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Final Report

on

Development of Protocols for Shelf Life, Safe Storage, Milling Outturn and Indicative Norms for Procurement of Major Pulses

Submitted to

Department of Consumer Affairs
Ministry of Consumer Affairs, Food and Public Distribution, Government of India

ICAR-CIPHET

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1. INTRODUCTION

Pulses are the edible seeds of legumes like pigeon pea, black gram, green gram, lentils, beans, peas and chickpeas. Many early civilizations developed food products from pulses for protein and also combined with a cereal crop to provide energy. Pulses are the vital part of the Indian diet, contain 20-25% protein by weight, which is double the protein content of wheat and three times that of rice. It is major source of lysine rich protein, which is supplementary to cereal based proteins rich in methionine. Dietary protein sources should contain cereals (55%), legumes (27%), and livestock produce (18%) (NIN, 2011). Mixed cereal and pulse based diet provides balanced intake of essential amino acids.

India is largest producer and consumer of pulses in the world accounting for 36% of the world area and 26% of the world production of pulses. Chickpea, pigeon pea, black gram, green gram and lentil are important pulse crops contributing about 48.11%, 16.89%, 9.03%, 10.89%, and 4.77%, respectively (DoES, DACFW, 2019-2020) to the total production of pulses in the country. The domestic demand and consumption, however, is much higher than production. The demand is price sensitive and generally picks up when the price of vegetables are higher. The demand of pulses is also increasing due to increasing consumption of commercially available pulse based processed food products. The demand projections indicated that around 30 million tonnes of pulses is required in our country while pulse production is limited to about 23 MT (DoES, DACFW, 2019-2020).

Dal, also written as *dhal*, is a processed product of pulses, which have been stripped of their outer hulls and split. Although dal generally refers to split pulses, whole pulses are known as *sabut* and split pulses as *dhuli dals*. Pulse milling is an important agro-based industry, which is unique and indigenous to India. Dry whole seeds of pulses possess a fibrous seed coat, or testa (husk, hull, or skin). The most beneficial effect of dehulling is the reduction of cooking time in terms of removing the impermeable seed coat of pulses, which hinder water uptake during cooking (Vishwakarma et al., 2017). Dehulling of a pulse is intended to improve digestibility and palatability, but as happens with the milling of whole grains into refined grains, hull removal affects the overall nutritional quality by way of reducing the dietary fibre, vitamins and minerals. Pulses with their intact outer hull are also quite popular in India and Pakistan as the main cuisine.

The estimated harvest and post-harvest losses in pulses ranged from 6.36% (pigeon pea) to 8.41% (chick pea) in India (ICAR-CIPHET report, 2015). Losses were found higher in major farm operations such as harvesting and threshing. Delayed harvest due to unseasonal rain may be the main concern of harvest losses. In threshing, use of high capacity wheat thresher resulted in high loss. Pulse storage losses at godowns have increased significantly compared to last decade because storage was not usually done. Proper storage management of pulses therefore needs to be practiced to further curtail the post-harvest loss of pulses.

Pulses are more sensitive to storage conditions than cereals. High temperature, high relative humidity, high seed moisture content, light exposure and an extended storage period have all been found to adversely affect the quality of pulses during storage. These factors may cause colour darkening and hard-to-cook defect in pulses. The hard-to-cook defect is characterized by increased energy requirements for cooking, poor palatability and reduced quality of protein. Colour darkening, especially in faba beans, decreases their market price and acceptability to the consumer.

Grain handling and storage conditions for pulses are important for insect control and grain quality. There is a range of insects that attack pulses during storage. Pea weevil (*Bruchus pisorum*) is the most serious amongst them. It completes its life cycle inside the field pea while in storage sometimes completely hollowing out the seed. The drugstore beetle (*Stegobium paniceum*) and the cow pea weevil (*Callosobruchus spp*) are other insects that have been detected in long term storage. Both of these have caused substantial damage during the storage period. Poor handling and storage of pulses will also adversely affect the grain kept for seed purpose.

Justification for the current study

- Creation of buffer stock requires huge investment by the government agencies with infrastructural support. Improvement in post-harvest management practices would prevent the post-harvest losses of this valuable produce, which is important for food and nutritional security.
- Contrary to the food grains, pulses are vulnerable to the attack of storage insects and pests. Attack of bruchids, particularly in high humidity conditions, can cause severe loss (sometimes ≥40% loss within one month). Thus implementation of precise storage management practices is essential.
- Need of storage of raw pulses and milled pulses as *dal* are entirely different. In general *dal* is less vulnerable to attack of insects and pests during storage.
- Moisture content plays very important role in storage of pulses. In fact pulses can be stored safely below 12% moisture content for about one year by adopting good management practices, while the optimum moisture content for milling of pulses is 10%.

- Continuous change in grain moisture content is a major concern for agencies involved in long-term storage. In general the gain or loss due to moisture content does not quantify the losses due to biotic and abiotic factors. Thus, the norms for release of pulses should be based on reliable standards (dry matter weight ± moisture gain/ loss - storage losses) so that the losses can be quantified with storage period.
- The type of bags used for packaging may affect the fumigation and aeration practices. Therefore, the type of bag to be used for packaging of pulses as well as *dal* should be identified based on scientific studies.
- The environmental conditions in different parts of India are different (temperate to humid) and, therefore, the storage management practices will be location specific and can be recommended with long term location specific storage studies.
- Quality standards of *dal* are primarily based on admixture, foreign matter, infestation level, and moisture content. Several other parameters, such as presence of husk patches on cotyledons, broken percentage and scouring level of cotyledons during milling, are also important to decide the market value of *dal*. These quality parameters may vary in bulk storage, hence need to be studied.
- Milling outturn ratio mainly depends upon process and machine parameters, storage duration and variety of pulse. Therefore, the standards for milling outturn ratio should be based on a scientifically designed study with uniform process/ machine parameters and calculation methods. The relationship between storage period and milling outturn ratio should be clearly defined.
- Recovery of *dal* during milling of pulses and their quality depends mainly upon the quality of raw material. Highly efficient processing machines and processes cannot improve the quality. Therefore the indicative norms for procurement of pulses need to be studied.

Objectives

1. To develop pulse and *dal* storage management practices norms for different regions of India.
2. To evaluate the effect of storage conditions on shelf life, milling outturn ratio and *dal* quality.
3. To articulate standards for milling outturn and their relation with storage period of selected pulses.
4. To identify indicative norms for procurement of selected pulses for buffer stock management in present infrastructure.

2. DATA COLLECTION PROCEDURES

The pulse production in India has increased substantially since last five years, even then it is insufficient to fulfil the domestic demand for pulses. Import of pulses was increasing every year due to increase in domestic demand of the country. India is importing about 4-5 million tonnes of pulses annually, may be one of the reason of higher pulse prices in the Indian market. Import of pulses was increasing every year and about 4-5 million tonnes of pulses are being imported annually. Recent break-through in pulse production was achieved due to development of Government support to farmers, improved varieties and favourable weather conditions. Further, the Government of India decided to create buffer stock for pulses with substantial support to the farmers in the form of increase in minimum support prices of pulses. The government also decided to create a buffer stock of 2 million tonnes of pulses. These initiatives resulted into stable prices of pulses with insured market for the farmers for their produce. National Agricultural Cooperative Marketing Federation (NAFED), Metals and Minerals Trading Corporation of India (MMTC) are involved in procurement of pulses, while Central Warehousing Corporation (CWC), State Warehousing Corporation (SWC), and Food Corporation of India (FCI) provided infrastructure for storage and distribution of pulses. The storage of pulses is done at more than 400 locations in different part of India.

Procurement of pulses at large scale from farmers for buffer stock may lead to quality issues and low recovery in long-term storage and milling outturn. Storage of pulses is entirely different from food grains storage due to the requirement of different environmental conditions and management practices. Therefore the storage management practices for bulk storage in the godowns should be suggested to avoid losses during storage. Several studies have shown that milling outturn is greatly affected by variety, storage duration, and storage conditions. Dynamic storage of pulses involves huge investment in procurement, handling, transportation, storage, milling, and further distribution. Thus, it becomes essential to have norms for procurement, storage and milling outturn ratio for best possible management of pulses in India.

This section describes the definition of milling outturn, storage loss, assumptions and considerations, commodities selected, schedules used for the data recording, type of data recorded, data collection procedures, and monitoring of the study. In this study, the pulses stored in CWC/ SWC/ Private Warehouses located in different parts of India and samples were taken at the site. Further, pulses and dal were stored at five study locations to record the variations in milling outturn, infestation, fumigation schedule, and changes in other quality parameters with storage period. All data, such as moisture content, temperature, relative humidity, etc. were recorded using the standard procedures. Altogether 08 Institutions (Study Centres) recorded the data as per the data collection schedules developed specifically for this study (*Annexure-I*).

2.1 Pulses Covered

The scope of this study was limited to the following pulses and their dals:

1. Chick pea (*Chana or Bengal gram*) (*Cicer arietinum* L.)
2. Pigeon pea (*Arhar/Tur*) (*Cajanus cajan* L.)
3. Black gram (*Urad*) (*Phaseolus mungo* L.)
4. Green gram (*Moong*) (*Phaseolus aureous* Roxb.)
5. Lentil (*Masoor*) (*Lens culinaris*)

2.2 Concepts, Definitions and Assumptions

The focus of this study was to develop safe storage management practices for pulses, suggest milling outturn during milling and its relationship with storage period and suggest procurement norms for the pulses. Therefore, the definitions of various terms used during storage and milling were defined.

Pulses: These are food grains obtained from legumes, which are meant for human consumption. It includes Pigeon pea (*Arhar/ Tur*), Chick pea (Bengal gram/ *Chana*), Horse Gram (*Kulthi*), Lentil (*Masoor*), Green Gram (*Moong*), Black Gram (*Urad*), Pea (*Matar*), Cow pea (*Lobia*/ *Barbati*), Soyabean, Dew Gram (Moth), Field bean/ Flat bean (*Sem fali*), Chickling vetch (Lathyrus/ *Khesari*). (IS 2813: 1995)

Foreign Matter: It is inorganic or organic foreign matter. The inorganic foreign matter includes sand, gravel, dirt, pebbles, stones, glass and metallic pieces, lumps of earth, clay and mud. The Organic foreign matter shall include hull, chaff, straw, weed seeds and other non-edible grains.

Admixture (Other Food grains): Food grains other than the grains under consideration.

Immature/shrivelled: Kernel or pieces of kernel of the main crop (pulses here) that are not fully developed.

Mechanically damaged grain: Grains or pieces of grains that are broken or internally damaged as a result of heat, moisture, or impact during threshing.

Discoloured grain: Grains that have changed the colour as a result of deteriorative changes.

Insect damaged: Grains that are partially or wholly bored by insects injurious to grain.

Weeviled grains: Weeviled grains that are partially or wholly bored by insects injurious to grain but do not include germ eaten grains and egg spotted grains.

Pitting: Passing the whole pulses quickly through the roller mill to create scratches or cracks in hull and to remove the waxy layer of seed coat is known as pitting. Pitting is performed prior to the application of any pre-milling treatments in the pulse milling.

Pre-milling treatments: Treatments on the hull to reduce strength of its bond with cotyledons and loosen the bond between hull and cotyledon for easy separation of hull is termed as pre-milling treatment or pre-treatment of pulses.

Milling: For pulses, milling is referred as removal of the seed coat. The seed coat removal to produce polished seed (dehulling) and cleavage of the two cotyledons to produce split seeds (splitting) completes the milling operation for whole pulses.

Whole grain (*Sabut*): Cleaned and graded whole pulses intended for human consumption.

Dal/ Dhal: Split halves of pulses with or without husk are termed as dhal/dal from all the pulses.

Dehulled whole dal (Gota): The whole pulses obtained after removing the hull. The cotyledons remain attached together.

Grade-I dal: The dal obtained from splitting the *gota* (dehulled whole dal) into two halves. Edges of this dal are sharp and surface is smooth with no cleavage. It is mainly referred for Pigeon pea and Chick pea dals.

Grade-II dal: The dal (dehulled splits) obtained during milling of Pigeon pea and Chick pea. Edges of this dal are round and surface is smooth and shines because of polishing.

Dal *dhoya* / *Dhuli* dal: The dal (dehulled splits) and gota (dehulled whole) obtained during milling of Black gram and Green gram. Surface of the dal is smooth and shines because of polishing.

Dal *Dara*: Split halves of pulses with husk and a small quantity without hull are termed as *dara* dal. This is specificallynormally prepared from Green gram and Black gram by milling.

Outturn Ratio (Milling outturn): It is defined as the percentage of dal obtained during milling of pulses (Grade-I and Grade-II dal) by using standard process and machines.

Quantitative loss: It is defined as the reduction in dry matter weight during storage. Losses such as quality deterioration, loss of food value, goodwill or reputation, seed vigour loss, etc., are not quantitative in nature.

The other terms are defined as and when used in this report. The major assumptions and considerations taken for this study were:

i. The data for this study would be collected for one year for the selected pulses stored in warehouses.
ii. Initial point to start data recording would be the time when stacking of the grain bags were done in a warehouse.
iii. No intervention in the prevailing warehouse practices would be done during data collection.
iv. Actual practices adopted by the warehouses would be followed for collection of data, sampling and measurements in the supervision of the warehouse officials.
v. The samples from the warehouses would be collected by the trained manpower specifically appointed for the purpose.
vi. In laboratory study, only one pulse crop and its dal will be stored at one selected location.
vii. The quantitative loss may be due to the incidence of insects, rodents, birds, mites, fungi, bacteria and respiration of grains. Changes in temperature, relative humidity (RH), moisture content, and chemical changes affect rate at which gain or loss in weight may take place during storage. Similarly, the milling outturn (OTR) is a factor of storage period, initial conditions of grain, climatic condition of warehouse, infestation, etc.

2.3 Sampling Design

Sampling is a process of selecting a subset of number of samples from a population for any study. The method adopted in this study are described below:

2.3.1 Selection of warehouses

The selections of warehouses for study were identified randomly from the extensive details provided by NAFED to get reliable sample size for statistical analysis. A list of warehouses was prepared for selection of depots. The depots storing the selected pulses were taken from all the zones for the study. The factors, such as operational feasibility and availability of commodities were also considered. Some substations were changed at the initial stages of the study due to operational difficulties.

2.3.2 Selection of godown/compartment/chambers in Depot

The chambers were selected randomly in the selected depot in the following manner:

a) Operationally feasible.
b) Leak proof, all ventilators, door shutters intact, and electricity fittings in order, levelled floor, having door nets/mesh doors.

c) Should not have any other material, such as gunny bales, dead stocks and unserviceable articles.
d) Compartment should be treated with the available chemicals covering floor, walls, platform, and ventilators, leaving no scope of live and hidden infestation in any corner/crevices of the godowns.
e) Two chambers/godowns were selected randomly in each depot. Total 10 stacks were selected randomly in each selected depot for 5 spells of storage periods (0, 3, 6, 9, and 12 months). There was no weighment involved in any of the selected stack and the data recorded by the warehouses were noted because of Covid-19 pandemic.
f) Samples of 20 kg for each stored pulse from the stacks were taken initially including fresh stacking and after every 3 months.

2.4 Experimental Plan

This study was conducted in two parts. In the first part of the study, samples were taken from the pulses stored in warehouses. In second part of the study, the pulses and dal were stored in laboratory and observations were recorded. The experimental plan of the study was as below:

2.4.1 Warehouse Storage Study

- **Pulses to be stored :** Pigeon pea, Chick pea, Black gram, Green gram, Lentil
- **Types of storage :** Warehouse in bags
- **Sites of storage :** Selected in consultation with NAFED.
- **Duration of storage :** 09-12 Months (two seasons)
- **Time of sampling :** 0 days, 3, 6, 9 and 12 months (as per availability)
- **Sample size:**
    - 20% of the total warehouses storing pulses and at least one warehouse at each selected location for each selected pulse.
    - Minimum 02 godowns in each warehouse (or 10% of total godowns in the warehouse).
    - Minimum 02 stacks (or 10% of total stacks in a godown).
    - Minimum 20 stacks for each pulse in each region will be selected for sampling.
- **Curative measures to be adopted during storage period:** fumigation, aeration and sanitation.
- **Sample size :** 20 kg for each pulse (0 days and quarterly)

2.4.2 Laboratory study:

Locations of laboratory studies

- Green gram – ICAR-CIPHET Ludhiana (Punjab)
- Lentil – IIPR, Kanpur (UP)
- Pigeon pea – UAS, Raichur (Karnataka)
- Chick pea – PDKV, Akola (Maharashtra)
- Black gram – MPUA&T, Udaipur (Rajasthan)

- **Type of storage:** Bag storage
- **Type of samples:** Freshly harvested pulses from local market.
  Dal prepared from freshly harvested pulse and stored for 3, 6, 9 and for 12 months.
- **Storage duration:** 12 months
- **Experimental plan:** Control, fumigation and its doses (3 treatments), type of bag (B-1 twill new jute bags for whole pulses, polyethylene bags of 25 micron thickness), initial storage moisture content (10, 12, and 14%), aeration duration and scheduling.

2.5 Responsibilities of Data Collection

Altogether following 08 Institutions were involved in carrying out this study. ICAR-CIPHET, Ludhiana was lead centre and other Institutions were cooperating centres. The project team of ICAR-CIPHET, Ludhiana coordinated the institutions involved in the study as given below:

S. No.	Name of Institution	States covered for sampling from warehouses	Pulse crop and dal for laboratory study
1	ICAR-CIPHET, Ludhiana	Rajasthan, Madhya Pradesh	Green gram
2	ICAR-IIPR, Kanpur	Uttar Pradesh, Madhya Pradesh	Lentil
3	PDKV, Akola	Maharashtra	Chick pea
4	UAS, Raichur	Karnataka	Pigeon pea
5	JNKVV, Jabalpur	Madhya Pradesh (Up to August 2020, thereafter by ICAR-CIPHET, Ludhiana)	-
6	MPUA&T, Udaipur	Rajasthan	Black gram
7	JAU, Junagarh	Gujarat	-
8	ANGARU, Baptla	Andhra Pradesh	-

ICAR-CIPHET team imparted training to the Principal Investigators of the concerned Institutions for the data collection, sampling and data recording at the beginning of the study. Principal Investigators (PI) at cooperating centre further trained the contractual staff appointed specifically for the study.

2.6 Methods Used for Sampling and Measurements

The sampling procedures and analysis methods prescribed by Bureau of Indian Standards (BIS) incorporating IS: 14818 (2000) IS: 2813 (1995), IS: 4333 Part I and Part II (2002) for food grains in respect of moisture content, change in weight, 1000-grain weight and loss due to insect infestation were followed for this study.

2.6.1 Sampling procedures

The IS: 14818 (2000) method of sampling was adopted during the entire study. The samplings were done within one month of initial receipt, issue of the stacks or after every three months during the study. The analysis of samples were done in the laboratories of the respective institutions.

2.6.2 Sampling time and sample analysis of warehouse stored pulses

The sampling time and analysis procedure adopted for data recording from the selected warehouses were as below:

a) **Type of gunny sacks used:** Depot officials provided the information about type of gunny sacks used and also observed and recorded also by observation at the time of sampling.

b) **Moisture content measurement:** Recorded from the warehouse records at the time of sampling. Samples from the periphery of the stacks or entire stack were taken quarterly by taking 20 kg sample of each pulse.

c) **Quality parameters of stack (percentage of damaged, discoloured, weeviled, damaged, 1000-grain weight, moisture content):** Quarterly in the Institution laboratory from the samples taken for analysis.

d) **Level of infestation:** Quarterly in warehouses by taking samples.

e) **1000-grain weight:** Quarterly by taking samples.

f) **Incidences of rodents, birds, mites, monkey trouble during storage**: Recorded from the warehouse records.

g) **Number of spray/fumigation applied with name of the chemicals used:** The warehouse staff provided the information during the study for records of stack management practice.

h) **Microbial load in grain samples:** Quarterly basis at Institutions, if suspected.

2.6.3 Sampling time and sample analysis of laboratory stored pulses

For laboratory study, the plan of activities and observations recorded were as below:

	Particulars
Procurement	Procurement of whole pulses, dal, packaging material and miscellaneous items
Stacking	Storage room preparation, Dunnage preparation, Stacking
Commodity	Whole Pulses and Dal
Sampling of whole pulses	Weekly (Infestation, moisture content, quality parameters), Monthly (OTR)
Sampling of dal:	Weekly (Infestation, moisture content, quality parameters)
	Observations
Daily	**Environmental conditions inside storage room and environment:** Relative humidity, Temperature
Initial analysis (0 days)	**Whole pulses:** Weight of pulses in bag, weight of bag and number of bags in one stack, Moisture content, Level of infestation if any, Foreign matter, content, Bulk density, 1000-grain weight, Weight loss, Insect damaged grain, Weevilled and germ-eaten grain, OTR, Grade-I Milling outturn, Grade-II Milling outturn, Dehulling efficiency, Dehulling loss
	Milled pulses (Dal): Moisture content, Bulk density, 1000 grain weight, Level of infestation if any, Foreign matter content, Cooking quality
Packaging material	Whole pulses: B-I twill new Gunny bags
	Dal: LDPE bags (25, 50 and 75 μm thickness)
Weekly observations	**Whole pulses and Dal:** Infestation level, Type of insect **Prophylactic measures:** Fumigation was done if infestation observed
Monthly observations	**Whole pulses:** Moisture content, Bulk density, 1000-grain weight, Weight loss, Insect damaged grain, Weevilled and germ-eaten grain, Total milling outturn, Grade-I Milling outturn, Grade-II Milling outturn, Dehulling efficiency, Dehulling loss
	Dal: Moisture content, Bulk density, 1000-grain weight, Weight loss, Insect damaged grain, Weevilled and germ-eaten grain

Quarterly observations	**Dal:** Uric acid (Both pulses and dal), Cooking quality of dal
Specific observations	**Whole pulses and dal:** Microbial load-visual mold growth (In rainy season and at the end of storage), Impact of fumigation/aeration (when done), visual observation for fungal growth or colour change

2.7 Data Collection Schedules

Altogether 4 schedules were developed and used to record the data (*Annexure-I*) as described below:

Schedule-1 was to record the data of each stack, which includes stack weight, moisture content and quality parameters of the pulse at the time of stacking and liquidation. Separate schedules were used for the godowns and every pulse.

