	1.105	1.023	0.896	0.861
MCPV	1.351	1.150	1.042	0.962	0.737	0.685
ALPEV	1.333	1.138	1.020	0.961	0.687	0.667
PICS	1.382	1.247	1.190	1.152	1.121	1.044
S.Em.±	0.061	0.070	0.026	0.059	0.039	0.025
C.D. at 5 %	0.184	0.212	0.079	0.179	0.120	0.075
C.V. %	7.240	9.040	3.550	8.440	6.150	4.020

Swelling index of chickpea grain stored in various packaging materials decreased with increase in storage period (Fig. 4.10). The initial swelling index was 1.680 at the time of storage of chickpea grain. Maximum swelling index was observed in PPL (1.446) at the end of storage period. Swelling index of the grain stored in JBP, JB, PICS and HDPEV was found 1.386, 1.340, 1.044 and 0.861, respectively at the end of storage. Minimum swelling index was recorded in ALPEV (0.667) followed by MCPV (0.685) on accomplishment of storage period. The regression equation of PPL was fitted to a first order polynomial. The predicted values were fairly matched with the experimental values.

Hydration and swelling properties of the grain was found lower in vacuum packed packaging materials like ALPEV, MCPV and HDPEV bags than without vacuum packed packaging materials on twelve months of storage.

The results for the change in hydration and swelling properties with the storage period might be due to formation of structural change and harder texture of pulse grain during storage which rendered the cells resistant to water absorption Bressani (1993) and Kilmer *et al.* (1994).

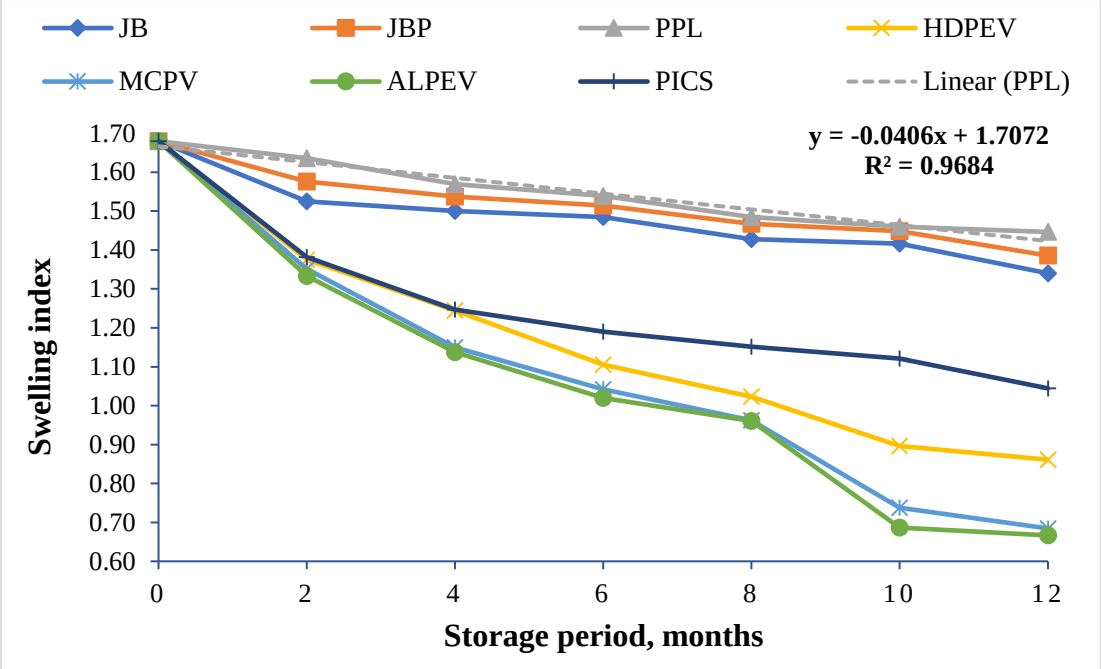


Fig. 4.10 Effect of different packaging materials on swelling index of chickpea grain

From the above study, it may be concluded that treatments PPL, JBP and JB were observed to be best among all treatments with minimum changes in hydration and swelling properties of the grain.