Schedule-2 was used to record the monthly environmental data whereas daily environmental data records were maintained separately.

Schedule-3 was used to report the observations of fortnightly sampling and their analysis. These samples were taken from the periphery of a stack for prophylactic and curative treatments.

Schedule-4 was used to record the data of quarterly liquidation of stacks. Microbial and mycotoxin incidence, if any, were also recorded in this schedule.

All the schedules were duly filled and signed by the field investigator and PI of the concerned Institution.

2.8 Monitoring of Study

A team of experts monitored the progress of work comprising Principal Advisor, Department of Consumer Affairs GoI; Director ICAR-CIPHET Ludhiana; Assistant Director General (Process Engg.), ICAR, New Delhi; Dr. K. Narsaiah, Head (Acting), AS&EC Division; and members nominated by the Department of Consumer Affairs, GoI, New Delhi.

3. METHODOLOGY AND DATA ANALYSIS

The aim of this study was to prepare norms for storage management, OTR and procurement of pulses from the data recorded at various depots of CWC/SWC. The study was conducted for large scale operations as well as in the Laboratory and the data were analyzed using proven statistical methods and standard scientific methodologies. The methods used for laboratory analysis, data analysis techniques, formula and equations used for computing the storage losses and errors in the same are discussed hereunder.

3.1 Moisture Content of Whole Pulses and Dal

Moisture content of the samples was determined according to the standard procedure of AOAC (2016).

Weighed sample of approximately 5 g of finely pulverized pulses were kept in a dried and pre-weighed petridish. Then the sample were dried in a hot air oven at 105°C for 20 h and cooled in a desiccator. The process of heating and cooling was repeated till the difference between the two successive weighing did not exceed one mg or remains constant. Cooled petridish with dried material were weighed (up to 3 decimal reading using precision balance). The moisture content (w.b.) was calculated using the following expression:

$$M = \left(\frac{W_i - W_f}{W_i - W_p}\right) \times 100 \qquad (1)$$

where, M is moisture content (%, w.b.); W_i is mass of sample with petridish prior to drying (g); W_f is mass of sample with petridish after drying (g); W_p is mass of empty petridish (g).

The moisture content on a dry basis (d.b.) can be converted from moisture content on wet basis (w.b.) using the following equation:

$$M_d = \left(\frac{(100 \times M)}{(100 - M)}\right) \qquad (2)$$

Where M_d is moisture content (%, d.b.)

3.2 Conditioning of Dal to Prepare Samples of Different Moisture Contents

The desired moisture content of the dal samples was obtained by either drying or remoistening them. The amount of water to be removed or added was calculated using the following equation (Vishwakarma et al., 2012):

$$W_w = \frac{W_m(M_r - M_o)}{(100 + M_o)} \qquad (3)$$

where, W_w is amount of water to be added/removed (g); W_m is initial mass of sample (g); M_r is desired moisture content of sample (%, d.b.); and, M_o is initial moisture content of sample (%, d.b.).

Samples of 10% moisture content (w.b.) were obtained by drying at 40±1ºC in a tray dryer. Accurately weighed sample was placed on the tray in thin layer and transferred into dryer preset at 40±1ºC. The sample along with the tray was weighed after every one h, immediately withdrawn when the desired moisture content reached and then packed as per the experimental design.

To obtain samples containing moisture content of 12 and 14% (w.b.), measured amount of water calculated from Eq. (3) was added to a batch and mixed thoroughly for uniform distribution of water. Thereafter, the sample was conditioned for 72 h at normal temperature. The sample was stirred at least thrice daily to achieve uniform moisture distribution and then packed in bags as per experimental plan.

3.3 Bulk density

Bulk density of pulses was determined by filling a 500 ml cylinder with grains from a set height of 150 mm from top of the cylinder, tapping twice and then weighing the contents (Vishwakarma et al., 2012). The cylinder were filled between 400-450 ml and actual volume up to filled height was recorded. The bulk density was computed using the following formula:

$$\rho_b = \left(\frac{W_b}{V_b}\right) \quad (4)$$

where, ρ_b is bulk density of the sample (kg.m^{-3}); W_b is mass of seeds/splits filled in container (kg); and, V_b is volume of container (m^3).

3.4 1000-Grain Weight

The 1000-grain weight was determined using a seed counter for counting the sound whole grains and subsequently weighing them using a precision balance with an accuracy of 0.001g. Manual counting and weighing was also performed using about 200 sound whole seeds per sample. The 1000-grain weight was calculated by using the following equation:

$$M_t = \frac{1000 \times W_p}{n_s} \quad (5)$$

where, n_s is number of seeds or splits; and, W_p is mass of n_s seeds/splits (g).

3.5 Weight Loss due to Insect Infestation

This method is a modified version of IS: 12529 (2005) because of an error observed in the calculation method. The weight loss (%) due to insect infestation was determined in the stored pulses. A representative sample of 500g was sieved using round holes sieve of 2 mm size to remove dust and foreign matter from the sample. Then about 100 g sample was taken and placed on an enamelled plate. The insect damaged grains were picked by hand with the help of a magnifying glass, whenever required. The number of insect damaged grains were counted using seed counter and their weight was also taken using a weighing balance. Percentage by number/ weight of insect damaged grains were calculated using following formulas:

$$\text{Insect damaged grains (\% by number)} = \frac{N_w}{N_t} \times 100 \qquad (6)$$

Where, N_w is number of weeviled/insect damaged grains in a sample; and N_t is total number of grains in the sample.

$$\text{Insect damaged grains (\% by weight)} = \frac{N_w \times M_t}{1000 \times W_a} \times 100 \qquad (7)$$

Where M_t is 1000-grain weight taken for same sample using sound grains (g); W_a is actual weight of sample in absence of infestation (g), which is calculated as:

$$\mathrm{W}_a = \mathrm{W}_t - W_w + \frac{N_w \times M_t}{1000} \qquad (8)$$

Where W_t is total weight of sample (g); W_w is weight of weeviled grains.

3.6 Milling Outturn

Uniform process and same machine (PDKV Dal Mill), supplied by one company was used at all the study centres to determine milling outturn. The process protocol for milling of each pulse was optimized and a uniform process protocol for each pulse was followed by the study centres. The final process protocol for milling of the pulses is discussed under Results and Discussion section. The methodology followed for determining the milling outturn for all selected pulses is described below:

3.6.1 Cleaning and grading

Pulses were cleaned for separation of dust, dirt, immature grains, and other extraneous materials. Then grading was done according to the size to remove shrivelled grains using vibratory cleaner-cum-grader.

3.6.2 Destoning

Some stones, hardened mud particles, metal and glass pieces may remain in the stock after cleaning and grading, which are of same size. Therefore, destoning was done using destoner.

3.6.3 Pitting/Scratching

PDKV dal mill was used to perform pitting operation for all pulses. The outlet of the dal mill was opened fully while inlet was closed prior to pitting. The pre-weighed sample of pulses (about 7 kg) was fed in the hopper and inlet gate was opened fully while operating the machine. The material passed through the emery rollers quickly for creating cracks and scratches on the hull. The hull and pitted pulses were collected and weighed. Pitting operation was not performed for lentil.

3.6.4 Oil and water treatment

This pre-treatment was applied to loosen the hull from the cotyledons for pigeon pea, green gram and black gram. The pitted pulses were mixed with mustard oil @ 0.3% for pigeon pea, and 0.1% for black gram and green gram, followed by water treatment @ 4-6%.

In case of chick pea, only water treatment was given. In case of lentil, no treatment was given to this pulse.

3.6.5 Conditioning (Tempering)

Once the oil and water treatment is applied, conditioning was done to ensure uniform distribution of oil and water throughout the grain mass. The oil and water treated pulses were heaped, covered and kept for 12 hours or overnight for tempering purpose.

3.6.6 Sun drying

The conditioned pulse was spread in thin layer for sun drying for 2-3 days or till the moisture content reached to about 10% (w.b.).

3.6.7 Dehulling and Splitting

PDKV dal mill was used for dehulling of the pre-treated pulses. Initially, the inlet and outlet of the machine were closed and the machine was operated. Thereafter, pre-treated and pre-weighed samples were fed in the hopper and inlet was opened to about one forth with closed outlet. Then the outlet was opened to about half after a certain optimized time for different pulses (60 s for black gram and green gram, 90 s for pigeon pea and chick pea, and 40 s for lentil). This time was optimized on the basis of surface scouring of cotyledon. The material passed through the emery rollers and dehulling took place. The hull mixed with broken and powder, gota, and dal were collected from different outlets of the machine. About 45-50%

of grains were dehulled in case of pigeon pea, black gram and green gram while in chick pea, about 65-70% grains dehulled and in lentil, more than 90% grains dehulled in the first pass.

The unhulled pulses were separated and pre-treatment was done again as per protocol developed for each pulse. The gota was split using the gota splitter of PDKV dal mill to obtain Grade-I dal. For complete dehulling and splitting, the process was repeated two to three times for pigeon pea, black gram and green gram.

3.6.8 Total milling outturn (for all pulses)

The total milling outturn was calculated using the following equation (Vishwakarma et al., 2018):

$$Y_t = \frac{(M_{ds}+M_{dw})}{(M_t-M_u)} \times 100 \qquad (9)$$

Where, Y_t is Total milling outturn (%); M_{ds} is mass of dehulled splits after dehulling in all passes (kg) M_{dw} is mass of dehulled whole (gota) after dehulling in all passes (kg); M_t is total mass of grain taken prior to pitting of pulses (kg); and, M_u is mass of unhulled grain obtained at the end of all passes (kg).

3.6.9 Grade-I milling outturn (For pigeon pea and chick pea)

The Grade-I milling outturn was calculated using the following equation:

$$Y_I\ (\%) = \frac{M_{dw}}{(M_t-M_u)} \times 100 \qquad (10)$$

3.6.10 Grade-II milling outturn (For pigeon pea and chick pea)

The Grade-II milling outturn was calculated using the following equation:

$$Y_{II}\ (\%) = \frac{M_{ds}}{(M_t-M_u)} \times 100 \qquad (11)$$

3.6.11 Dehulling efficiency

The dehulling efficiency represents the performance of machine for particular pulses during operation. It also represents the possibility of broken and powder formation. Dehulling efficiency was calculated using the following equation (Vishwakarma et al., 2018):

$$\eta = \left(1 - \frac{M_u}{M_t}\right) \times \left(\frac{(M_{ds}+M_{dw})}{(M_{ds}+M_{dw}+M_b+M_p)}\right) \times 100 \qquad (12)$$

where, η is dehulling efficiency (%); M_p is mass of powder (kg); and, M_b is mass of broken (kg)

3.6.12 Dehulling loss

The dehulling loss (L_d) was calculated by following equation (Vishwakarma et al., 2018):

$$L_d(\%) = \frac{(M_b+M_p)}{(M_t-M_u)} \times 100 \qquad (13)$$

3.7 Specific Quality Parameters for Whole Pulses and Dal

3.7.1 Microbial load

Mould growth was observed visually at the time of stacking, rainy season and at the end of storage periods for the pulses and dal stored for laboratory study.

3.7.2 Uric acid

This method is based on the precipitation of proteins and treatment of protein free filtrate with sodium cyanide (NaCN) then Benedict's uric acid reagent and measuring the resultant blue colour calorimetrically. Uric acid was measured for some samples only because of non-availability of NaCN, which has been banned for laboratory use and not being supplied by the chemical suppliers at present. The method followed for uric acid measurement is as below:

- A sample of 50 g was weighed and pulverized in to fine powder.
- 4-20 g powder was taken and suspended in 200 ml water.
- The mixture was allowed to stand for 2 h and then mixed in a warring blender for 10 min. and centrifuged at about 2000 rpm for 10 min. In 100 ml of clear supernatant, 10 ml Sodium tungstate solution was added and mixed.
- Then 10 ml standard sulphuric acid solution was added to precipitate the proteins present in the extract. After mixing, the solution was kept for 5 min and then filtered.
- Aliquot of the filtrate containing between 0.15-0.3 mg uric acid per 10 ml filtrate was taken in a 50 ml volumetric flask and 5 ml of sodium cyanide solution was added followed by 1 ml of Benedict's uric acid reagent.
- The sample was stirred gently and volume was made up to mark with distilled water. The intensity of the colour was measured in a potentiometric colorimeter using 520 nm filter.
- The optical density obtained was recorded as OD1. Then 10 ml of standard uric acid solution containing 0.2 mg of uric acid was taken in a 50 ml flask, 5 ml of sodium cyanide was added and 1 ml of Benedict's uric acid reagent was added.
- The sample was diluted to mark after 5 minutes and the intensity of colour was measured in a photoelectric colorimeter using a 520 nm filter.
- A parallel test using the same quantity of good un-infested sample as the sample under test was run as a control.

$$\text{Uric acid (mg/g)} = \frac{(\text{OD1} - \text{OD2}) \text{x} 10 \text{x} 2}{\text{weight of sample, g}} \qquad (14)$$

3.8 Analysis Tools and Techniques

Data screening and analysis were done using the following steps:

- The data collected by the designated Institutions were entered into the MS Excel. The digital data was compiled at ICAR-CIPHET, Ludhiana.
- The data received from centers were scrutinized for discrepancies and errors during data collection and entry. Wherever the inconsistencies were observed, possible corrections were made by referring the hard copy records in the filled schedules of concerned centers. In case the reconciliation in the data were not possible for the errors/ discrepancies, such data were not considered for the analysis.
- Data analysis was done state-wise and crop-wise separately for each pulse. The data of the centers with undue and unjustified fluctuations in the OTR values and without proper justification, were not included in the analysis. Further, the non-responsive data points, sample size for milling less than 5 kg, milling done in single pass (for pigeon pea, black gram, chick pea and green gram), improper mass balance, reporting of exorbitantly higher OTR in comparison to the possible OTR from a pulse, etc., were also removed prior to the analysis.
- The scrutinized data were arranged center-wise and then crop-wise and region-wise for the analysis for each pulse, separately.
- For preparing standards for storage management, OTR, procurement standards, etc., at national level, the data of all the centers were merged together for each pulse, separately. Then the outliers were identified and removed and the analysis was done to arrive at standards.

3.8.1 Confidence Interval (CI)

Confidence interval gives a range of values in which the data is supposed to lies in. The CI was calculated using the following expression:

$$CI = \bar{X} + Z \times \frac{SD}{\sqrt{N}} \tag{15}$$

Where CI is confidence interval; $\bar{X}$ is mean value of sample population; SD is standard deviation of population; N is number of observations; and Z is Z-Table value (for CI 95% Z=1.96; for CI 99%, Z=2.576; and for CI 99.9%, Z=3.291).

3.8.2 Merging OTR of Warehouse study and laboratory study

The OTR obtained from analysis of warehouse samples and laboratory study were combined using weighted average and combining variance using the following expressions:

The recovery of dal is given as:

$$R_o = \frac{N_w \times R_w + N_l \times R_l}{(N_w + N_l)} \tag{16}$$

Where, R_o is OTR, N_w is number of observations in warehouse analysis (all replicates); N_l is number of observations in laboratory analysis (all replicates); R_w is average OTR obtained from warehouse samples; and R_l is average OTR obtained from laboratory stored sample analysis

The standard deviation of combined OTR is given as:

$$SD = \sqrt{\frac{(N_w - 1) \times SD_w^2 + (N_l - 1) \times SD_l^2 + \frac{N_w \times N_l}{(N_w + N_l)} \times \left(R_w^2 + R_l^2 - 2 \times R_w \times R_l\right)}{(N_w + N_l - 1)}} \tag{17}$$

The t-tests (dependent samples or paired t-test) were conducted to compare the difference in mean values of different parameters. Standard deviation, standard errors, model fittings, and ANOVA were done using Statistica Version-6 software.

4 RESULTS AND DISCUSSION

This study was conducted by collecting the stored pulse samples from the warehouses and storage of pulse and dal under ambient conditions for the laboratory study. Initially the protocol for milling of the selected pulses was prepared and outturn ratio (OTR) was defined. Then the samples of 20 kg were collected from the selected warehouses quarterly and analysed for different quality parameters. The data were compiled and analysed separately for the laboratory and warehouse studies and then optimally combined to arrive at norms, standards and protocols for the selected pulses. The results obtained in the study are discussed in this chapter.

4.1 Standard Operating Procedure (SOP) for Milling of Selected Pulses

The SOPs for milling of pulses were prepared using the existing practices, optimal conditions taken from the various research findings, and evaluating all them with PDKV dal mill (Fig. 1).

Fig. 1: PDKV Dal mill used in the study for milling of selected pulses

The SOPs for pigeon pea, chick pea, black gram, green gram and lentil were developed by UAS, Raichur, PDKV, Akola, MPUA&T, Udaipur, ICAR-CIPHET, Ludhiana, and ICAR-IIPR, Kanpur, respectively. Thereafter, these SOPS were evaluated at all the institutions involved in the study where the respective pulses were expected to arrive for the study. After validation, the SOPs were circulated to all the Institutions. Thereafter milling of the pulses were done as per the SOP and OTR were determined for all the samples collected from warehouses and laboratory study samples. The optimum conditions for the unit operations as per the standard operating procedures for milling of selected pulses were as follows:

- The material must be cleaned and graded by removing the undersize grains before milling.
- The optimum moisture content for pitting operation for all the pluses was 9-10% (w.b.). In case the moisture content was more than 10%, the material was dried. Pitting operation was not performed for lentil.
- For manual oil/water treatment, requisite quantity of pre-treatment agent i.e. oil/water were added gradually in 10-15 min. In case the oil/water applicator was used, the flow of oil/water was kept at constant rate and uniform mixing was ensured.
- For drying under Sun, the pre-treated pulses were spread in thin layer as far as possible. The pulse samples were spread in the morning and gathered in the evening. A heap was formed and covered with water resistant sheet for the whole night. Caution was taken to protect the pre-treated pulses from rain or dew.
- Moisture content for dehulling of all the selected pulses ranged between 9-10% (w.b.).
- Dehulling was performed at optimum machine parameters as described in Section 3.6. Sufficient pressure inside the dehulling machine was ensured during the milling. For this purpose, the outlet was kept closed for 40-90 seconds (less time for lentil, black gram, and green gram, and more time for pigeon pea and chick pea) and then opened one third. The outlet opening was increased when surface scouring was observed.
- Gota and dal were separated after each pass and unhulled pulses (remained after first pass) were taken for next round of pre-treatment before dehulling in subsequent passes.
- Polishing of Grade-I dal (dal obtained by splitting gota) was not performed. Grade-I and Grade-II dals were dried, if required to bring moisture content below 12% (w.b.).

The process flow chart of SOP for different pulses are shown in Fig. 2-5.

4.1.1 SOP for Pigeon pea Dal

- For pitting of pigeon pea, machine outlet was opened completely.
- Milling of pigeon pea in emery roller was done by roller milling for each pass.
- The Grade-I dal obtained by splitting gota was dried to less than 12% moisture content for better storage.
- Colour sorters may be used to further improve the quality.

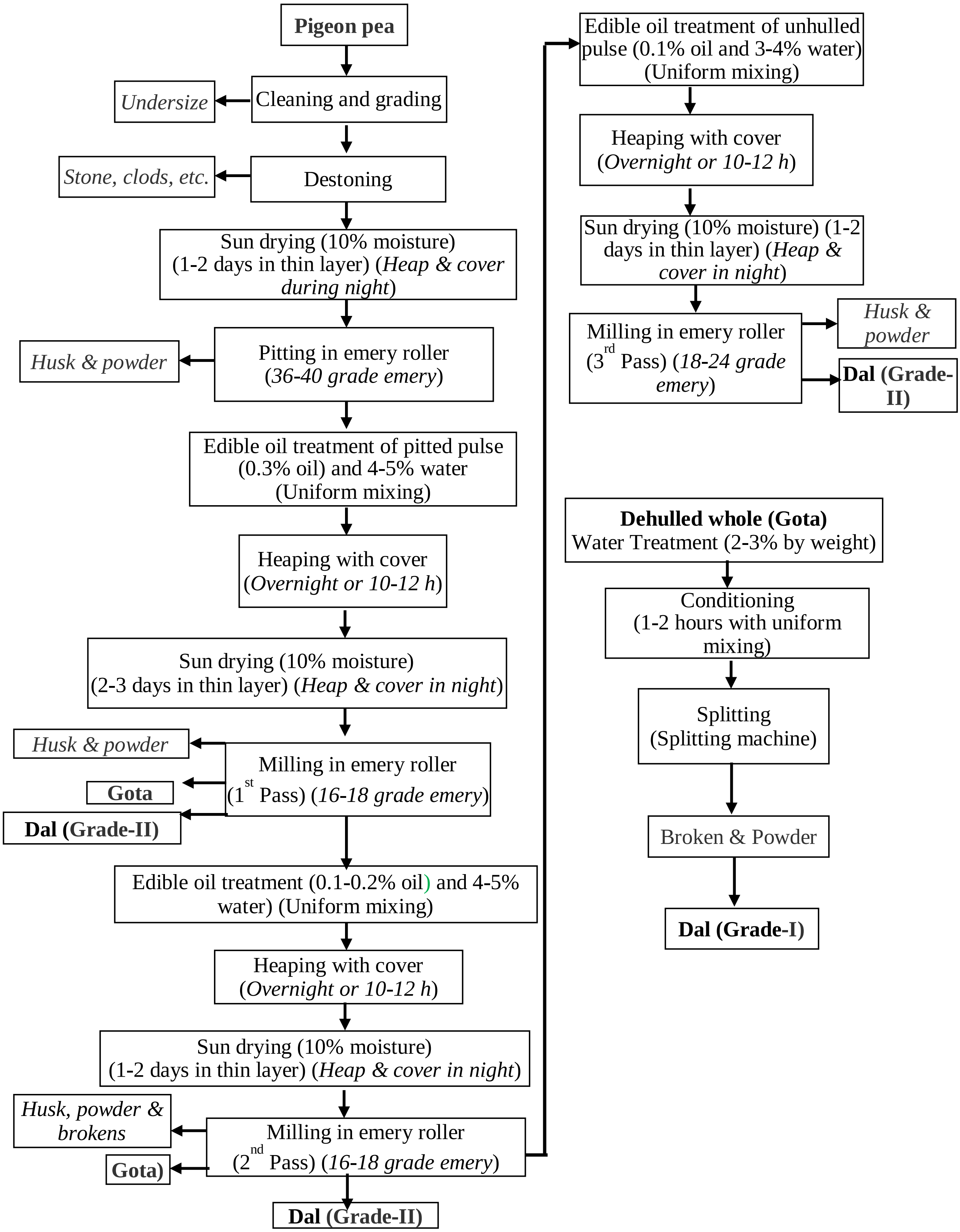


Fig. 2: SOP for dehulling of Pigeon pea

4.1.2 SOP for Chick Pea Dal

- Pitting in chickpea refers to breaking the tip (nose). For pitting of chick pea, machine outlet was opened completely.
- Electrical or oil fired dryers may also be used for drying.
- Colour sorters may be used to further improve the quality.

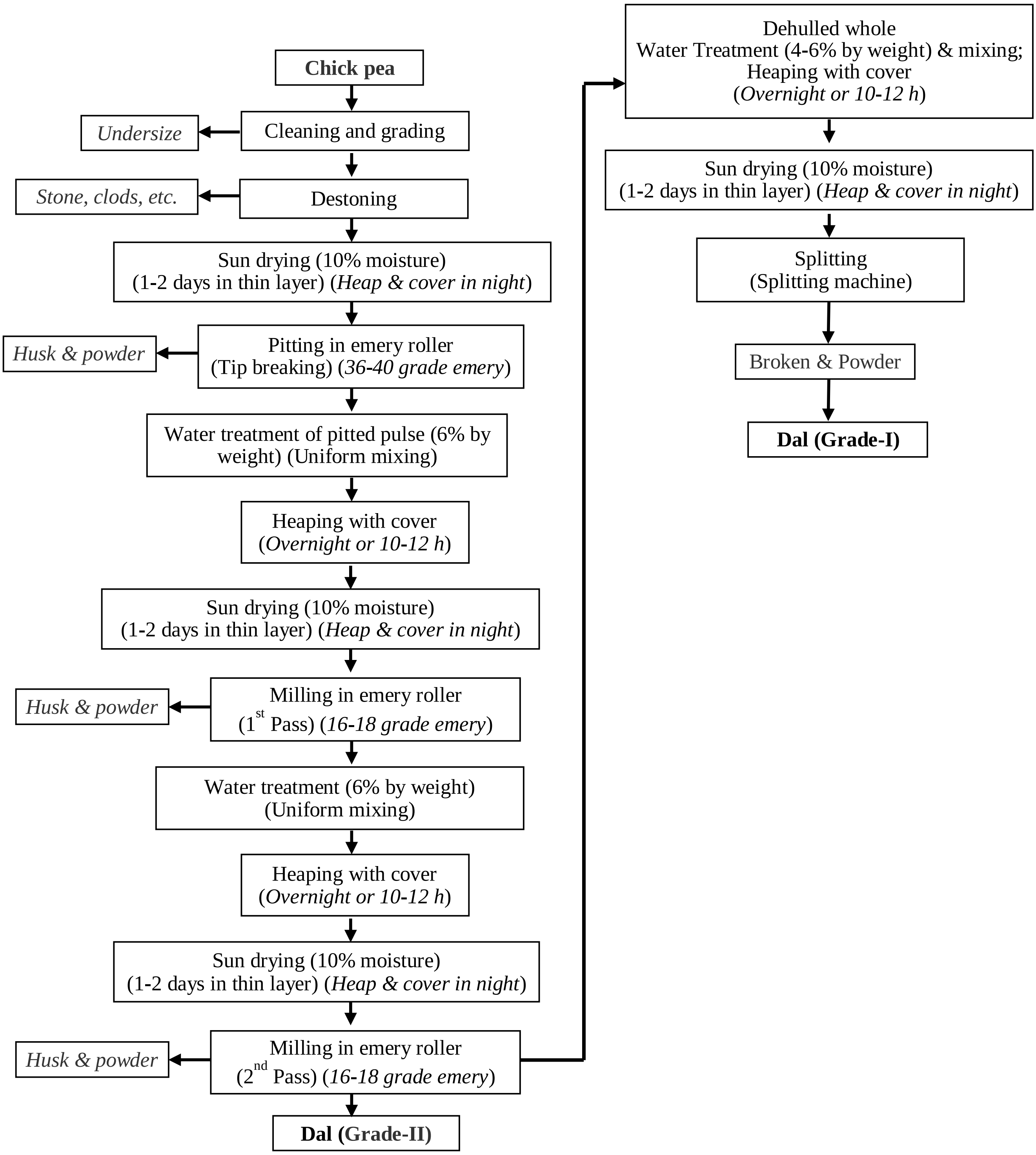


Fig. 3: SOP for dehulling of chick pea

4.1.3 SOP for Green Gram and Black Gram Dal

- Three types of dal from green gram and black gram were prepared namely *Sabut* (whole grain), *Dal dara* (split grain with husk) and *Dhuli dal* (Split grain without hull).
- *Sabut* was produced by removing impurities, foreign matter, and shriveled grains, grading, drying to about 10% moisture content, and packaging.
- For *dal dara*, dried pulse of 10% moisture content was fed to the burr mill or emery mill. Only husk and powder were separated and remaining produce (unhulled splits, dehulled splits, dehulled whole, and unhulled whole grains) was packed.
- *Dal dhuli* refers to the mixture of dehulled whole and dehulled splits. All the pre-milling treatments were essential to produce *dal dhuli*.
- Pitting in green gram/black gram was to create cracks in hull with completely open outlet.
- Milling of green gram and black gram in emery roller is done by roller milling.
- Polishing of dal using soap stone powder is not permitted in any circumstances.

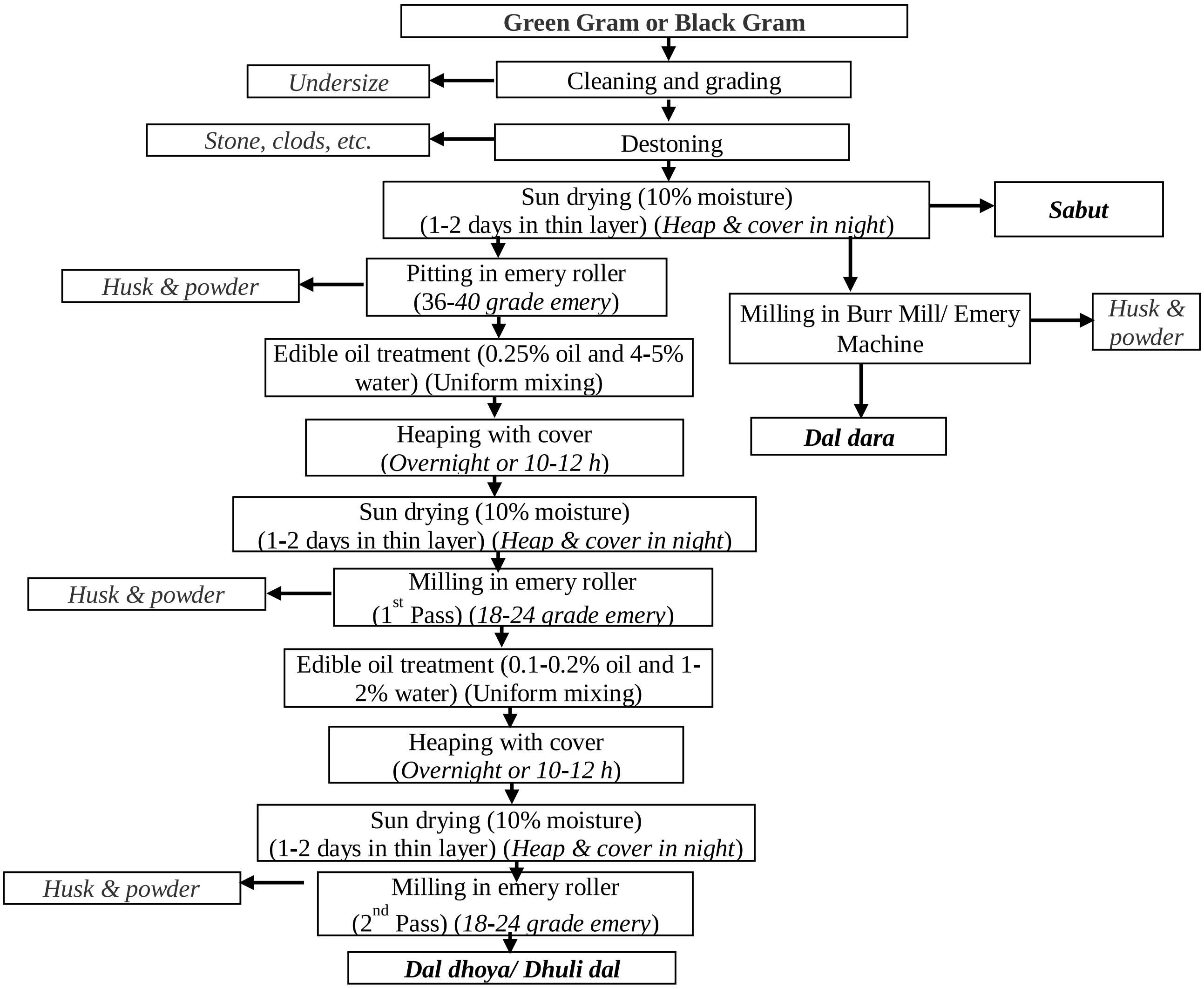


Fig. 4: SOP for dehulling of green gram and black gram

4.1.4 SOP for Lentil dal

Preparation of lentil dal does not require pre-milling treatment except conditioning. Further, the dehulled whole and dehulled splits are not separated in lentil dal. Polishing of the dal using soap stone powder is not permitted in any circumstances.

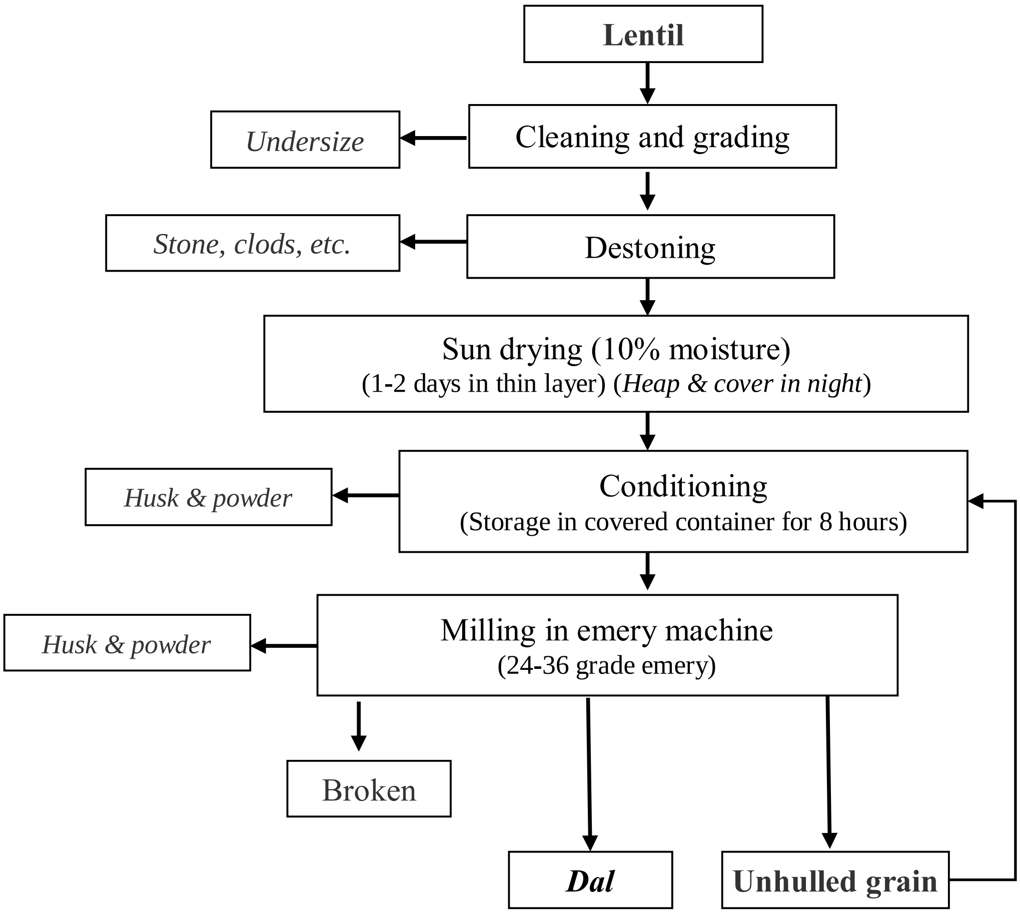


Fig. 5: SOP for dehulling of Lentil

4.2 Climatic Conditions in the States under Study

The climatic conditions viz. temperature, atmospheric pressure, wind system or precipitation show a great variability across India ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained winter snowfall. The states covered under this study were Uttar Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Maharashtra and Andhra Pradesh having diversified climatic conditions. The climate of Uttar Pradesh is primarily defined as humid subtropical with dry winter type with parts of western Uttar Pradesh as hot semi-arid type. Madhya Pradesh has a subtropical climate with three distinct seasons: winter (December to February), summer (March to May) and the rainy season (June to October). The Western part of Rajasthan falls under hot desert and remaining portions of the state falls under hot semi-arid. The climate of the Rajasthan state ranges from arid to semi-arid. The climate of Gujarat involves diverse conditions. The plains of Gujarat are very hot and dry in summer and cold and dry in winter. During summers, the daytime temperature is around 49°C and at night no lower than 30°C. The monsoon season lasts from June to September. Maharashtra has a tropical climate, with three distinct seasons: summer (March–May), monsoon (June–September), and winter (October–February). The climate of Andhra Pradesh is generally hot and humid. The summer season in this state generally extends from March to June. During these months the moisture level is quite high. In summer, the temperature generally ranges between 20°C and 40°C. At certain places the temperature is as high as 45°C on a summer day. The summer is followed by the monsoon season, which starts during June and continues till September. October to February are the winter months in Andhra Pradesh and these months are cooler. Karnataka has a tropical monsoon type of climate. This type of climate is hot and moist in summer and cool and dry in winter.

4.3 Warehouse Storage of Whole Pulses

4.3.1 Sampling status from warehouses

The pulse-wise samples drawn, number of warehouses covered in different states and stacks coverage for sampling are given in Table 1. The samples were taken from 529 stacks of pulses stored in 101 warehouses of CWC/SWC. The coverage of samples were statistically sufficient to arrive at scientifically correct and statistically valid conclusions. All the pulses were not stored in all the states. For example, lentil was stored in M.P. and U.P. only and therefore, the data were reported for these two states only. Altogether 208 samples were taken for chick pea, 177 samples of pigeon pea, 72 samples of black gram, 42 samples of green gram, and 30 samples of lentil. A sample of 20 kg each were drawn in each visit for each selected crop and stack.

Table 1: Warehouses covered and number of samples taken

Name of Centre	Name of States covered	No. of Godowns covered	Name of pulses	No. of stack covered for sampling from different godowns during all visits
ICAR-CIPHET, Ludhiana	Rajasthan	14	Chickpea	38
			Green gram	38
	Madhya Pradesh	9	Lentil	15
			Chickpea	39
			Black gram	2
ICAR-IIPR, Kanpur	Uttar Pradesh, Madhya Pradesh	11	Chickpea	45
			Black gram	28
			Lentil	15
ANGRAU, Bapatla	Andhra Pradesh	15	Pigeon pea	20
			Chick pea	20
			Black gram	16
Jabalpur	Madhya Pradesh	Samples were not taken by the centre. ICAR-CIPHET, Ludhiana collected samples after August 2020		
UAS, Raichur	Karnataka	11	Pigeon pea	52
PDKV, Akola	Maharashtra	17	Pigeon pea	30
			Chickpea	18
			Black gram	7
JAU, Junagarh	Gujarat	10	Pigeon pea	75
MPUAT, Udaipur	Rajasthan	14	Chickpea	48
			Black gram	19
			Green gram	04
Total		**101**		**529**
Chickpea: 208; Pigeon pea: 177; Black gram: 72; Green gram: 42 and Lentil: 30 samples				

4.3.2 Quality of Procured and Stored Pulses

The moisture contents at the time of procurement/ storage of pulses were noted from warehouse records. Extent of foreign matter, admixture and damaged grains were calculated by pooling the data of all the samples drawn from the warehouses throughout the year. The quality of pulses procured and stored in different states are presented in Table 2.

Table 2: Moisture content and quality parameters of the pulses procured and stored in warehouses in different states

State name	Pulse	Initial moisture content (%)	Foreign matter (%)	Admixture (%)	Damaged grain (%)	Total unwanted matter (%)
Andhra Pradesh	Black gram	11.44±0.24	0.23±0.06	0.02±0.01	0.98±0.64	**1.23±0.37**
	Chick pea	11.24±0.39	0.10±0.08	0.00	0.80±0.91	**0.91±0.53**
	Pigeon pea	11.11±0.28	0.09±0.08	0.01±0.01	1.13±0.92	**1.22±0.54**
Madhya Pradesh	Black gram	10.60±0.33	0.75±0.42	0.00	0.00	**0.75±0.24**
	Lentil	10.41±0.64	1.20±0.80	0.02±0.07	0.30±0.49	**1.53±0.54**
	Chick pea	10.92±0.66	0.93±0.87	0.46±1.72	0.77±1.16	**2.16±1.30**
Maharashtra	Black gram	11.55±0.12	0.83±0.13	0.00	2.27±0.37	**3.10±0.23**
	Chick pea	11.41±0.25	0.44±0.48	0.00	1.12±0.87	**1.55±0.57**
	Pigeon pea	11.38±0.25	0.50±0.38	0.00	0.94±0.69	**1.44±0.45**
Rajasthan	Black gram	11.23±0.35	4.60±3.80	0.01±0.01	0.23±0.20	**4.83±2.19**
	Chick pea	11.30±0.73	0.41±0.67	0.01±0.01	0.25±0.40	**0.65±0.45**
	Green gram	10.92±0.48	0.14±0.41	0.01±0.01	0.23±0.29	**0.37±0.29**
Uttar Pradesh	Black gram	12.00±0.14	0.15±0.06	0.19±0.03	0.19±0.37	**0.53±0.22**
	Chick pea	11.84±0.27	0.08±0.02	0.12±0.01	0.02±0.03	**0.22±0.02**
	Lentil	12.28±0.86	1.39±0.78	1.28±1.13	1.52±1.25	**4.19±1.07**
Gujarat	Pigeon pea	9.95±0.65	0.52±0.66	0.00	0.41±0.16	**0.93±0.39**
Karnataka	Pigeon pea	11.27±0.63	1.31±0.48	0.00	0.28±0.63	**1.59±0.46**

The moisture content of pulses at the time of storage were in the range of 11-12% for all the pulses in all the states except Gujarat where storage moisture content of pigeon pea was 9.5-10.5%. This might be because of the FSSAI standards permitted the procurement of pulses at <12% moisture content.

It may be observed that the total unwanted material was more than 2% in some of the states for some pulses, particularly for chick pea in M.P., for lentil in U.P., and for black gram in Maharashtra and Rajasthan. These unwanted material did not include shrivelled grain. Such admixture affects the storability of pulses as well as *dal* quality during milling. This may be minimized at the time of procurement and the overall level of such impurities may be ensured to ≤1.5% during procurement.

4.3.3 Variations in 1000-grain weight

The variations in 1000-grain weight of samples taken from the procured and stored pulses in warehouses is given in Table 3.