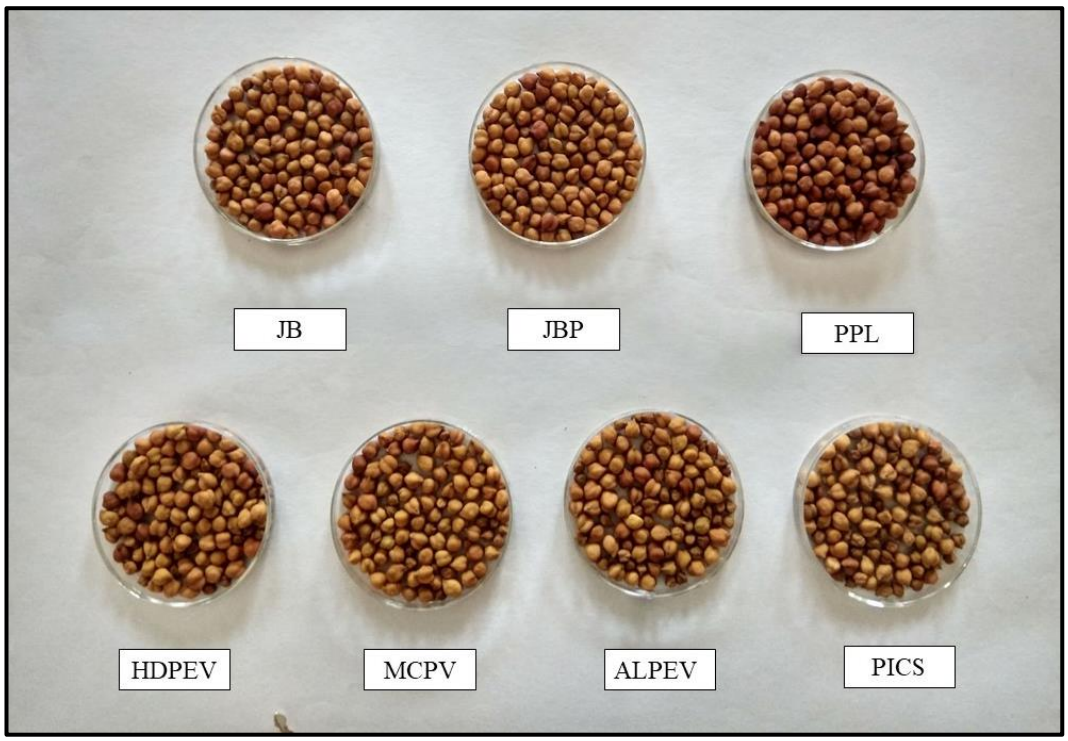


Plate 4.2 Hydration and swelling properties of chickpea grains

4.3.6 Seed quality

The effect of various packaging materials on seed quality aforesaid germination and seed vigour index is reported in following sub-heads.

4.3.6.1 Germination

From the Table 4.14, it is revealed that the effect of different packaging materials on germination of the chickpea grain was found significant on eight, ten and twelve months of storage period. PPL had significantly highest germination during on eight, ten and twelve months of storage period. However, JBP was found at par with PPL during on eight, ten and twelve months of storage period. JB was found significantly lowest for germination on eight, ten and twelve months of storage period.