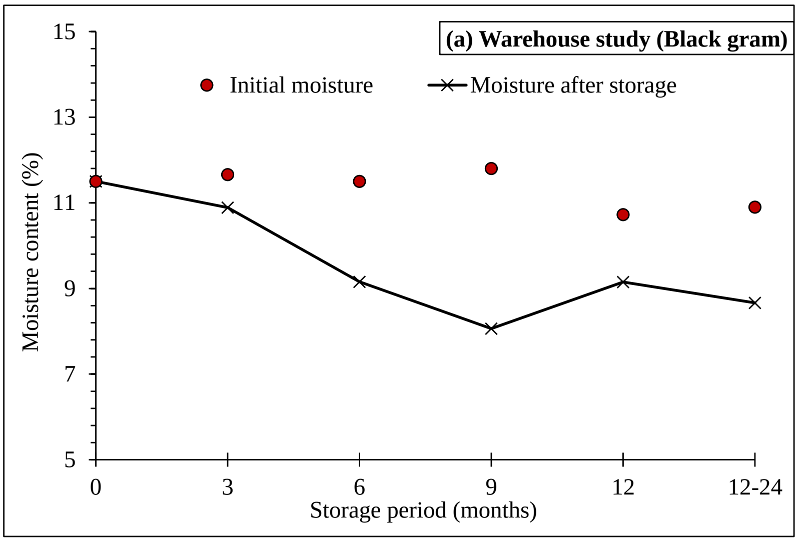
Table 3: Variations in 1000-grain weight of the pulses procured and stored in warehouses in different states

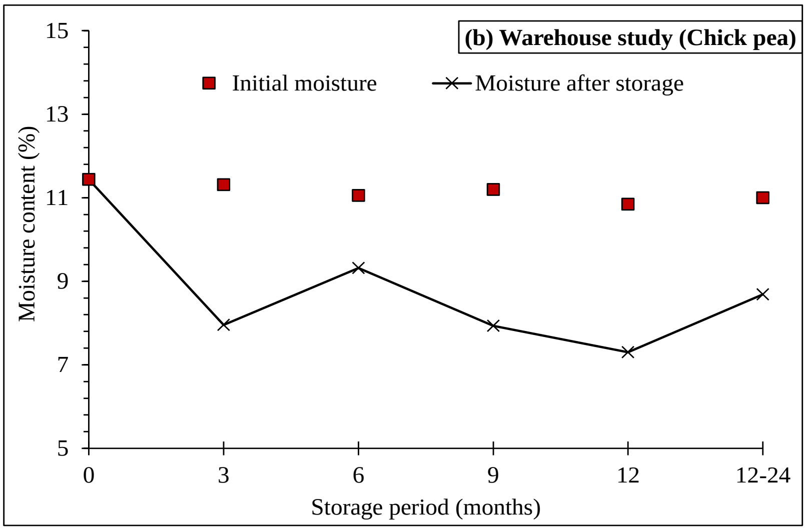
State name	Pulse	Procurement moisture content (%)	1000-grain weight (g)			Confidence Interval (99.9%)
			Minimum	Maximum	Average	
Andhra Pradesh	Black gram	11.44±0.24	43.47	55.14	**49.11±3.16**	49.11±3.46
	Chick pea	11.24±0.39	189.07	235.12	**214.72±13.53**	214.72±10.80
	Pigeon pea	11.11±0.28	86.86	115.49	**106.05±8.08**	106.05±5.32
Madhya Pradesh	Black gram	10.60±0.33	28.11	31.01	**29.56±1.59**	29.56±1.85
	Lentil	10.41±0.64	24.88	57.30	**38.32±7.77**	38.32±3.51
	Chick pea	10.92±0.66	129.24	297.80	**182.07±45.54**	182.07±13.62
Maharashtra	Black gram	11.55±0.12	43.12	53.44	**48.04±3.33**	48.04±3.16
	Chick pea	11.41±0.25	200.00	272.50	**234.13±18.89**	234.13±14.65
	Pigeon pea	11.38±0.25	94.47	155.00	**110.12±17.56**	110.12±10.92
Rajasthan	Black gram	11.23±0.35	31.83	47.37	**40.17±4.97**	40.17±3.96
	Chick pea	11.30±0.73	117.23	268.26	**158.76±38.61**	158.76±10.52
	Green gram	10.92±0.48	28.21	56.18	**45.70±5.29**	45.70±1.77
Uttar Pradesh	Black gram	12.00±0.14	36.1	39.7	**37.63±1.86**	37.63±3.53
	Chick pea	11.84±0.27	210.20	250.03	**216.06±26.14**	216.06±15.71
	Lentil	12.28±0.86	30.6	35.9	**33.02±2.36**	33.02±3.89
Gujarat	Pigeon pea	9.95±0.65	102.36	136.47	**111.61±6.32**	111.61±2.76
Karnataka	Pigeon pea	11.27±0.63	83.36	125.16	**103.43±8.95**	103.43±4.17

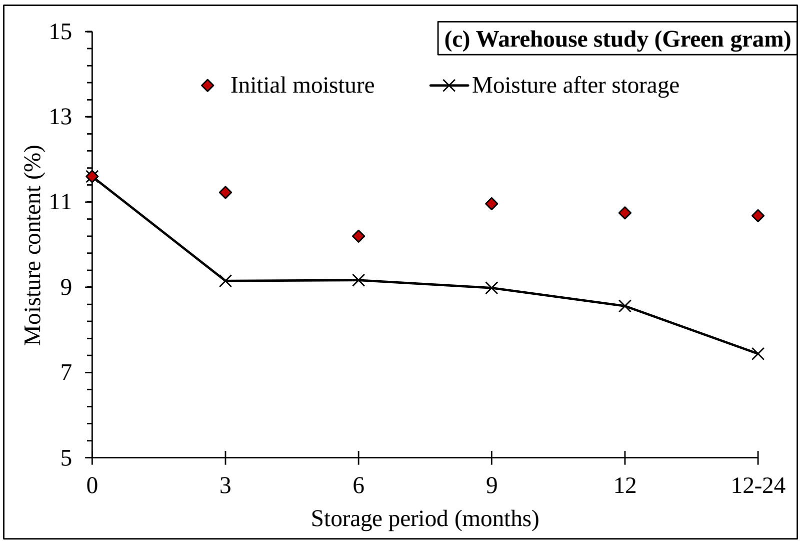
It may be observed from Table 3 that even when highest confidence interval (99.9%) was taken, the variations in 1000-grain weight of stored pulses might be considered of uniform size in Andhra Pradesh for black gram and pigeon pea only. In all the states, there were no uniformity in the grain size of pulses procured and stored. The grain size and 1000-grain weight play crucial role in milling and OTR and non-uniform size may affect these parameters negatively. This is because of increasing undersize content in the pulses created difficulty in setting machine parameter during milling. Therefore, the size grading of pulses becomes essential at the time of procurement. Further, in case of different varieties arriving in the same *mandi*, a distinction in size may be made and storage of both varieties may be done in separate stacks.

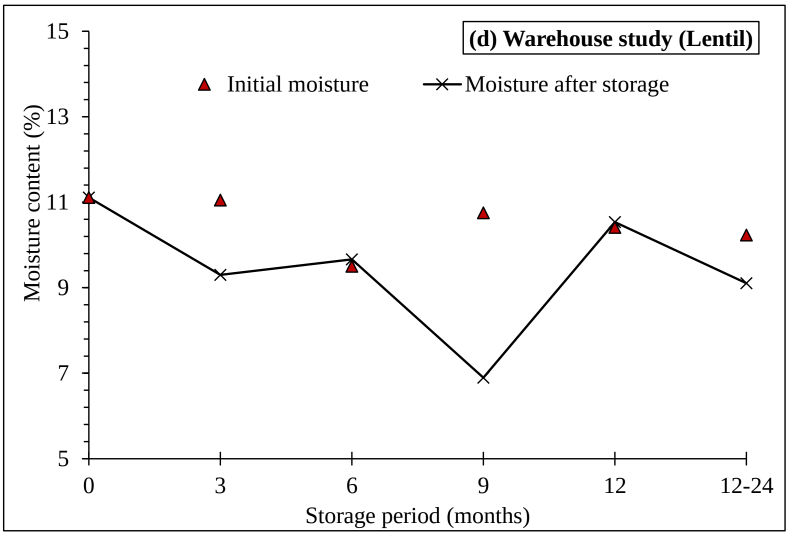
4.3.4 Change in moisture content with storage period

The variations in moisture content of pulses with storage period are shown in Fig. 6 (a-e).









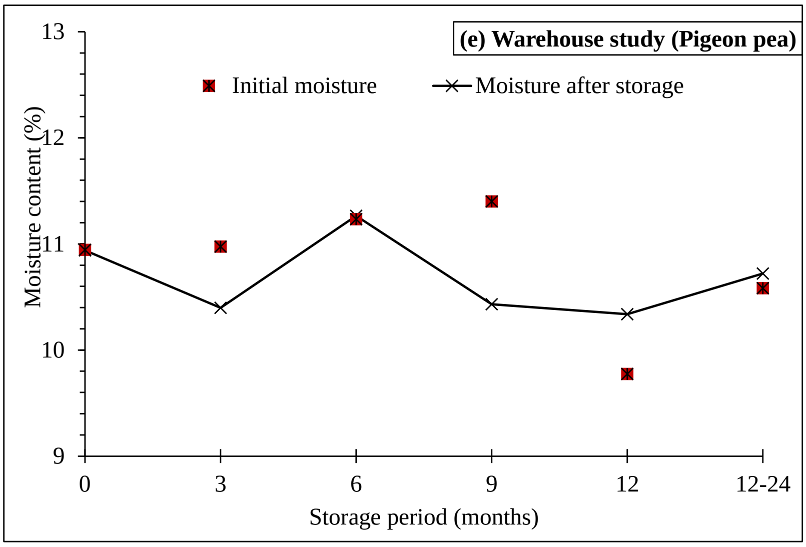


Fig. 6: Effect of storage period on moisture content of stored pulses: (a) Black gram, (b) Chick pea, (c) Green gram, (d) Lentil and (e) Pigeon pea

The difference in initial moisture contents (stacking moisture contents) were because of procurement of pulses at different durations. It may be observed that the moisture content of all the pulses decreased with increasing storage period. However, moisture content of pigeon pea and lentil increased with storage period when initial moisture content was less than 9.5%. The average moisture content of black gram, chick pea, green gram, lentil and pigeon pea stored in selected warehouses was 11.35%, 11.14%, 10.90%, 10.51%, and 10.82%, respectively at the time of storage. After 12 months of storage, the moisture contents of black gram, chick pea, green gram, lentil and pigeon pea decreased to 9.15%, 7.30%, 8.56%, 9.11%, and 10.34%, respectively. Thus, a reduction in weight from 0.48% (pigeon pea) to 3.84% (chick pea) may take place in 12 months storage of studied pulses. Such a decrease in weight may lead to monetary loss to the procuring agency. Further, the decreasing trend of moisture content indicated that the environmental conditions may increase or decrease the rate of moisture change, but the moisture content of pulses can reduce with increase in storage period. This happens because of storage of pulses at higher initial moisture contents. It necessitates the need for revision in the procurement moisture content norm to reduce the monetary loss and to avoid the issue of mass balance in the warehouses. Further, the recommended milling moisture content of pulses is 9-10% and therefore the procurement should be done near to this moisture content.

Warehouses are using resistance type moisture meters to measure the moisture content of pulses, which are not reliable. Therefore, the moisture content measured by moisture meter, as practiced in warehouses, and by scientific laboratory method were verified for the fresh stacks. The samples taken immediately after storage (within 15 days of storage) were analysed in the laboratory immediately. Warehouses reported moisture contents values higher by 0.3-2% than those were measured in the laboratory. This variation might be due to the several reasons including measurement errors, calibration, mixing of lots of different moisture in one stacks, etc. Further, the accuracy of moisture meters used by the warehouses were not calibrated for a particular pulse and accuracy is also poor (±0.2%). Therefore, mass balance may not be proper in storage of pulses in the warehouses.

4.3.5 Infestation level and its relationship with storage period and climatic condition

The type of insect infestation in the pulses and loss due to insect infestation with storage period is reported in Table 4.

Table 4: Effect of storage period on insect infestation in pulses stored in warehouses in different states

Pulse	Storage period (months)	Major infestation Insect name	Loss (%)	States where infestation was observed
Black gram	3	-	0.00	Andhra Pradesh, Maharashtra, Uttar Pradesh
	6	*C. chinensis*	0.38±0.28	
	9	-	0.05±0.06	
	12	*C. chinensis, Tribolium castaneum*	0.10±0.29	
	13-24	*C. analis* Psocids (*Liposcelis* sp.)	0.28±0.80	
Chick pea	3	*C. chinensis, Tribolium castaneum, Liposcelis* sp. (Psocids)	0.00	Andhra Pradesh, Maharashtra
	6	*C. chinensis*	0.23±0.01	
	9	*C. chinensis*	0.12±0.78	
	12	*C. chinensis*	0.08±0.11	
	13-24	*C. chinensis*, *Liposcelis* sp. (Psocids), *C. maculatus*	0.01±0.11	
Green gram	3	-	0.00	-
	6	-	0.00	
	9	-	0.00	
	12	-	0.00	
	13-24	-	0.00	
Lentil	3	-	0.00	-
	6	-	0.00	
	9	-	0.00	
	12	-	0.00	
	13-24	-	0.00	
Pigeon pea	3	*C. chinensis*	1.01±2.09	Andhra Pradesh, Gujarat, Karnataka, Maharashtra
	6	*C. chinensis*	0.54±0.83	
	9	*C. chinensis*	0.33±0.35	
	12	*C. chinensis*	0.33±0.61	
	13-24	*C. chinensis*	0.91±1.39	

The infestation in food grains may cause the loss of dry matter. However, such loss depends purely on the level of infestation. As per FCI norms, no insects per 500 g wheat/rice/paddy samples is considered as "Clear grain"; 1-2 insects per 500 g sample is considered "Few infestation" and more than 2 insects in 500 g sample is considered "Heavy infested grains". Further, the insects do not cause any loss in wheat when insect population is 3 or less (Keskin & Ozkaya, 2015) in initial six months of storage. The "Heavy" infestation may cause dry matter loss up to 0.03% in 1 month storage period in wheat (Keskin & Ozkaya, 2015).

However, this definition was not found applicable in case of pulses in this study. The dynamics of pulse beetles (*Callosobruchus chinensis,* also called bruchids) was observed to be different from insects found in wheat and rice (rice moth, khapra beetle etc.). The larvae of bruchids remain inside the grain and cannot be detected visually. The infestation by bruchids may be identified by white spots on the grain or hole in the grain, which is formed when the larvae becomes adult and escapes by making a hole in the grain. It was observed that the bruchids flew away from the pulse stock leaving a hole in the pulse, which could be identified by naked eye. Thus, in many cases, the samples taken from the stack showed 'clear' because no insect was found in the sample, but the damaged grains having holes were present in the samples. Though the warehouses adopted curative measures (fumigation) immediately whenever 2 or more insect population per 500 g sample was observed in fortnightly sampling observations as per standard FCI practice, the infested grains were still present in the pulses.

Therefore, although the loss due to insect infestation was measured successfully in this study, but the fumigation treatment effectiveness was not defined. However, it was identified in laboratory study. <u>A detailed separate study on this aspect is required to control the bruchids attack in pulses.</u>

The main bruchid identified to attack the stored pulses was *Callosobruchus chinensis* whereas *Callosobruchus maculatus* was found in chick pea. The maximum losses due to insect damage were 2.80% in black gram (Andhra Pradesh); 6.40% in chick pea (Andhra Pradesh); and 11.40% in pigeon pea (Karnataka), which indicated the severity of damage caused by the bruchids. Further, the losses due to infestation were observed in majority of the pulse samples collected from Andhra Pradesh, Gujarat, Karnataka, Maharashtra, and Uttar Pradesh (except lentil). The infestations were mainly observed in monsoon season (June to October) in these states. This might be because prolonged high temperature and high relative humidity (RH) are the favourable conditions for growth and multiplication of bruchids.

Though the average losses due to insect infestation were ≤1% (Table 4), it affected the OTR severely because the infested grains were converted into powder during milling. Thus, a proper bruchid management practice is required to be adopted during pulse handling and storage.

4.4 Milling Outturn (OTR) of Pulses Stored in Warehouses

Milling of the pulses at different study centres were performed using same machine (PDKV dal mill) with one SOP for one pulse and at the same operating parameters. Therefore, the variation in OTR due to machine and process were negligible. The storage periods were different and hence the storage period and infestation affected the OTR for all selected pulses.

4.4.1 OTR of dal from Pigeon pea

Milling of pigeon pea yielded two grades of dal i.e. Grade-I and Grade-II. The dal obtained by splitting gota is termed as Grade-I whereas the splits formed during dehulling was called Grade-II dal. The variation of OTR for different grades dal from pigeon pea with storage period is shown in Fig. 7.

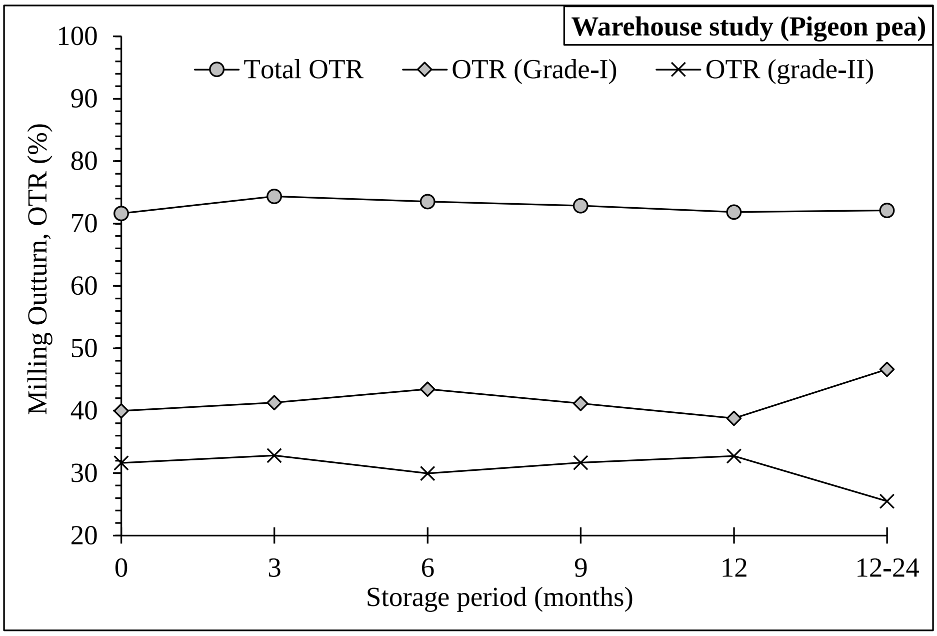


Fig. 7: Effect of storage period on dal recovery from pigeon pea

The total dal recovery from fresh pigeon pea was 71.61%, which increased to 74.37% after 3 months of storage and thereafter hovered around 72%. However the increase or decrease in OTR were not significant statistically ($p \geq 0.05$). The Grade-I dal recovery increased from 39.98% to 46.62% with storage period, though a decrease in the middle phase of storage period was also observed. The Grade-II dal recovery decreased with storage period. The change in recovery with storage period were mainly attributed to two factors namely bond between hull and cotyledon and infestation. The bond between hull and cotyledon is very tight in freshly harvested pigeon pea. With passage of time, the moisture content of pigeon pea goes down and hence the bond is loosened and recovery is generally increased. The level of infestation is the other factor and with increase in bruchid infestation, the recovery decreased because the infested grains were converted into powder during milling. A critical examination of data showed that 9-12 months of storage period samples were taken in the monsoon months and the level of infestation were high during that period. Thus, the decrease in OTR in these months were mainly attributed to the insect infestation.

It may be inferred from Fig. 7 that the Grade-I, Grade-II and total dal recovery from pigeon pea may vary between 38.79-46.62%, 25.51-32.82%, and 71.61-74.37%, respectively.

4.4.2 OTR of dal from Chick pea

Milling of chick pea yielded two grades of dal i.e. Grade-I and Grade-II. The variation in OTR for different grades dal from chick pea with storage period is shown in Fig. 8.

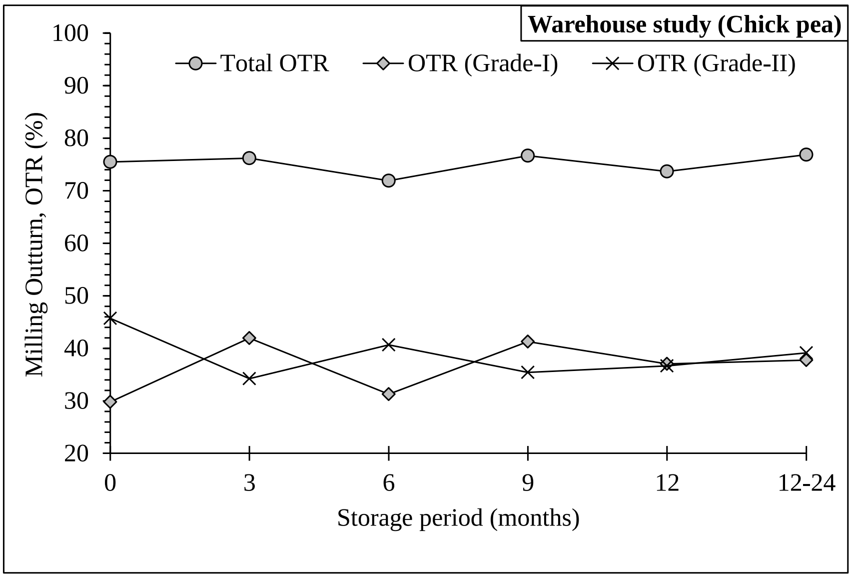


Fig. 8: Effect of storage period on dal recovery from chick pea

The total dal recovery from fresh chick pea was 75.49%, which increased to 76.86% after 12 months of storage and ranged between 71.90-76.86% during the study period, though the changes were not significant ($p \geq 0.05$). The Grade-I dal recovery was 29.79% from fresh chick pea and increased up to 41.95% after storage. The Grade-II recovery ranged between 34.24-45.69% during storage. The changes in recovery with storage period were mainly due to the wide variation in seed size and bruchid infestation in the monsoon months. In fact, the recovery from small size grains were significantly less than the bolder grains and adjustment of machine parameters was not possible for smaller seeds. Thus, the size grade or 1000-grain weight of pulses should be used as a criteria for procurement and further storage of whole pulses should be done in separate stacks.

It may be inferred from Fig. 8 that the Grade-I, Grade-II and total dal recovery from chick pea vary between 29.79-41.95%, 34.24-45.69%, and 71.90-76.86%, respectively. The Grade-I dal recovery in chick pea was significantly lower than that of pigeon pea.

4.4.3 OTR of dal *dhuli* from Black gram

Dehulled whole grains (gota) and dehulled splits (dal) are considered as *dal dhuli* for black gram. The variation in OTR for different type/ form of dal from black gram with storage period is shown in Fig. 9.

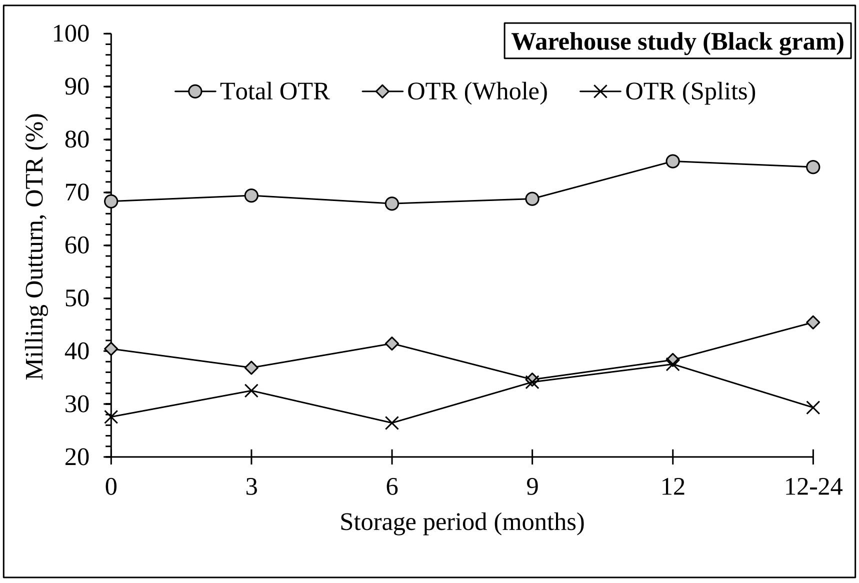


Fig. 9: Effect of storage period on dal dhuli recovery from Black gram

The total dal recovery from fresh black gram was 68.30%, which increased to 75.92% after 12 months of storage and the increase in OTR was statistically significant ($p<0.05$). The recovery of *dal dhuli* fluctuated with storage period. The change in recovery with storage period were mainly due to the wide variation in seed size (particularly in Rajasthan), bruchid infestation in the monsoon months, and loosening of bond with increase in storage period.

It may be inferred from Fig. 9 that the total dal recovery from black gram vary between 67.89-75.92% and recovery will increase significantly with increase in storage period.

4.4.4 OTR of dal *dhuli* from Green gram

Green gram samples were collected from Rajasthan state only because it was not stored in other states. Similar to the black gram, dehulled whole grains and dehulled splits are considered as *dal dhuli* for green gram also. The variation in OTR for different type/ form dal from green gram with storage period is shown in Fig. 10.

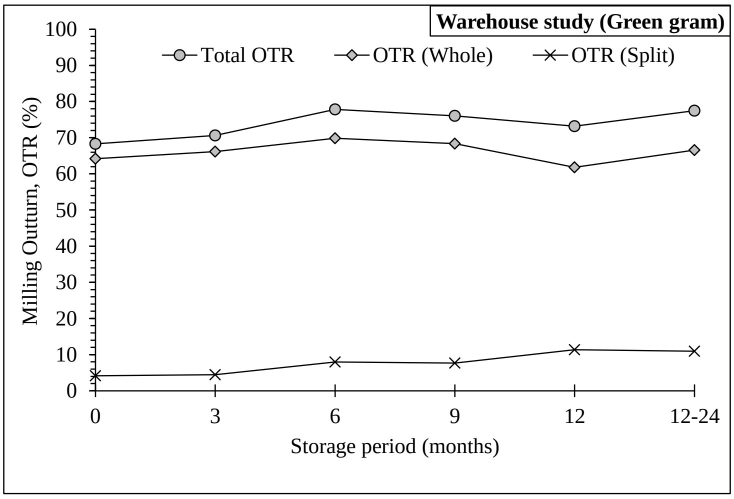


Fig. 10: Effect of storage period on dal *dhuli* recovery from green gram

The total dal recovery from fresh green gram was 68.31%, which increased up to 77.49% beyond 12 months of storage and the increase in OTR was statistically significant ($p<0.05$). The recovery of *dal dhuli* increased with increase in storage period. The increase in recovery with increasing storage period was mainly due to no infestation in green gram stored in Rajasthan during the entire study period, particularly in the Western part of Rajasthan even in the monsoon months.

It may be inferred from Fig. 10 that the total *dal dhuli* recovery from green gram may increase significantly with increase in storage period and more recovery may be expected from millers with passage of storage period.

4.4.5 OTR of dal from Lentil

Lentil samples were collected from Madhya Pradesh and Uttar Pradesh. Similar to the black gram and green gram, dehulled whole and dehulled splits are considered as dal *dhuli* for lentil. The variation in OTR for dal from lentil with storage period is shown in Fig. 11.

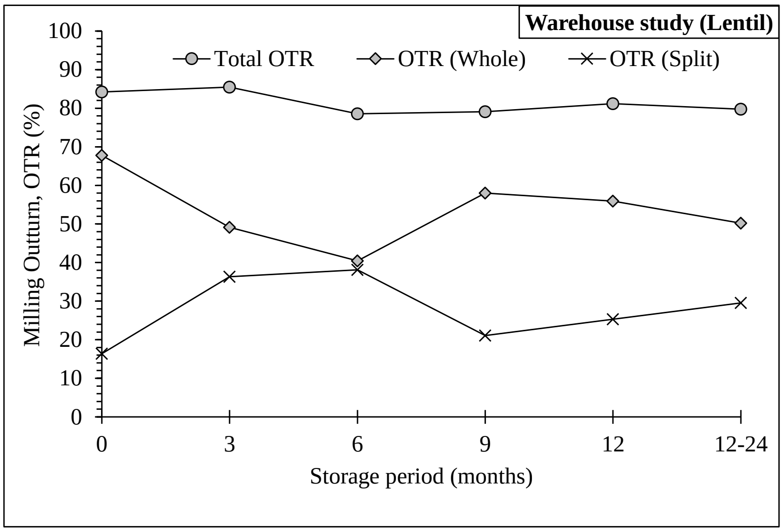


Fig. 11: Effect of storage period on dal *dhuli* recovery from lentil

The total dal recovery from fresh lentil was 84.20%, which decreased up to 79.74% beyond 12 months of storage though the decrease in OTR was not significant statistically ($p \geq 0.05$). The recovery of dehulled whole and dehulled splits fluctuated with storage period. The decrease in recovery with storage period was mainly due to the wide variation in grain sizes. In the fresh samples, the grain size was bold and hence recovery was high, however, in the subsequent samplings, proportion of small size grains were quite high and hence the recovery decreased because the machine parameters could not be adjusted according to grain size. Thus, the size grade or 1000-grain weight must be used as a criteria for procurement of lentil and storage of both grades should be done in different stacks. It may be inferred from Fig. 11 that the total dal recovery from lentil may decrease with storage period to some extent.

4.4.6 Milling Efficiency and Milling Loss

Performance of a machine is judged by its ability to produce maximum desired material with minimum product loss. Accordingly, dehulling efficiency and dehulling loss represent the machine performance and pre-treatment efficacy. The variations in dehulling efficiency and dehulling loss for selected pulses with storage period are presented in Fig. 12 and Fig. 13, respectively.

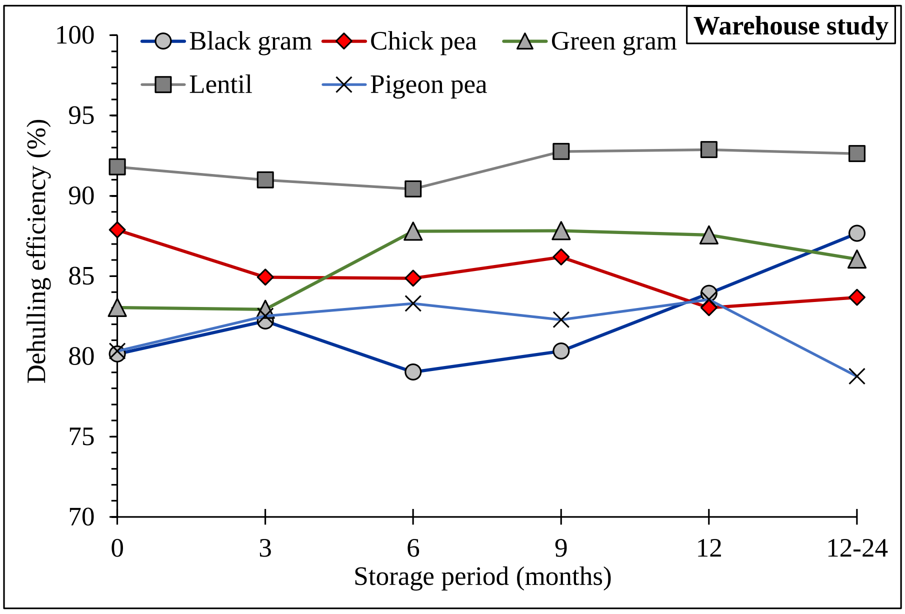


Fig. 12: Variation in dehulling efficiency with storage period for selected pulses

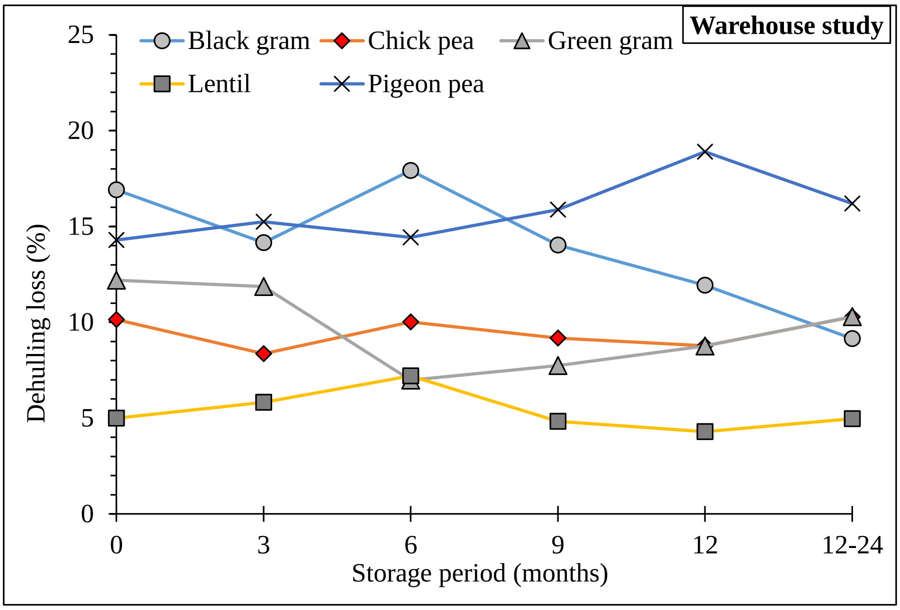


Fig. 13: Variation in dehulling loss with storage period for selected pulses

Dehulling efficiency of lentil was highest among all the selected pulses because lentil is easy-to-mill and pre-milling treatments are not required for this pulse. Further, the infestation was not observed during storage of lentil and the dehulling loss (broken and powder formation) ranged between 4.29-7.20%. The dehulling efficiency of pigeon pea was minimum among all the selected pulses because this pulse is difficult-to-mill, hence considerable loss in the form of broken and powder took place during milling. Additionally, the insect infestation and variation in grain size (1000-grain weight) of pulses were other reasons for decrease in dehulling efficiency and increase in dehulling loss with increasing storage period. Further, Fig. 12-13 indicated that the dehulling losses increased with decreasing OTR as well as with decreasing dehulling efficiency. It may, therefore, be inferred that the dal mill used in this study gave satisfactory performance for all pulses and the variations in OTR, dehulling efficiency and dehulling loss were due to increase in storage period, level of infestation, and varied grain sizes.

4.4.7 General Observations about Warehouse Storage Practices

- In majority of the private warehouses, stacks were placed on the polyethylene sheet at the floor and wooden/plastic dunnage were not used.
- There were some warehouses where inconsistency in the data recording and management practices were observed, particularly in Madhya Pradesh. In many cases, the stack charts were missing and records of fumigation and prophylactic treatments were not updated for months.

- The common method of aeration in the warehouses was through natural ventilation by opening the warehouse doors during office hours in a day. Such practices are not sufficient to maintain proper storage environment inside a warehouse having 10-12 stacks with more than 3000 bags in each stack. Further, the chances of cross-infestation may be high in such cases.
- The storage management practices were not properly followed in the Central Warehousing Corporation (CWC) godowns. In many cases, the samples of pulses, in the present study, were not taken from CWC warehouses because of very old stock of pulse kept unattended.
- In some warehouses, pulses were stacked in one chamber along with stacks of groundnut pods and other grains. Such practice are not appropriate for proper storage management of pulses. Groundnut pods are more vulnerable to bruchid attack and very fast infestation may take place in the pulses also.
- Proper quality testing facilities including essential instruments were not available with majority of the private/ SWCs/ CWC warehouses. Further, no separate room for quality testing of samples were found in most of the warehouses.

4.5 Laboratory Storage Study of Whole Pulses and OTR

Whole pulses (1050 kg,) packed in gunny bags (50 kg/ bag) were stored in laboratory as per the stacking method of FCI. The storage places of the pulses were: Chick pea at PDKV, Akola (Maharashtra); Pigeon pea at UAS, Raichur (Karnataka); Black gram at MPUA&T, Udaipur; Green gram at ICAR-CIPHET, Ludhiana (Punjab); and Lentil at ICAR-IIPR, Kanpur (Uttar Pradesh). About 500 g samples were taken weekly for quality analysis and insect infestation levels. Further, 20 kg sample of each whole pulse was drawn every month for determination of OTR. The results of laboratory study are discussed in this section.

4.5.1 Quality of Stored Pulses

Though the pulses were supposed to be stored in the laboratory after proper cleaning, some quantity of foreign matter still remained in chick pea and pigeon pea samples. The extent of foreign matter, admixture and damaged grains were estimated every month. The quality of pulses stored in laboratory are presented in Table 5.

Table 5: Quality characteristics of pulses at the time of procurement and after storage in laboratory conditions in different states

State name	Pulse	Initial moisture content (%)	Foreign matter (%)	Admixture (%)	Damaged grain (%)	Total unwanted matter (%)	1000-grain weight (g)	Bulk density (kg/m^3)
Karnataka	Pigeon pea	10.50	0.10	0	0	**0.10**	112.95 ±3.73	834.81 ±8.13
Maharashtra	Chick pea	9.89	0.16	0	0	**0.16**	235.85 ±18.08	770.20 ±15.26
Rajasthan	Black gram	11.10	0	0	0	**0.00**	45.75 ±1.09	915.55 ±32.88
Punjab	Green gram	10.61	0	0	0	**0.00**	33.79 ±0.53	893.87 ±24.79
Uttar Pradesh	Lentil	9.90	0	0	0	**0.00**	38.11 ±1.81	904.73 ±39.44

The moisture content of pulses at the time of storage ranged between 9.89% (chick pea) to 11.10% (black gram). Thus, the initial moisture content of different pulses was well within the safe limit of storage. In chick pea and pigeon pea, only 0.16% and 0.10% foreign matter was present initially whereas the other pulses were free from any unwanted material.

4.5.2 Change in moisture content with storage period

In the laboratory study, green gram and lentil were stored in December 2019, black gram in February 2020, pigeon pea in April 2020, and chick pea was stored in June 2020. Therefore, the month-wise variations in moisture content of whole pulses during storage are shown so that effect of environmental conditions can be observed clearly. The variations in moisture content of pulses with storage period (month-wise) are shown in Fig. 14.

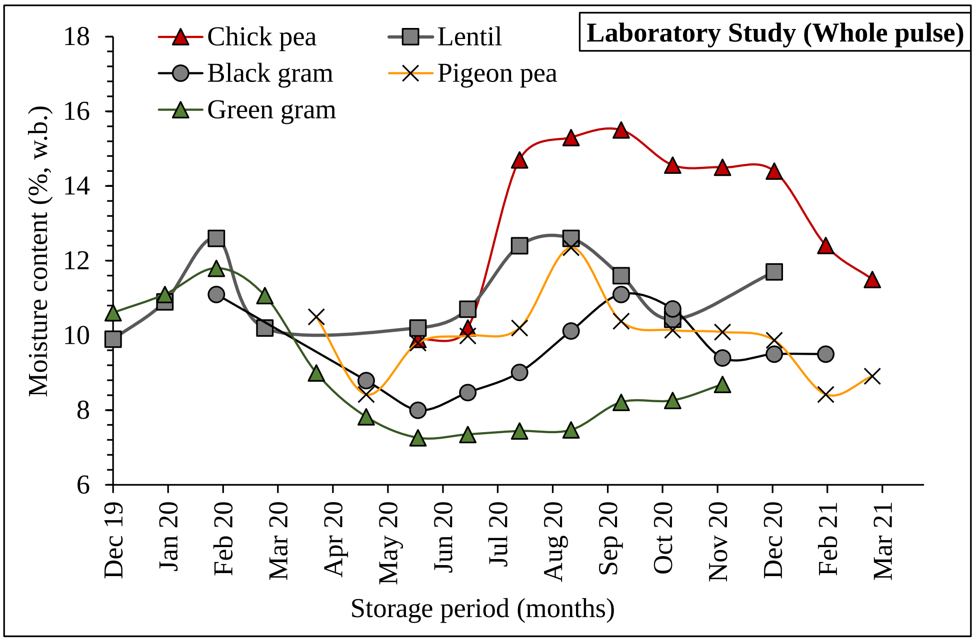


Fig. 14: Effect of storage period on moisture content of pulses

It may be observed that the moisture content of green gram and lentil increased in February 2020 (in 3rd month). This increase was due to continuous cloudy condition with frequent rain for about 15 days. Consequently, the stored pulses gained moisture. Similarly, the moisture content of black gram was also found higher in the commercial sample procured in month of February 2020, prior to storage.

Moisture contents of all the pulses decreased after February 2020, which continued up to June 2020 due to hot and dry weather conditions (summer season) during this period. All the pulses gained moisture during July 2020-September 2020 because the environmental conditions were hot and humid with frequent rainfall (monsoon season). Thereafter, moisture content of pulses was found decreased after October 2020 due to cold and dry environmental conditions (winter season) in case of all selected pulses except lentil.

It was further observed from Fig. 14 that the chick pea gained or lose moisture at much faster rate in comparison to the other pulses followed by lentil. The moisture absorbed by green gram was least in comparison to the other pulses.

The moisture content of chick pea was 9.89% at the time of storage in June 2020, which was increased to 15.50% in October 2020 and 11.50% in March 2021. Thus, a gain of about 1.5% is expected during storage of chick pea.

Pigeon pea was stored at 10.50% moisture content in April 2020, reached to 12.35% in September 2020 and finally attained 8.91% in March 2021. It indicated that pigeon pea may lose more weight, if stored at higher moisture contents.

Black gram was stored at 11.10% moisture content in February 2020 and its moisture content reduced continuously. Even after gain of moisture in the monsoon season, the moisture content was 11.10% in October 2020 and finally reached to 9.50% in March 2021. It indicated that black gram should be stored at lesser moisture content to avoid weight loss during storage.

Green gram was stored at 10.61% moisture content in December 2019, reached to 11.80% in February 2020 due to prolonged rainy days in this month and thereafter lose moisture continuously even in monsoon season and finally reached to 8.69% moisture in December 2020. It indicated that green gram should be stored at lesser moisture content to avoid weight loss during storage.

Storage of lentil was done at 9.90% moisture content in December 2019, reached to 12.60% in February 2020 due to prolonged rainy days during this month. Then decreased and again increased during monsoon season and attained 12.60% moisture content in September 2020. Thereafter, the moisture content decreased and finally reached to 11.70% moisture in January 2021. It indicated that lentil absorbs and lose moisture at a faster rate and gain of 1.5% is expected when lentil is stored at <10% moisture content.

It may be inferred from this study that the pulses should be procured and stored at around 10% moisture content. Procurement and storage at higher moisture content may lead to weight loss and a concern of mass balance may arise. Further, a weight gain of 1.5% is expected after 9 months of storage in chick pea and lentil, if stored at <10% moisture content. Moreover, in pigeon pea, black gram and green gram stored at <10% moisture content, a weight loss of about 1% is expected in summer season only.

4.5.3 Infestation level and its relationship with storage period and climatic condition

As the pulses were stored during different months, month-wise comprehensive table was prepared to understand the role of climatic conditions on insect attack in the selected pulses. Further, the curative measures were adopted immediately (Phosphine fumigation) but the impact was not much towards the loss of dry matter. The extent of infestation and loss due to insect infestation with storage period are shown in Fig. 15 and Table 6.