Table 4.14 Effect of different packaging materials on germination (%) of chickpea grain during storage

Treatment	Storage period, Months					
	2	**4**	**6**	**8**	**10**	**12**
JB	94.00	92.67	91.33	85.33	79.33	70.67
JBP	94.67	93.33	92.00	91.33	90.67	89.33
PPL	96.67	94.67	93.33	92.67	92.00	91.33
HDPEV	94.00	92.67	91.33	89.33	87.33	86.00
MCPV	93.33	92.00	91.33	87.33	86.00	85.33
ALPEV	93.33	91.33	90.67	86.67	82.67	82.00
PICS	94.67	92.67	92.00	90.00	88.67	87.33
S.Em.±	0.71	0.87	0.56	0.76	0.94	1.13
C.D. at 5 %	NS	NS	NS	2.29	2.86	3.42
C.V. %	1.31	1.63	1.06	1.47	1.88	2.31

The effect of different packaging materials on germination during storage is graphically shown in Fig. 4.11. The initial germination of the grain was observed 97.33 % before packaging and storage. The germination of chickpea grain reduced with increase in storage period might be attributed to insect infestation and grain damage. The decline in germination percentage over the storage period irrespective of treatment was due to ageing effect leading to depletion of food reserves, seed deterioration,

fluctuating temperature, relative humidity and grain moisture content as influenced by storage packaging materials (Kumar *et al*., 2007). Maximum germination was recorded in PPL (91.33 %) followed by JBP (89.33 %) and PICS (87.33 %) at the end of storage period. Germination of the grain for HDPEV, MCPV and ALPEV was found 86.00 %, 85.33 % and 82.00%, respectively. Minimum germination was recorded in JB (70.67 %) at the end of storage period (Plate 4.3). The regression equation of PPL was fitted to a first order polynomial. The predicted values were fairly matched with the experimental values.

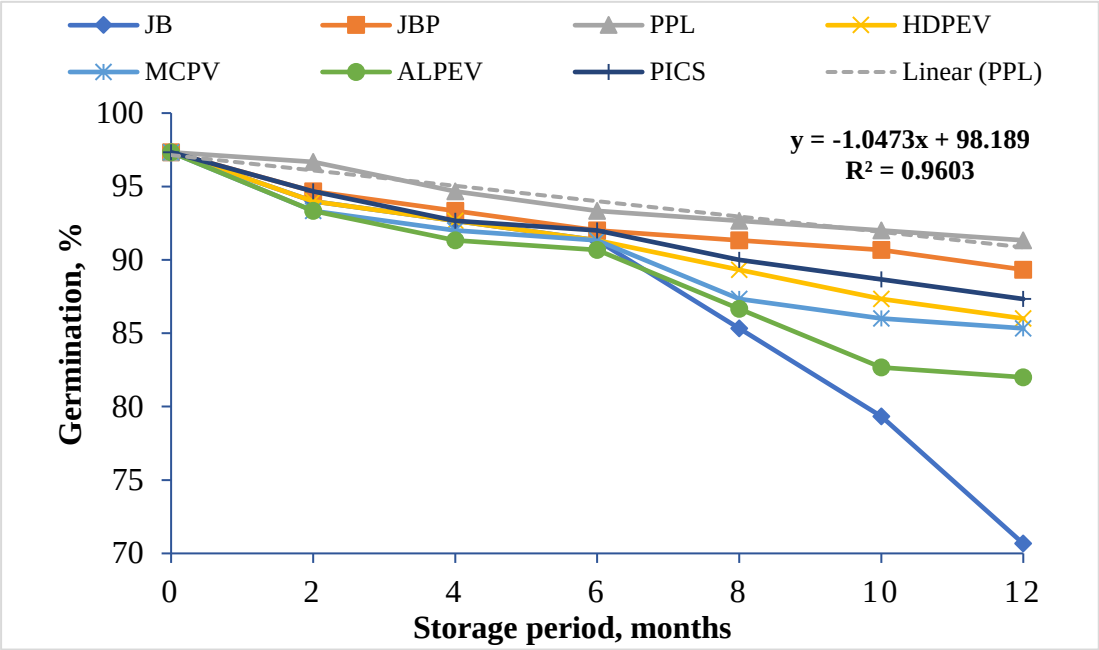


Fig. 4.11 Effect of different packaging materials on germination of chickpea grain

The decrease in germination during storage was also reported by Mookherjee *et al*. (1970) in chickpea, and Jagtap (2006) in sorghum.

4.3.6.2 Seed vigour index

Seed vigour index as influenced by different packaging materials during storage period are presented in Table 4.15. The initial seed vigour index was 1458 at the time of storage of chickpea grain. Study revealed that the effect of packaging materials on seed vigour index were found significant on eight, ten and twelve months of storage period. PPL resulted significantly highest seed vigour index on eight, ten and twelve months of storage period. However, JBP was found at par with PPL during on eight, ten and twelve months of storage period. JB had significantly lowest seed vigour index on eight, ten and twelve months of storage period.



JB



JBP



PPL



HDPEV



MCPV



ALPEV



PICS

Plate 4.3 Germination of the grain of different packaging materials

Table 4.15 Effect of different packaging materials on seed vigour index of chickpea grain during storage

Treatment	Storage period, Months					
	2	**4**	**6**	**8**	**10**	**12**
JB	1317	1299	1236	1139	965	829
JBP	1437	1380	1353	1219	1091	1056
PPL	1455	1404	1381	1244	1173	1114
HDPEV	1276	1270	1233	1096	967	935
MCPV	1269	1254	1229	1050	906	869
ALPEV	1249	1246	1204	996	872	846
PICS	1390	1321	1301	1189	1053	996
S.Em.±	55.199	58.490	68.018	49.048	57.504	37.189
C.D. at 5 %	NS	NS	NS	148.786	174.436	112.813
C.V. %	7.13	7.73	9.23	7.5	9.92	6.79

Seed vigour index declined with increase in storage period irrespective of packaging materials (Fig. 4.12). It might be due to changes in free radical scavenging enzymes, increase in free radical production, degradation of protein and DNA, increase in amino acid pool for reduction in vigour and viability during ageing (McDonald, 2004). Significantly highest seed vigour index was recorded in chickpea grain stored in PPL (1114) followed by JBP (1056) at the end of storage period. Seed vigour index for PICS, HDPEV, MCPV and ALPEV was found 996, 935, 869 and 846, respectively. Minimum seed vigour index was recorded by JB (829) at the end of twelve months of storage. The regression equation of PPL was fitted to a first order polynomial. The predicted values were fairly matched with the experimental values.

The results of present study are in agreement with Chormule *et al.* (2015) in chickpea, Meena *et al.* (2017a) in cotton and Naguib *et al.* (2011) in wheat.

Based on the results of the above study, it may be concluded that the treatments PPL and JBP were observed to be better among all treatments with maximum seed quality of the grain *viz.*, germination and seed vigour index during the storage period.

Seed quality of the grain was found lower in vacuum packed packaging materials like ALPEV, MCPV and HDPEV bags than without vacuum packed bags on twelve months of storage. It might be due to anaerobic respiration within the package and low hydration and swelling properties of the grain.