Table 6: Variation in pulse beetle (bruchid) infestation and curative measures with storage month

Storage period (month)	Chick pea			Pigeon pea			Black gram			Green gram			Lentil		
	EC	TF	Loss (%)	EC	TF	Loss (%)	EC	TF	Loss (%)	EC	TF	Loss (%)	EC	TF	Loss (%)
Dec 2019	-	-	-	-	-	-	-	-	-	CD	-	0	CD	-	0
Jan 2020	-	-	-	-	-	-	-	-	-	CD	-	0	CD	-	0
Feb 2020	-	-	-	-	-	-	-	-	0	CH	2	0.01	CH	1	0.30
Mar 2020	-	-	-	-	-	-	-	-	-	CD	-	0	CD	-	0
Apr 2020	-	-	-	HD	-	0	HD	-	-	HD	-	0	HD	-	-
May 2020	-	-	-	HD	-	0	HD	-	0	HD	-	0	HD	-	-
Jun 2020	HD	-	0.00	HD	-	0	HD	-	0	HD	-	0	HD	-	0
Jul 2020	HH	-	0.00	HH	1	0.10	HD	-	0	HH	-	0	HH	-	0
Aug 2020	HH	-	0.00	HH	-	0.09	HD	-	0	HH	-	0	HH	-	0
Sep 2020	HH	2	0.80	HH	-	0.11	HD	-	0	HH	-	0.01	HH	-	0
Oct 2020	HH	-	0.50	HH	-	0.15	HD	-	0	N	1	0.02	HH	-	0
Nov 2020	N	-	0.54	N	1	0.18	CD	-	0	CD	1	0.08	CD	-	0
Dec 2020	CD	-	0.52	N	1	0.25	CD	-	0	CD	-	0	CD	-	-
Jan 2021	CD	-	0.56	N	-	0.28	CD	-	0	-	-	-	CD	-	0
Feb 2021	N	-	0.52	N	-	0.3	CD	-	0	-	-	-	-	-	-
Mar 2021	N	-	0.56	N	-	0.33	-	-	-	-	-	-	-	-	-

EC: Environmental condition; TF: Fumigation treatment frequency; HH: Hot and humid climate; HD: Hot and dry climate; CH: Cold and humid climate; CD: Cold and dry climate, N: Normal environment.

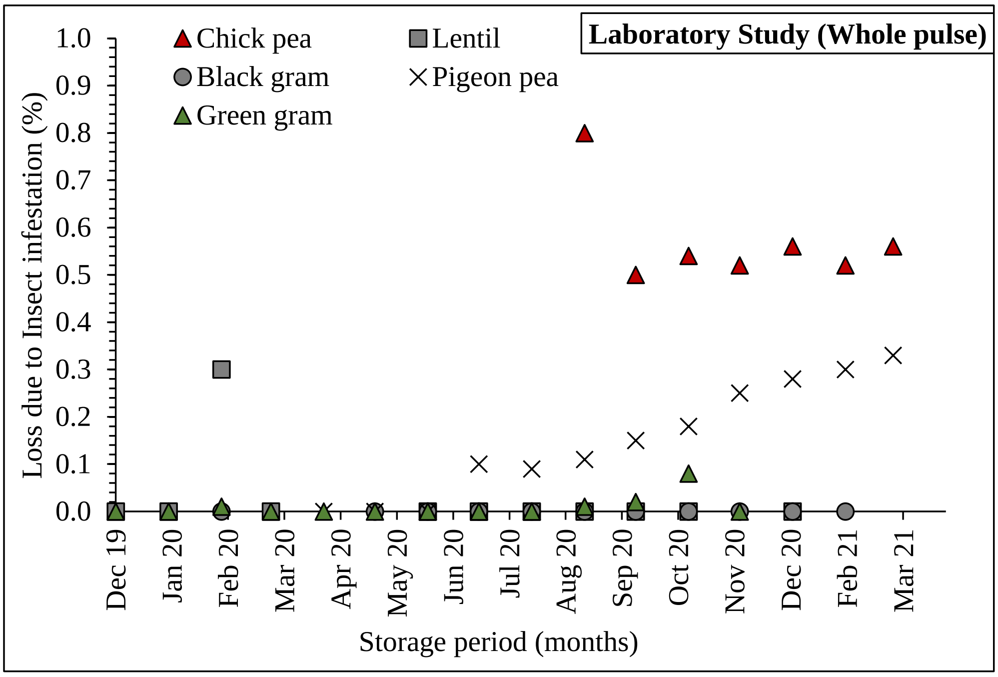


Fig. 15: Incidence of bruchid infestation and extent of loss with storage period

The bruchid infestation in black gram was not observed because the storage was done in Rajasthan where climatic condition was hot/cold and dry. Further, the bruchid infestation was observed in all other pulses when humid climate prevailed irrespective of environmental temperature. Green gram (Punjab) and lentil (Uttar Pradesh) were infested even in the February month when environmental temperature was <20°C, however RH was >75% for 18 days in this month at the study locations. Further, the bruchid infestation in pigeon pea, chick pea, and green gram were observed in the monsoon season. It suggests that RH plays important role for the infestation of bruchids in pulses.

It may be observed from Fig. 15 that the loss due to infestation remained unchanged in chick pea after first incidence in September 2020. Thus, the damage caused by bruchids was in the entire lot of chick pea and it was not limited to the outer periphery of the stack. It also indicated that the fumigation treatment controlled the bruchids effectively. Similar was the case with lentil and green gram too. However, in pigeon pea, the loss due to bruchids increased to some extent even after fumigation, which indicated the vulnerability of pigeon pea towards bruchids. Repetitive treatment is therefore necessary for pigeon pea after observance of bruchids.

Further, it was observed that the bruchids came again in stored green gram and chick pea after fumigation treatment and hence the treatment was repeated again within one week of first fumigation. The incidence of bruchid attack after first fumigation was observed visually in the stored stack whereas the sample analysis showed 'clear' after fumigation treatment. This was because of the dynamics of bruchids as the adults fly away from the grain lot and many a times these were not present in the grain samples. Therefore, insect traps should be used in the storage area to identify the incidence of bruchids. Further, sampling is essential every week in monsoon season or whenever the RH remains >65% for more than 4-5 days continuously.

4.5.4 Milling Outturn (OTR) of Pulses with Storage Period

Milling of the pulses, stored in the laboratory were done every month with the same machine (PDKV dal mill) as per SOP using the same operating parameters. The variation of Total OTR, Grade-I OTR, Grade-II OTR, dehulling efficiency, and dehulling loss with storage period for the pulses are shown in Fig. 16, 17, 18, 19, and 20, respectively.

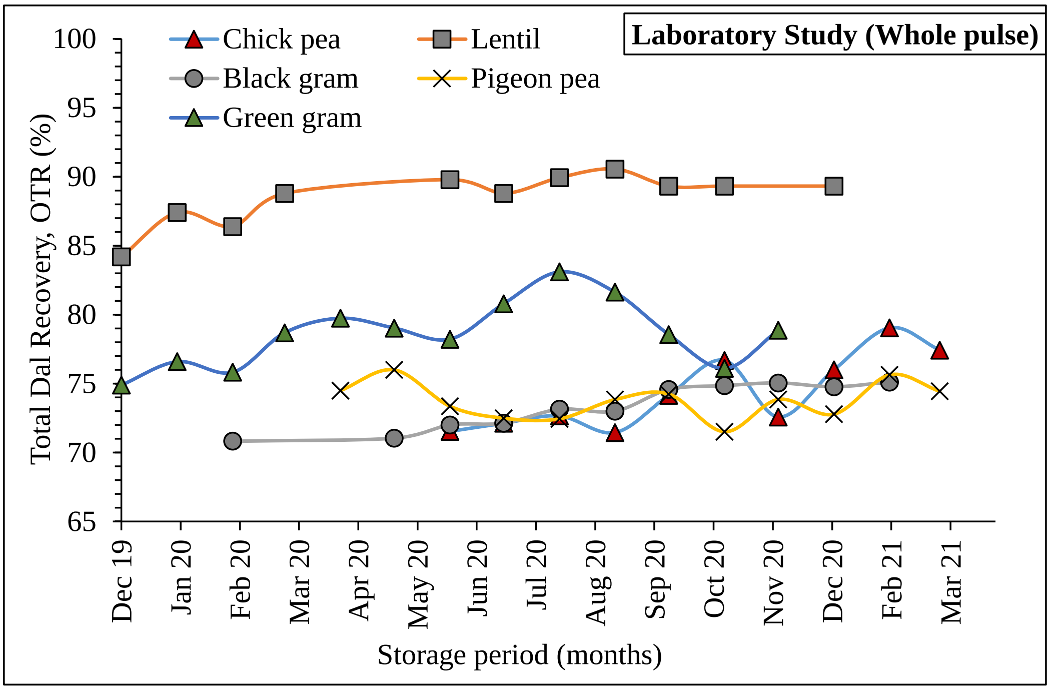


Fig. 16: Effect of storage period on Total OTR from selected pulses

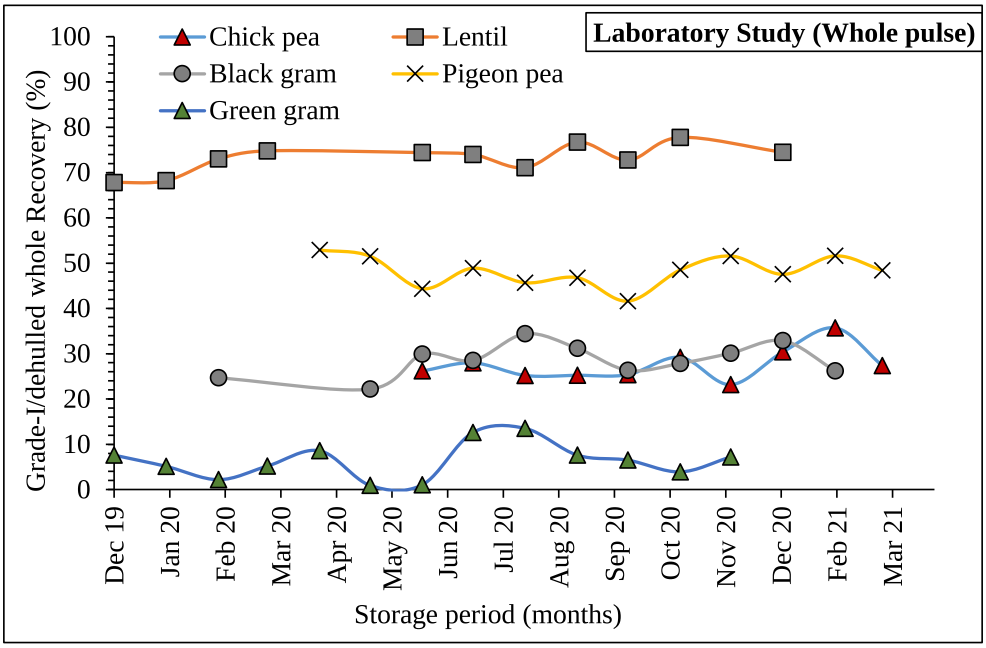


Fig. 17: Effect of storage period on Grade-I/ dehulled whole recovery from pulses

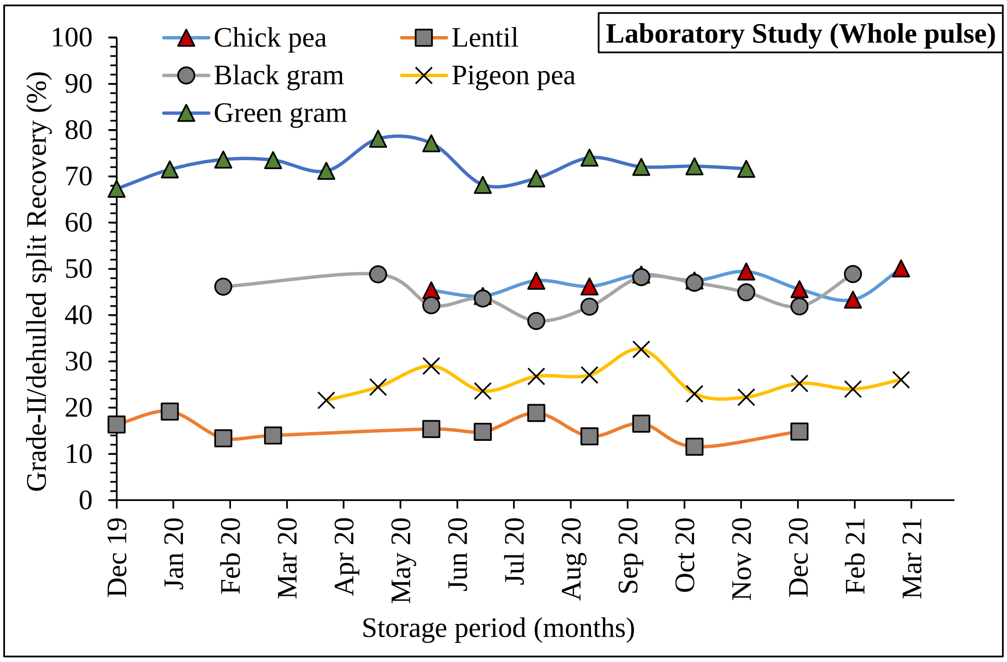


Fig. 18: Effect of storage period on Grade-II/ dehulled split recovery from pulses

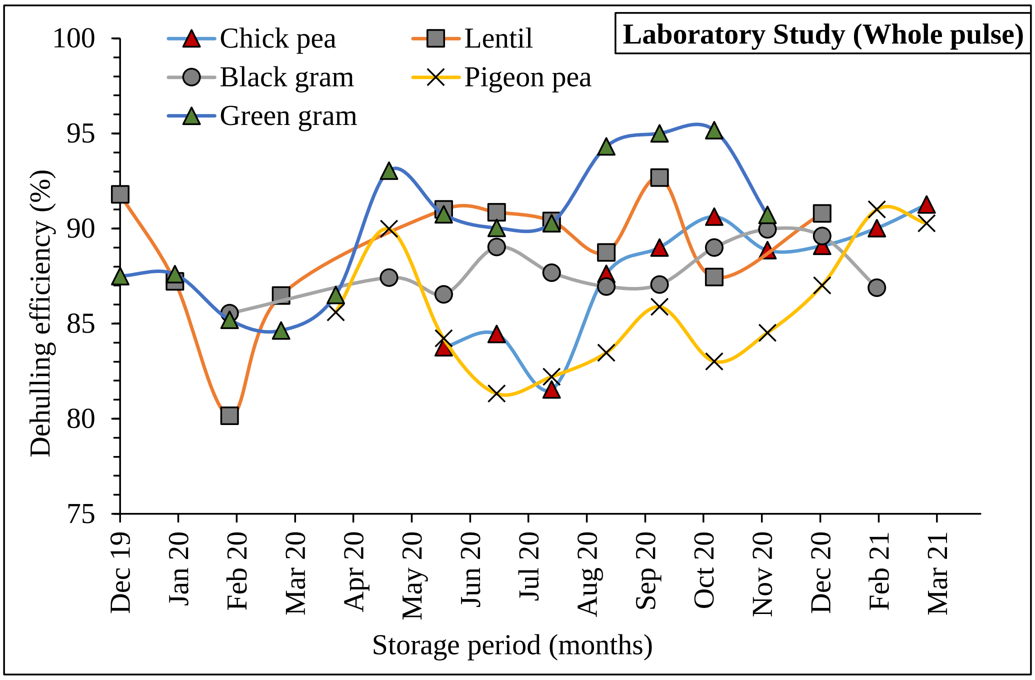


Fig. 19: Effect of storage period on dehulling efficiency of pulses

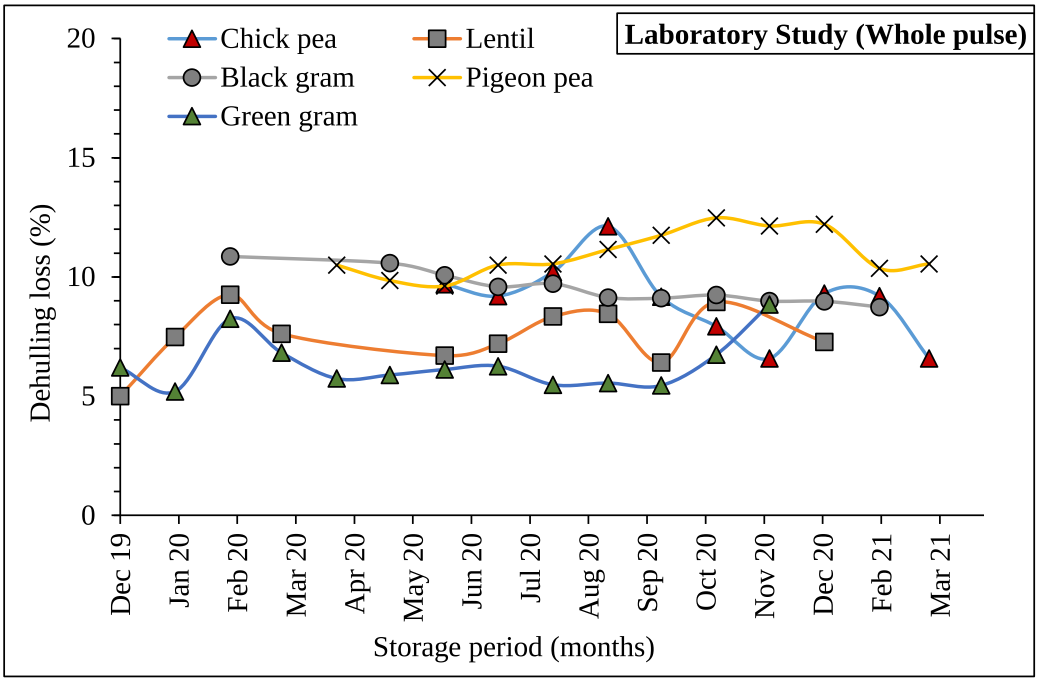


Fig. 20: Effect of storage period on dehulling loss during milling of pulses

The total OTR from chick pea, pigeon pea, black gram, green gram, and lentil varied between 71.46-79.05%, 71.52-75.64%, 72.02-75.12%, 74.90-83.11%, and 84.20-90.57, respectively. Further, the total OTR increased in general with storage period unless extraneous factors (insect infestation) caused damage to the stored pulses. Whenever the insect infestation has been observed (Fig. 15), the OTR of pulses decreased (Fig. 16), dehulling efficiency decreased considerably (Fig. 19), and dehulling loss increased (Fig. 20). For example, the infestation in green gram and lentil was observed in February 2020, and total OTR decreased whereas dehulling loss increased in this month. Similarly, in chick pea infestation was for the first time in September and dehulling loss was highest in this month. It may be inferred that the recovery of pulse (OTR) will increase with increase in storage duration in the absence of insect infestation. Further, the infestation resulted in increase of the broken and powder formation during milling of pulses.

The Grade-I and Grade-II dal OTR from chick pea ranged between 23.16-35.70%, and 43.35-50.09%, respectively. Whereas in pigeon pea, the Grade-I and Grade-II dal OTR varied between 41.61-52.89%, and 21.61-29.78%, respectively. The Grade-I dal OTR increased with storage period, however, this increase was not significant ($p \geq 0.05$). The higher OTR in laboratory study might be due to uniformity in seeds sizes and lower level of infestations.

The OTR for dal *dhuli* from black gram increased significantly from 70.83% (fresh grains) to 75.12% (after 12 months of storage) with storage period. However, in green gram, the OTR for dal *dhuli* increased significantly from 74.90% (fresh grain) to 83.11% up to 8 months of storage and thereafter decreased. The decrease was mainly attributed to the infestation in September month, which was also evidenced from increase in dehulling loss.

The OTR for dal from lentil increased significantly with storage period from 84.20% in the beginning of storage to 89.33% after 12 months of storage. Further, the dehulled whole recovery of lentil also increased with storage period, which indicated that dehulling became easier with increasing storage period.

Further, a slight decrease in the OTR of lentil, pigeon pea, and green gram were observed after 12 months of storage in laboratory storage study. Such decrease indicated that the storage period of whole pulses should not be more than one year owing to additional cost in maintaining the stock, need of frequent fumigation to control insect infestation, and increase in Grade-II dal recovery.

4.6 Storage Study of Dal

Initial moisture content of the dal samples prepared from fresh procured pulses was measured and then samples of 10%, 12% and 14% moisture content were prepared by adding water or drying as elaborated in Section 3.3. Dal samples were then packed in low density polyethylene bags (LDPE) of 25, 50 and 75 micro-meter (μ) thickness. A total 5 kg dal was packed in each bag and total quantity of dal used in the study was 1350 kg of each selected pulses. The storage places of the dals were: Chick pea at PDKV, Akola (Maharashtra); Pigeon pea at UAS, Raichur (Karnataka); Black gram at MPUA&T, Udaipur; Green gram at ICAR-

CIPHET, Ludhiana (Punjab); and Lentil at ICAR-IIPR, Kanpur (Uttar Pradesh). Two randomly selected packets were opened every month for quality analysis and discarded after the analysis. Some of the quality parameters were analysed quarterly. The results of laboratory study for storage of dal are discussed in this section.

4.6.1 Change in moisture content with storage period

In the laboratory study, green gram and lentil were stored in December 2019, black gram was stored in February 2020, pigeon pea was stored in April 2020, and chick pea was stored in June 2020. Therefore, the variations are shown with month of storage so that effect of environmental conditions may be observed clearly. The variations in moisture content of pulses with storage period (month of storage) are shown in Fig. 21, 22, 23, 24 and 25 for pigeon pea, chick pea, black gram, green gram, and lentil, respectively.