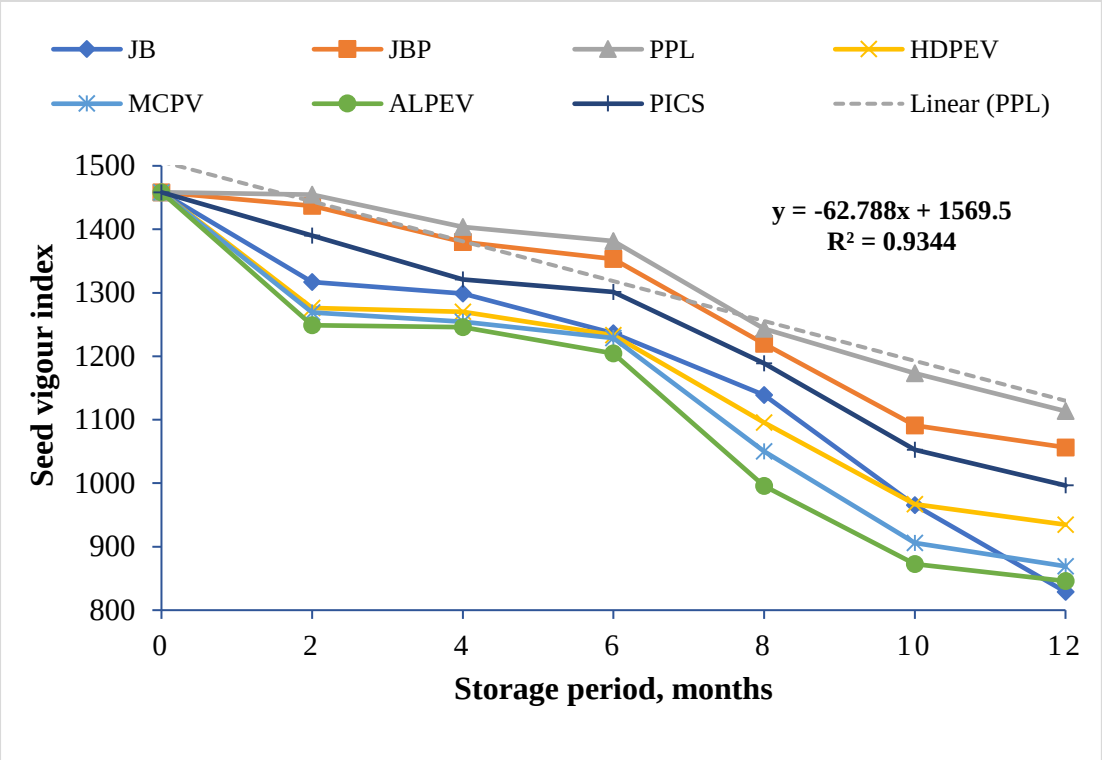


Fig. 4.12 Effect of different packaging materials on seed vigour index of chickpea grain

Considering the overall aspects of the study, it may be concluded that PPL was observed to be best packaging material amongst all treatments with minimum change in entomological and physico-chemical parameters, cooking quality, hydration and swelling properties and seed quality of chickpea grain for twelve months of storage. Cooking quality, hydration and swelling properties and seed quality of the grain was found lower in vacuum packed materials than without vacuum packed bags on twelve months of storage.

Summary and Conclusions

CHAPTER V

SUMMARY AND CONCLUSIONS

India is the largest chickpea (*Cicer arietinum* L.) producing country accounting for 72% of the global chickpea production. Chickpea is a good source of carbohydrates, important vitamins and minerals. It is a major and cheap source of protein for millions of vegetarians in the developing countries. Chickpea is predominantly consumed in the form of whole grain, dhal, flour, sprouted grain, green or matured dry seeds and is used in the preparation of a variety of snacks, sweets and condiments.

Pulses are more difficult to store than cereals and suffer much greater damage from insects and microorganisms. The pulse beetle and bruchids are mostly found during the storage of chickpea and reduces the market value of seed, germination percent and nutrition value. Many synthetic insecticides have been found effective against this pest, but are hazardous, due to their residual effect in the food. This adverse effect of insecticides need diversified efforts for evolving more convenient, safer and alternative methods which are simple, safe and convenient to minimize the losses of chickpea.

The experiment was consisting of packaging and storage of chickpea grain in the different packaging materials for the period of twelve months. The freshly harvested and fully matured chickpea grain (*GJG-3)* was procured from the Agricultural Research Station, Dhari, Junagadh Agricultural University. The experiment was carried out in the Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh during the year 2017-18. The grain was cleaned, graded and sorted manually to remove extraneous materials such as dust, dirt, stones, chaff, immature grains, insect infested and damaged grains. The grain was dried by sun drying to obtain optimum final moisture content 7.5-7.6 % (w.b.) for safe storage.

Cleaned and dried grains were packed in different packaging materials viz., jute bag (control), polyethylene lined jute bag, polypropylene (PP) woven laminated bag, high density polyethylene (HDPE) bag, multilayer coextruded plastic bag, polyethylene

laminated aluminium foil bag, perdue improve crop storage (PICS) bag with 5.0 kg sample size.