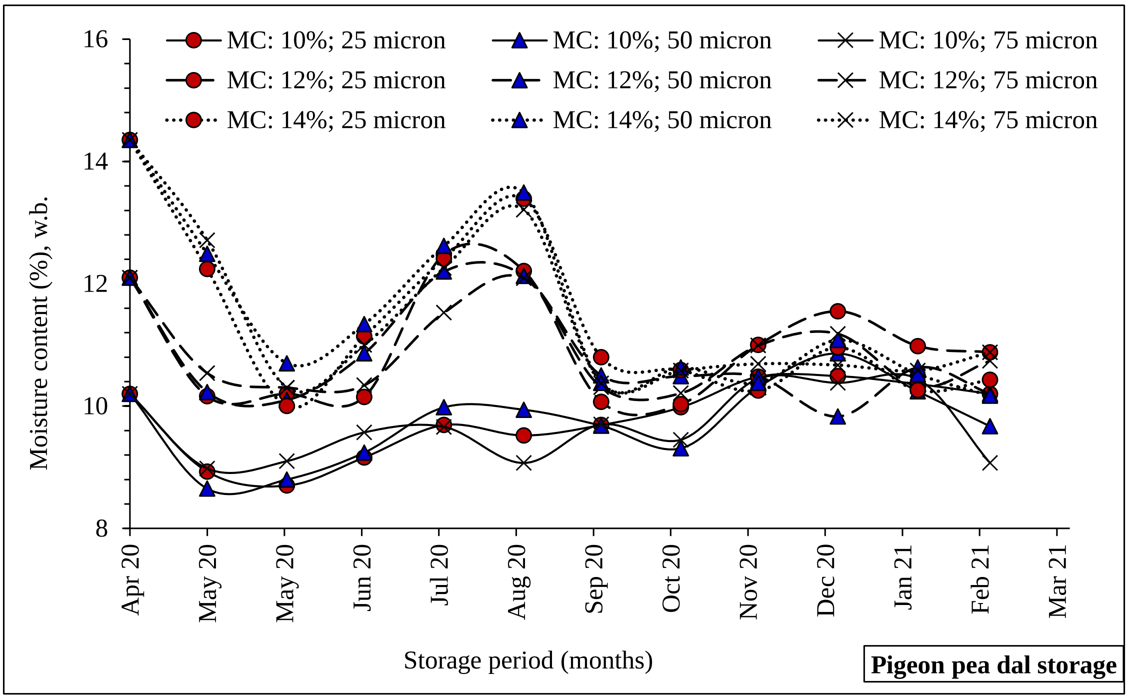


Fig. 21: Effect of storage period on moisture content of pigeon pea dal

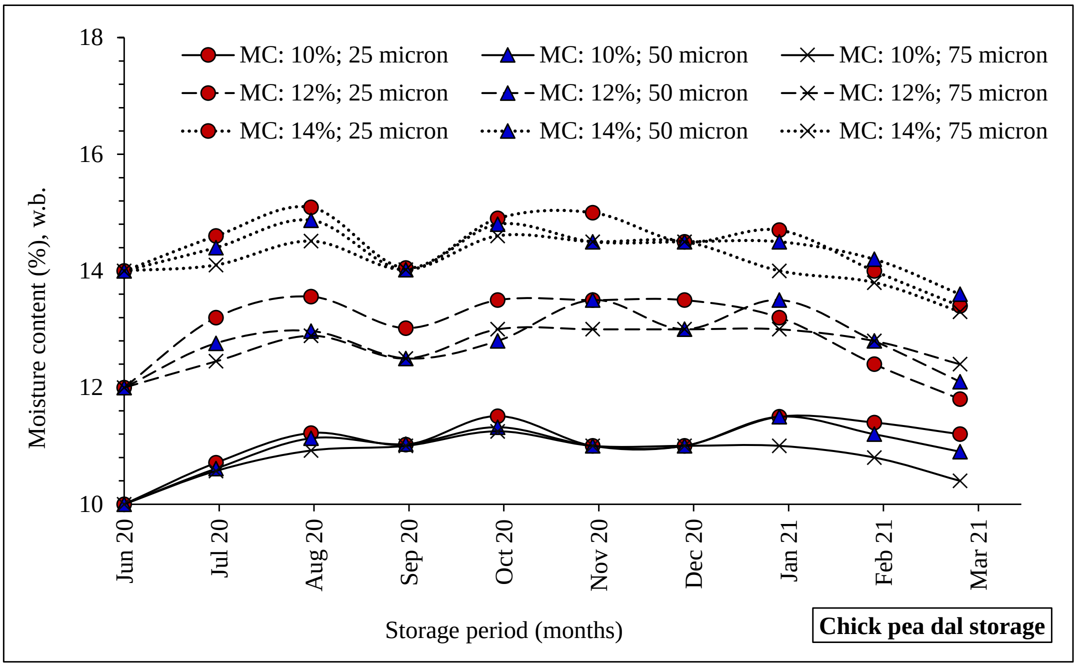


Fig. 22: Effect of storage period on moisture content of chick pea dal

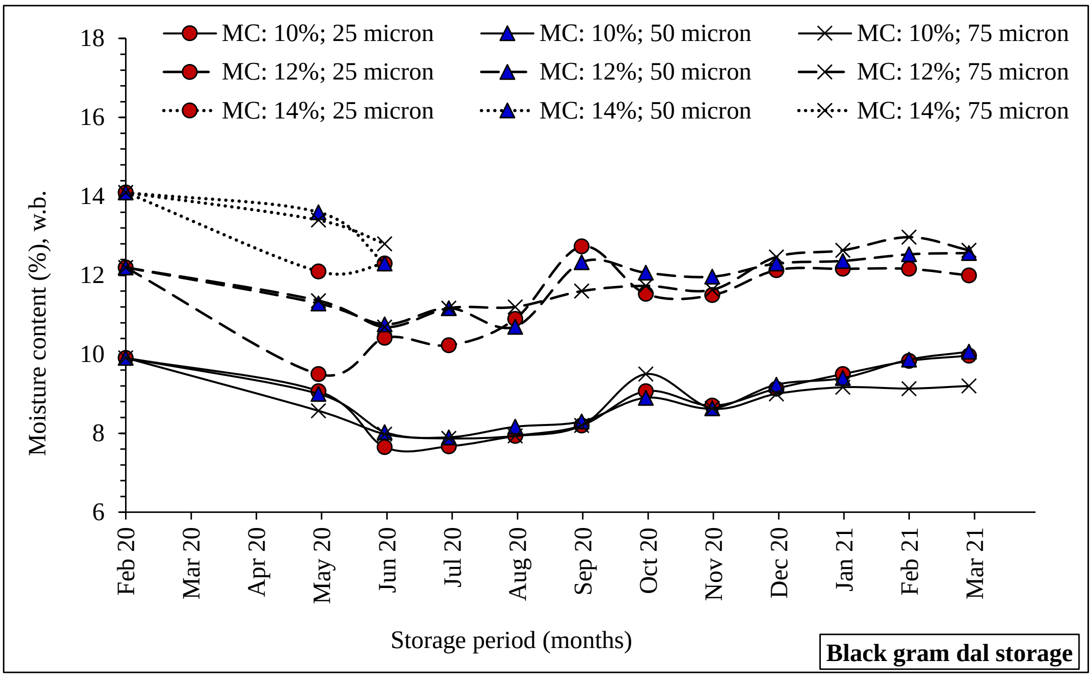


Fig. 23: Effect of storage period on moisture content of black gram dal (*Visual fungal growth at 14% moisture after June 2020 and samples discarded***)**

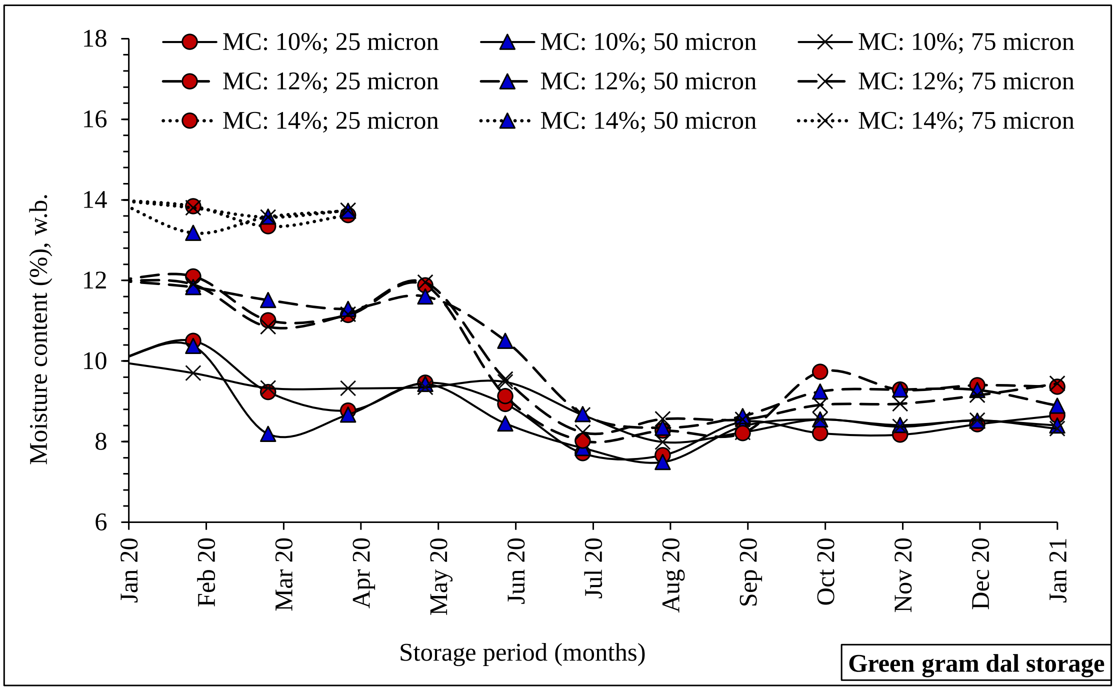


Fig. 24: Effect of storage period on moisture content of green gram dal (*Visual fungal growth at 14% moisture after April 2020 and samples discarded*)

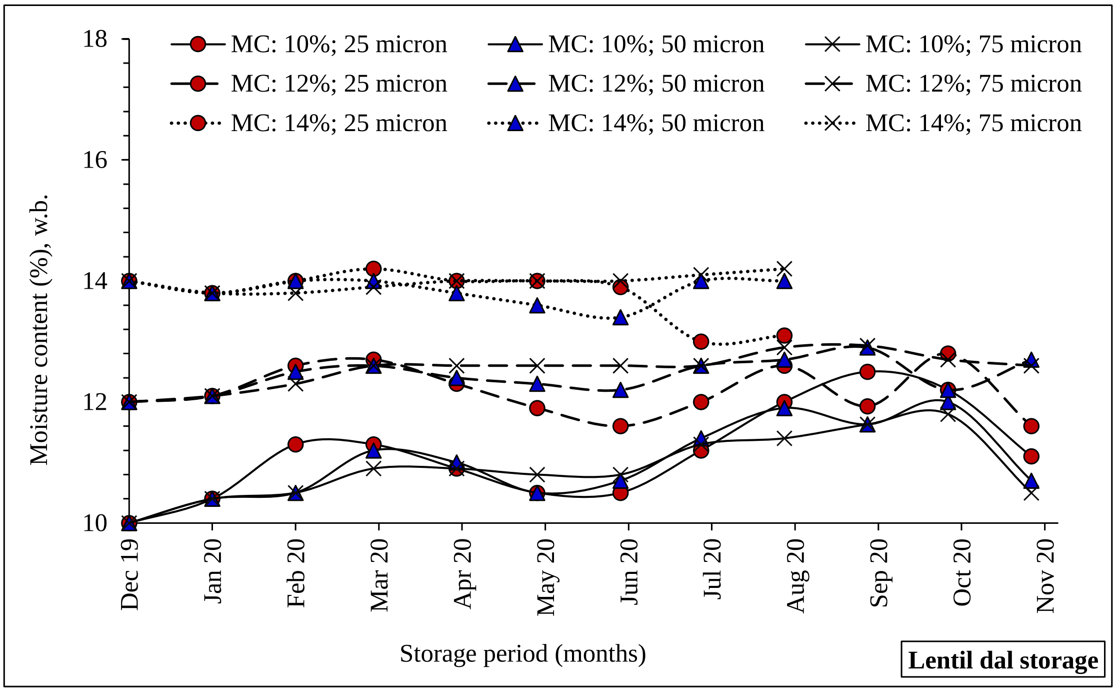


Fig. 25: Effect of storage period on moisture content of lentil dal (*Visual fungal growth at 14% moisture after August 2020 and samples discarded*)

Fungal growth was observed in green gram and black gram dal of 14% moisture content after 3 and 4 months of storage, respectively and hence these samples were discarded. In lentil dal, visual fungal growth was observed after 8 months of storage. Fungal infection in pigeon pea dal, stored at 14% moisture content was not observed because the moisture content of dal decreased to about 10.50% within 3 months of storage period, which was within the safe limit for storage. Chick pea dal was observed to be safe during the entire storage period. It may, therefore, be inferred that the moisture content (w.b.) of dal for storage should be ≤12% for prolonged storage.

Ideally the moisture content of dals should not change after packaging in plastic film having water vapour and air barrier properties. However, in LDPE films packets, the air exchange takes place at very slow rate. That is why moisture content of all the dals stored in LDPE bags changed according to the environmental conditions (Table 6 and Table 8). Thickness (25-75 μ) of the film did not affect change in moisture content of dals during storage. It may be inferred that the LDPE film may not be a suitable material for packaging of dals. Polypropylene (PP) or laminates may be suitable material, however, study is required to support this statement.

Irrespective of initial moisture content, pigeon pea dal equilibrated between 10-11% moisture content within 6 months of storage (Fig. 21). However, chick pea dal stored at 10% moisture content gained weight and reached to around 11% moisture content, whereas the chick pea dal stored at 12% also gained moisture content and reached to around 12.5%. Chick pea dal, stored at 14% moisture, lose moisture and reached to about 13% (Fig. 22). Similar was the variation in moisture content for black gram dal (Fig. 23). However, green gram dal and lentil dal moisture equilibrated between 10-11% within 8 months of storage, irrespective of initial moisture content (Fig. 24 and Fig. 25). It further indicated that the storage of dal should be done below 12% moisture content.

4.6.2 Quality of Stored Dal

Changes in some quality characteristics of dal, stored in laboratory are reported in Table 7. Uric acid content of dal were not determined because the NaCN (Sodium cyanide) has been banned for laboratory use.

The increase in 1000-cotyledon weight and bulk density of selected dal samples with moisture contents were due to increase in water content only. Reduction in cooking time with increase in moisture content was observed, though the decrease was not significant ($p \geq 0.05$). Further, the change in cooking time with storage period was not consistent and non-significant.

Table 7: Change in quality characteristics of dals with storage period in different states

State name	Pulse	Initial moisture content (%)	1000-cotyledon weight (g)	Bulk density (kg/m^3)	Cooking time with storage period (min)			Water absorption with storage period (g/g dal)		
					3 months	6 months	9 months	3 months	6 months	9 months
Karnataka	Pigeon pea	10	44.02	790.98	30	31	32	2.07	2.15	2.14
		12	-	-	27	28	28	2.10	2.12	2.12
		14	-	-	27	28	29	2.26	2.42	2.25
Maharashtra	Chick pea	10	67.21	710.00	38	40	36	0.65	0.65	0.61
		12	69.11	696.00	38	34	34	0.61	0.65	0.58
		14	70.32	683.00	34	36	35	0.5	0.58	0.55
Rajasthan	Black gram	10	16.25	842.00	23	22	22	-	-	-
		12	16.55	839.00	22	21	21	-	-	-
		14	16.80	828.00	Sample discarded due to visual fungal growth					
Punjab	Green gram	10	16.49	929.98	22	20	20	1.87	1.90	2.60
		12	17.01	911.84	21	19	18	1.87	1.87	2.83
		14	17.62	821.42	Sample discarded due to visual fungal growth					
Uttar Pradesh	Lentil	10	32.60	915.20	-	-	-	-		
		12	38.20	926.40	-	-	-	-		
		14	40.60	948.00	-	-	-	-		

The water absorption by selected dals did not change significantly with initial storage moisture content. Further, the water absorption by the dals increased with increase in storage period. This increase was mainly due to reduction in moisture content of dals with storage period. Thus, it may be inferred that the storage period and initial moisture content of dals for storage may not affect the quality of dal when storage is done in 25-75 micron thick LDPE packets.

4.6.3 Infestation level and its relationship with storage period and climatic condition

As the dals were stored in different months, month-wise comprehensive table was prepared to understand the role of climatic conditions on insect attack. Further, the curative measures were not adopted because the effect of fumigation might not enter in the LDPE packets. The extent of infestation with storage period are reported in Table 8.

Table 8: Variation of infestation in the stored dals

Storage period (month)	Chick pea		Pigeon pea		Black gram		Green gram		Lentil dal	
	EC	Inf. level	EC	Inf. level	EC	Inf. level	EC	Inf. level	EC	Inf. level
Dec 2019	-		-		-		-	-	CD	Clear
Jan 2020	-		-		-		CD	Clear	CD	Clear
Feb 2020	-		-		CD	Clear	CH	Clear	CH	Clear
Mar 2020	-		-		N	Clear	CD	Clear	CD	Clear
Apr 2020	-		HD	Clear	HD	Clear	HD	Clear	HD	Clear
May 2020	-		HD	Clear	HD	Clear	HD	Few	HD	Clear
Jun 2020	HD	Clear	HD	Clear	HD	Clear	HD	Clear	HD	Clear
Jul 2020	HH	Clear	HH	Clear	HD	Clear	HH	Few	HH	Clear
Aug 2020	HH	Clear	HH	Clear	HD	Clear	HH	Clear	HH	Clear
Sep 2020	HH	Clear	HH	Clear	HD	Clear	HH	Few	HH	Clear
Oct 2020	HH	Few	HH	Clear	HD	Clear	N	Clear	HH	Clear
Nov 2020	N	Few	N	Clear	CD	Few	CD	Clear	CD	Clear
Dec 2020	CD	Few	N	Clear	CD	Few	CD	Clear	CD	
Jan 2021	CD	Few	N	Clear	CD	Few	CD	Clear	CD	
Feb 2021	N	Few	N	Clear	CD	Few			-	
Mar 2021	N	Few	N	Clear	-	-			-	

EC: Environmental condition; Inf. Level: Level of infestation; HH: Hot and humid climate; HD: Hot and dry climate; CH: Cold and humid climate; CD: Cold and dry climate, N: Normal environment.

Rice moth (Grain weevil) infestation was observed in chick pea dal and black gram dal in October and November months, respectively. The infestation took place in all the samples of these dals irrespective of initial moisture content and thickness of the LDPE packet. It indicated that the eggs were present on the dal samples since beginning and growth took place when favourable environmental conditions came. The extent of loss due to rice moth infestation was up to 2% in chick pea dal whereas negligible loss was observed in black gram dal. Other pulses were not affected by rice moth during the study period.

The surprising part of the infestation was incidence of bruchid (*Callosobruchus chinensis*) in green gram dal. However, no damage or loss was observed due to bruchid infestation in green gram during the storage period. The attack of this insect was observed in the month of May and found in all green gram dal samples, irrespective of moisture content and packaging material. In general bruchids attack whole pulses only. However, green gram dal contains dehulled whole and dehulled splits and bruchids might be attracted towards dehulled whole green gram. This is a new phenomenon of bruchid infestation and any extensive entomological study is required to find out the reason of such infestation in green gram dal.

It may be inferred from the storage study of dals that the storage of dals should be done ≤12% moisture content (w.b.). The LDPE film up to 75 micron thickness may not be a suitable packaging material for dals and other packaging material should be explored. Infestation may take place in dals and loss up to 2% may take place in chick pea whereas other pulses may not be affected much. Low RH condition is more suitable for the storage of dals.

4.7 *Sabut* and OTR for Dal *dara* from Black Gram and Green Gram

Green gram (*Sabut moong*) and black gram (*sabut urad*) are also sold in the Indian market. Further, *Moong dara* and *Urad dara* (splitting green gram and black gram with hull) is also another form of dal available in Indiana market. The recovery of this form of green gram and black gram dal was studied during January-March 2021 only. The OTR for these dals are described in this section.

4.7.1 *Sabut Chana, Sabut Urad, Sabut Moong* and *Sabut masoor*

Sabut (cleaned and graded whole pulses) from chick pea, black gram, green gram, and lentil are not preferred to be prepared from smaller grain sizes. Therefore, the 1000-grain weight was taken as the first criteria for determining the *sabut* recovery. Based on the study, the 1000-grain weight for preparing *sabut* grain from chick pea, black gram, green gram, and lentil were >40g. On this basis, only those samples were considered in which smaller grains were not more than 5%. Further, the OTR also depended on unwanted matter present in the samples. The OTR of *sabut* from chick pea, black gram, green gram and lentil samples were calculated for total unwanted matter (foreign matter, admixture, damaged grain, and weeviled grain) <2% and undersize <5%, and overall rejection <5%. The OTR for *sabut chana* was 91.50 ±1.08%; *urad sabut* was 93.05±1.29%; *moong sabut* was 93.70±0.90%, and *sabut masoor* was 93.50 ±1.14%.

4.7.2 OTR for *Dara* dal from Black gram and Green gram

The OTR for *dara* dal was determined from 18 samples of black gram and green gram each. As this part of study was planned at later stage, the variation with storage period is not reported.

The OTR for *dara* dal from black gram was found to be 87.64±2.49% whereas the OTR for dal *dara* from green gram was 89.18±2.17%. The possibility of change in OTR for *dara* dal is only when infestation takes place and reduction in OTR may be possible. This reduction in OTR can be maximum up to the infested grain (%), though not verified from experiments.