The jute bags, polyethylene lined jute bags and PP woven laminated bags were packed and sewed by portable stitching machine. For PICS bag packaging, the grains were filled and packed in inner double layer HDPE bags of PP bags. The vacuum packaging machine was used for vacuum packaging (700 mm Hg) and sealing of the grain of HDPE bags, multilayer coextruded plastic bags and polyethylene laminated aluminium foil bags.

All the bags were stored at room temperature (13.2 - 38.5 °C, 18.8 - 91.1 % RH) for twelve months on platform in the laboratory. The proximate compositions were determined before packaging. The environmental parameters like temperature and relative humidity were recorded daily at room conditions during storage. Entomological parameters *viz*., insect population and grain damage and physico-chemical properties like moisture content, weight loss and protein content cooking quality in term of cooking time, hydration and swelling properties *viz*., hydration capacity and hydration index and seed quality such as germination and seed vigour index of chickpea grain were analysed at two months interval during twelve months of storage. The results were statistically analyzed by Completely Randomized Design with three replications at 5 per cent level of significance.

The following conclusions were drawn from the present investigation:

1. The initial proximate composition of chickpea (*GJG-3*) grain *viz.*, moisture content (w.b.), protein, carbohydrate, fat, crude fibre and total ash of chickpea grain was found to be 7.59 %, 22.39 %, 61.76 %, 3.56 %, 1.26 % and 3.20 %, respectively.
2. The insect population (46 numbers/500 g), grain damage (26.33 %) and weight loss (7.51 %) was found only in chickpea grain stored in jute bag at the end of twelve months of storage period.
3. Maximum moisture content (12.38 %) of the grain was recorded in jute bag followed by polyethylene lined jute bag and PP woven laminated bag on four months (August) of storage period then it decreased during storage. However, little variation was observed in other treatments. Minimum moisture content was

observed in polyethylene laminated aluminium foil bag followed by multilayer coextruded plastic bag, HDPE bag and PICS during entire storage period.

4. Maximum protein content in the grain was recorded in HDPE bag (19.09 %) and it was at par with polyethylene lined jute bag, PP woven laminated bag, multilayer coextruded plastic bag, polyethylene laminated aluminium foil bag and PICS during entire storage period. Minimum protein content in the grain was found in jute bag (15.32 %) at the end of storage period.
5. Minimum cooking time of the grain was observed in jute bag (47.25 min) and maximum cooking time was recorded in vacuum packed materials i.e., polyethylene laminated aluminium foil bag (74.67 min) followed by multilayer coextruded plastic bag and HDPE bag on twelve months of storage.
6. Hydration capacity (0.240 g/grain), hydration index (0.986), swelling capacity (0.248 ml/grain) and swelling index (1.446) was found maximum in PP woven laminated bag at the end of the storage. Hydration and swelling properties of the grain was found lower in vacuum packed materials like polyethylene laminated aluminium foil bag, multilayer coextruded plastic bag and HDPE bag than other treatments.
7. Maximum germination (91.33 %) and seed vigour index (1114) was recorded in chickpea grain stored in PP woven laminated bag at the end of storage period. Seed qualities like germination and vigour index of the grain was found lower in vacuum packed materials than without vacuum packed bags on twelve months of storage.
8. Considering the overall aspects of the study, it may be concluded that PP woven laminated bag was observed to be best packaging material amongst all treatments with minimum change in entomological and physico-chemical parameters, cooking quality, hydration and swelling properties and seed quality of chickpea grain for twelve months of storage.

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Appendices

Appendix A

The technical specification of vacuum packaging machine

Equipment	Specification
Vacuum packaging machine with inert gas flushing Model: Single chamber Make: Packmech Engineers, Ahmedabad	Chamber size: 0.45 x 0.43 x 0.17 m Sealing bar length: 420 mm No. of sealbar: 4 Vacuum pump: 10 m^3/h Weight: 60 kg Power consumption: 600 watt Power supply: 230 V, 1 phase, 50/60 Hz