4.8 Norms for OTR of Dal from Stored Pulses

Average OTR was calculated for warehouse samples and laboratory samples studied pulses separately for all the data recorded. The OTR obtained from warehouse data and laboratory analysis were optimally combined using Eq. (16) and Eq. (17), which is valid for milling of pulses up to one year storage period. The total recovery from the pulses are reported in Table 9.

The recovery of dal is applicable for one year for all the pulses of good quality (Rejections level <5% including foreign matter, admixture, undersize, weeviled, and damaged grain). Suggesting separate standard for different months may not advisable due to operational and management difficulties.

4.9 Fumigation Protocol for Warehouses

Whole pulses and dal stored in a particular climatic conditions of different region are vulnerable to insect attack and the level of infestation is greatly dependent on the prevailing climatic conditions viz. temperature and humidity of that region. The effect of climatic conditions of different regions were also reflected on the storability of selected pulses in the different states covered in this study.

In the present study, aluminium phosphide tablet preparation, conforming to IS: 6438-1980 (Reaffirmed 2009), was used as fumigant (9 g/ton pulse). This treatment is approved by the Registration Committee under the Insecticide Act, 1968. The fumigation was carried out as per the FCI fumigation guidelines of treatment and IS 7247-31974 (Reaffirmed 2005). The whole pulses can be stacked up to a maximum of 16 bags height (3 m) by following available stacking standards of FCI. After placement of fumigation tablets, the stacks were immediately covered with fumigation cover and allowed an exposure duration of 7 days. Then aeration for one hour was given when cover was partially lifted followed by 6 hours aeration in completely uncovered condition. Fumigation impact was observed by monitoring the infestation level.

It was also observed that when the godown is fumigated, the beetles flied away from the godowns. However these attacked again after 3-4 days of fumigation, which raises the need of regular sampling (weekly) and monitoring, particularly in monsoon season.

Fumigation of all stacks should be done at a time as the insects may move to other stacks when only one stack is fumigated.

Table 9: Standard OTR of Dal from pulses for one year milling period

Name of Dal	No. of observations		Total OTR (%)		Grade-I OTR (%)		Grade-II OTR (%)		Standard OTR		
	Warehouse	Lab	Ware house	Lab	Ware house	Lab	Warehouse	Lab	**Total OTR (%)**	**Grade-I (%)**	**Grade-II (%)**
Chick pea dal	618	30	75.39 ±5.87	74.37 ±2.73	37.91 ±15.35	27.58 ±3.56	37.48 ±14.71	46.79 ±2.25	**75.35 ±5.76**	**37.43 ±15.16**	**37.91 ±14.50**
Pigeon pea dal	480	36	73.19 ±4.41	73.77 ±1.32	41.92 ±9.13	48.27 ±3.35	31.15 ±9.30	25.49 ±3.11	**73.23 ±4.27**	**42.36 ±9.00**	**30.75 ±9.12**
Black gram dal	150	33	72.62 ±7.01	73.33 ±1.64	-	-	-	-	**72.75 ±6.39**	-	-
Green gram dal	126	39	74.28 ±4.86	78.63 ±2.38	-	-	-	-	**75.31 ±4.77**	-	-
Lentil dal	90	33	80.37 ±3.88	88.54 ±1.85	-	-	-	-	**82.56 ±5.01**	-	-
Sabut chana	-	18	-	91.50 ±1.08					**91.50 ±1.08**	-	-
Urad Sabut	-	18	-	93.05 ±1.29	-	-	-	-	**93.05 ±1.29**	-	-
Moong Sabut	-	18	-	93.70 ±0.89	-	-	-	-	**93.70 ±0.89**	-	-
Sabut masoor	-	12	-	93.50 ±1.14	-	-	-	-	**93.50 ±1.14**	-	-
Urad Dara	-	18	-	87.64 ±2.49	-	-	-	-	**87.64 ±2.49**	-	-
Moong dara	-	18	-	89.18 ±2.17	-	-	-	-	**89.18 ±2.17**	-	-

5 RECOMMENDATIONS AND FUTURE STRATEGIES

On the basis of the results obtained from this study, the following Standard Operating Procedures for procurement, storage, milling, and OTR are recommended.

5.1 Procurement of Pulses

- Procurement of pulses should be done within one month of harvesting. Date of start of procurement and end date should be defined for each state and each pulse depending upon the harvesting time in a particular state.
- Quality parameters for procurement of all the pulses should be as follows:

Moisture content	≤11% (w.b.), Full value cut when moisture is >11%, and No purchase if moisture content ≥14% (w.b.)
Foreign matter (other than food grains)	<1.0% Full value cut for ≥1% foreign matter
Admixture (Food grains other than selected pulse)	Nil Full value cut for admixture
Mechanically damaged grains (broken, partly unhulled, fissured grains)	up to 1% Full value cut for >1% damaged grains
Weeviled grains/Infested grains (grains having hole, it does not include grains have white spots of insect eggs)	Nil No purchase should be made if weeviled grains are observed
Grains having white spot of eggs	≤1%
Shriveled grains and undersize	<3%
Overall limit (including admixture, mechanically damaged, weeviled, shriveled and undersize)	**<5%**

- Size and 1000-grain weight of pulses plays important role in dal recovery. However, different varieties of each pulse are grown in one state. Therefore, procurement should be done separately for small size and bold size grains and their storage should be done in the separate stacks. The range of 1000-grain weight recommended for different pulses are as under:

S. No.	Name of pulse	1000-grain weight range (g)	
		Small seed variety	Bold seed variety
1.	Chick pea	117-182	>182
2.	Pigeon pea	83-100	>100
3.	Black gram	30-40	>40
4.	Green gram	30-40	>40
5.	Lentil	28-40	>40

- About 10% measurement/ instrument error in moisture content values was observed between warehouse and laboratory measurements. The values given by the moisture meters used by procuring agencies and warehouses were on higher side, which leads to loss to the procuring agency. Accurate moisture meter with less than 0.1% least count and 0.02% accuracy, particularly Near Infrared Moisture Meters (NIR moisture meter) having printing facility is recommended for the moisture measurements. The sampling for moisture measurement at the time of stacking and liquidation should be compulsory to be taken from whole stack and method of drawing sample from every 10th bag may be followed (IS: 14818, 2000). Further, moisture content values should be reported with standard deviation to ensure the least error in moisture measurements.

5.2 Storage Management Practices for Whole Pulses in Warehouses

- Initially the adult insects may not be visible, the procured pulses may contain eggs, larvae and pupae of insects, which convert into adult insect after completion of its life cycle. Fumigation of pulses immediately after storage must be done to eliminate field infestation.
- Whole pulses in gunny bags (50 kg each) can be stacked up to a maximum of 16 bags height (maximum 3 m). Available stacking standards of FCI for other grains may be followed.
- Pulses must not be stored in one godown with other crops, particularly groundnut and other crops, which are highly susceptible to bruchid attack.

- All the stacks in a particular godown must be fumigated simultaneously irrespective of insect infestation in order to avoid insect movement among stacks.
- Bruchids fly away from the stack during fumigation and attack again after 3-4 days of fumigation, particularly in monsoon season. Therefore, in monsoon season regular sampling (weekly) and monitoring is essential.
- Identification of bruchids from sampling failed many a times because of their dynamics. Pheromone traps, insect trap (TNAU developed) or light traps should be used in the warehouses. In each godown (chamber) one such traps must be placed.
- Aluminum phosphide (9 g/ton pulse, 7 days exposure in airtight condition) should be used for the fumigation of pulses.
- Instead of opening the practice of opening doors during day hours, exhaust fans should be used for aeration; also roof turbo ventilators should be made mandatory in the warehouses.
- In normal environmental conditions (<65% RH), the samples should be drawn for determination of insect infestation after every 15 days. When the relative humidity persist more than 65% for 4-5 consecutive days, the samples should be drawn weekly (every 7^{th} day) and visual observation must be done.
- Dunnage covered with plastic sheet must be used for stacking of the pulses.
- Accurate moisture meter with less than 0.1% least count and 0.02% accuracy should be used. The agencies should procure Near Infrared Moisture Meters (NIR moisture meter) having printing facility as soon as practically possible for the moisture measurements.
- The pulse samples collected from Rajasthan (particularly from Western part of Rajasthan) had **nil or very little infestation** during the entire study period, which might be owing to persistence of dry climatic conditions for longer duration. Some districts of Western part of Rajasthan may be identified and developed as hub for storage of pulses.
- All other standard grain storage management practices of FCI should be followed.

5.3 Storage Management Practices for Dal Storage

- Fungal growth and lumps formation were observed even just after 3-4 months of storage of black gram and green gram dals stored in LDPE bags at moisture content more than 12% at laboratory conditions. Therefore, dal must be taken from millers at less than or equal to 12% moisture content (wet basis) in all regions of India.
- Storage of dals in LDPE bags (up to 75 μ thickness) is not safe because environmental conditions affected even after packaging. Polypropylene or plastic laminates of suitable

thickness should be used for packaging and storage of dals. The packaging must be airtight to ensure least damage by insects.

- Delivery of Grade-I and Grade-II dals must be taken separately for storage.
- Stack height for dal storage should not be more than 1.5 m.
- Forced aeration is essential for storage of dal. Instead of opening the practice of opening doors during day hours, exhaust fans should be used for aeration; also roof turbo ventilators should be made mandatory in the warehouses.
- Dal should not be stored with other food grains, whole pulses, oilseeds, or any other item.
- Every depot should mandatorily have cleaning and drying facility. This will ensure better storage management of pulses.
- All other standard grain storage management practices of FCI should be followed.

5.4 Standards for Milling and OTR of Dal

- Though the OTR increased with increase in storage period, it is practically difficult to implement. The uniform milling outturn (OTR) should be used as standard throughout the year for milling of pulses.
- The standard operating procedure given in Fig. 2, Fig. 3, Fig. 4, and Fig. 5 should be followed for milling of pulses.
- Modern machineries and equipment must be used for milling of pulses.
- The uniform OTR values recommended for dal from different pulses are as below:

Name of Dal	Standard OTR (%)		
	Total OTR (%)	**Grade-I dal (%)**	**Grade-II dal (%)**
Chick pea dal (*Chana dal*)	**75.35**	**37.43**	**37.91**
Pigeon pea dal (*Tur/ arhar dal*)	**73.23**	**42.36**	**30.75**
Black gram dal (*Urad dhuli*)	**72.75**	-	-
Green gram dal (*Moong dhuli*)	**75.31**	-	-
Lentil dal (*Masoor dal*)	**82.56**	-	-
Chick pea whole (*Sabut chana*)	**91.50**		
Black gram whole (*Sabut Urad*)	**93.05**	-	-
Green gram whole (*Sabut Moong*)	**93.70**	-	-
Lentil whole (*Sabut masoor*)	**93.50**		
Urad Dara dal	**87.64**	-	-
Moong dara dal	**89.18**	-	-

- The by-products (husk, brokens, powder, undersize grains, foreign matter, etc.) obtained during milling of pulses are sold as animal feed. Therefore, the cost of by-products should be considered while fixing the milling charges.
- Grade-I dal is characterized by sharp edges, no cup formation on cotyledons and no scouring on cotyledon surface. Grade-I dal must not be polished.
- Sometimes millers use soap stone powder for polishing of grade-II chick pea and pigeon pea dals, black gram *dhuli*, green gram *dhuli* and lentil dal. Soap stone powder is a hazardous chemical and must not be used for polishing. Fine grade emery or rubber polishers may be used.
- The moisture content of dals taken from millers must be ≤12% (wet basis) and drying must be done when moisture goes above 12%.
- Common admixture of pigeon pea and chick pea dal is pea dal (*matar dal*). Sometimes *khesari dal* is also mixed with Grade-II dal. Any such admixture should not be permitted.

5.5 General Recommendations

- This study may be a bench mark study for bulk storage of pulses in the warehouses. In future some more studies should be conducted in which issues related to quality and losses due to insect infestation may be dealt. The effect of other parameters, such as forced aeration of stacks, quality of grains, and quantification of loss due to individual biotic factors specifically for pulses may also be studied in future.
- The OTR may increase in near future with advancement of technologies and modernization of machineries. ICAR-CIPHET may work in collaboration with DoCA on modernization of pulse milling in India.
- **Storage of imported pulses at ports:**
  - Methyl bromide is banned for use as fumigant because of its ozone depleting property. Many countries, both industrialized and developing, have committed to phase out methyl bromide well in advance of the Montreal Protocol schedule (1987) and this phase out had to be completed by 2005. FCI stopped use of methyl bromide long back for treatment of food grains. Hence, the methyl bromide should not be used at ports even when Plant Quarantine Department permits its use.
  - The first fumigation must be done using Aluminum phosphide (9 g/ton pulse, 7 days exposure in airtight condition) immediately after receipt in port warehouse.

- Number of insects (bruchids) in a sample is very critical in pulse storage. It may cause severe damage within 2 month because of their fast growth and egg laying capability. Once bruchid is observed, fumigation should be done immediately.
- The RH is usually >65% near the sea ports. Therefore, pheromone traps or insect trap (TNAU developed) should be placed in the port warehouses and monitored regularly. In each godown (chamber) in which pulses are stored, one such trap must be placed.
- Port warehouses should be equipped with exhaust fans and installing roof turbo ventilators should be made mandatory in the warehouses.

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Annexure-I

Data Collection and Analysis Recording Schedules

Schedule 1: Identification Particulars of warehouse/Godown

	Particulars	
A. General information of the warehouse		
1.	Name of the Warehouse / Depot	
2.	Name of Agency owning the Warehouse/ Depot	
3.	Address of the Warehouse/ Depot	
4.	Name of District	
5.	Capacity of the Warehouse/ Depot	
6.	Connectivity of the warehouse with State/ National Highways and nearest railhead	
7.	No. of godowns in the Warehouse/ Depot	
8.	No. of godowns having pulses under storage	
9.	Name of pulses stored in the Warehouse/ Depot	
B. Particulars of the Godowns having Pulse Storage		
1.	Identification particulars of the godowns having pulse storage	
2.	Name of pulses stored in the identified godown	
3.	Stack numbers of the pulses	
4.	Approx. measurement of selected godown (L×W×H)	
5.	Leakage in roof, if any	
6.	Condition of doors and floor	
7.	Observations about cleanliness and hygienic condition of warehouse.	
8.	Steps taken for storage and preservation of Pulses: 1. Type of dunnage: wooden/ bamboo/ plastic sheet 2. Curative measures adopted in general: (a) Inspection (b) Prophylactic treatment (insecticide spray) (c) Curative treatment (fumigation) (d) Rodent control measures 3. Whether stacking is proper and space for inspection, chemical treatment and warehousing operation (alleyways and hallways) is available	

Date: **Signature of Field Investigator**

Signature of CCPI/ CoPI

Schedule 2: Information of Stacking/Procurement of Pulses

A. Identification particulars of Stack

1.	Name of Pulse	
2.	Stack information	
	a. Warehouse Name & Address	
	b. Name of Agency owning the warehouse	
	c. Identification particulars of godown	
	c. Stack Number	
	d. Date of stacking	
3.	Whether fresh or transferred from other warehouse	
4.	Type of Sack/Gunny	
5.	Average weight of sack/gunny (kg)	
6.	Type of dunnage	
7.	Total number of bags at the time of stacking	
8.	Total weight of complete stack at the time of stacking (kg)	
9.	Moisture content at the time of stacking (as reported by the agency) (%)	
10.	Moisture measurement method (Moisture meter/ oven/ any other)	
11.	Make and accuracy of moisture meter	
12.	Infestation level at the time of stacking (if reported)	
In case of fresh stacking of pulse		
1.	Identification particulars of godown	
2.	Stack number	
3.	Weight of sample drawn at the time of stacking (kg)	
4.	Sampling method (Randomly / from periphery after stacking)	
5.	Date of sampling	
6.	Identification number of sample	

Date: **Signature of Field Investigator**

Signature of CCPI/ CoPI

B. Identification slip of the sample at the time of Stacking / storage

1	Name of Pulse	
2	Warehouse name and address	
3	Name of agency owning the warehouse	
4	Date of stacking/ storage	
5	Stack identity number	
6	Total number of bags in the stack	
7	Identification number of sample	
8	Moisture content of sample (as reported by the agency)	
9	Date of receipt of sample in the laboratory	

Date: **Signature of Field Investigator**

Signature of Laboratory Technical Officer

Schedule 3: Information of Liquidation of Pulses

A. Identification particulars of Stack

1.	Name of Pulse	
2.	Stack information	
	d. Warehouse Name & Address	
	e. Name of Agency owning the warehouse	
	f. Identification particulars of godown	
	e. Stack Number	
	f. Date of stacking	
3.	Total number of bags at the time of stacking	
4.	Total number of bags at the time of liquidation	
5.	Total weight of complete stack at the time of liquidation (kg)	
6.	Moisture content at the time of liquidation (as reported by the agency) (%)	
7.	Moisture measurement method (Moisture meter/ oven/ any other)	
8.	Make and accuracy of moisture meter	
9.	Infestation level at the time of liquidation (if reported)	
10.	Condition of pulse at the time of liquidation	
11.	Weight of sample drawn at the time of liquidation (kg)	
12.	Sampling method (Randomly / from periphery after stacking)	
13.	Date of sampling	
14.	Identification number of sample	

Date: **Signature of Field Investigator**

Signature of CCPI/ CoPI

B. Identification slip of the sample at the time of Liquidation

1	Name of Pulse	
2	Warehouse name and address	
3	Name of agency owning the warehouse	
4	Date of stacking/ storage	
5	Date of liquidation	
6	Stack identity number	
7	Total number of bags in the stack at the time of liquidation	
8	Identification number of sample	
9	Moisture content of sample at the time of liquidation (as reported by the agency)	
10	Date of receipt of sample in the laboratory	

Date: **Signature of Field Investigator**

Signature of Laboratory Technical Officer

Schedule 4: Fortnightly Observations records of Pulse Stacks (as per agency record)

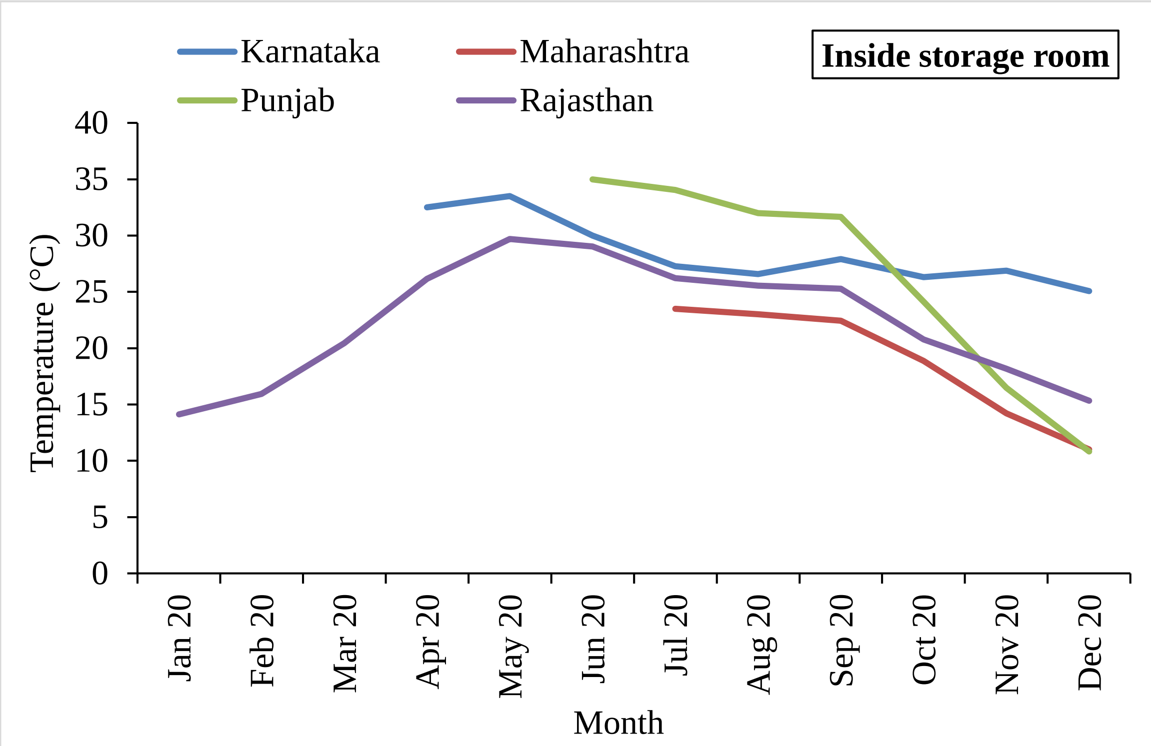
A. Identification particulars of the stack		
13.	Name of Pulse	
14.	Stack information	
	g. Warehouse Name & Address	
	h. Name of Agency owning the warehouse	
	i. Identification particulars of godown	
	g. Stack Number	
	h. Date of stacking	
B. Sample analysis results reported by the agency		
3.	Method of sampling	
4.	Weight of sample drawn (kg)	
5.	Weevilled grains	
6.	Insect observed (common /Scientific name)	
7.	Infestation level	
8.	No. of pests/25 g sample (live/dead)	
9.	Moisture content (%)	
10.	1000 g weight (g)	
C. Information of curative measures adopted by the agency during the fortnight		
11.	Level of infestation (clear, few, heavy)	
12.	No. of spray/ fumigation	
13.	Name of chemicals used	
14.	Presence of mites, rodents, birds, mites, monkeys and micro-organisms -visual observation	
15.	Spillage weight (kg)	
16.	Whether spillage was collected or not	

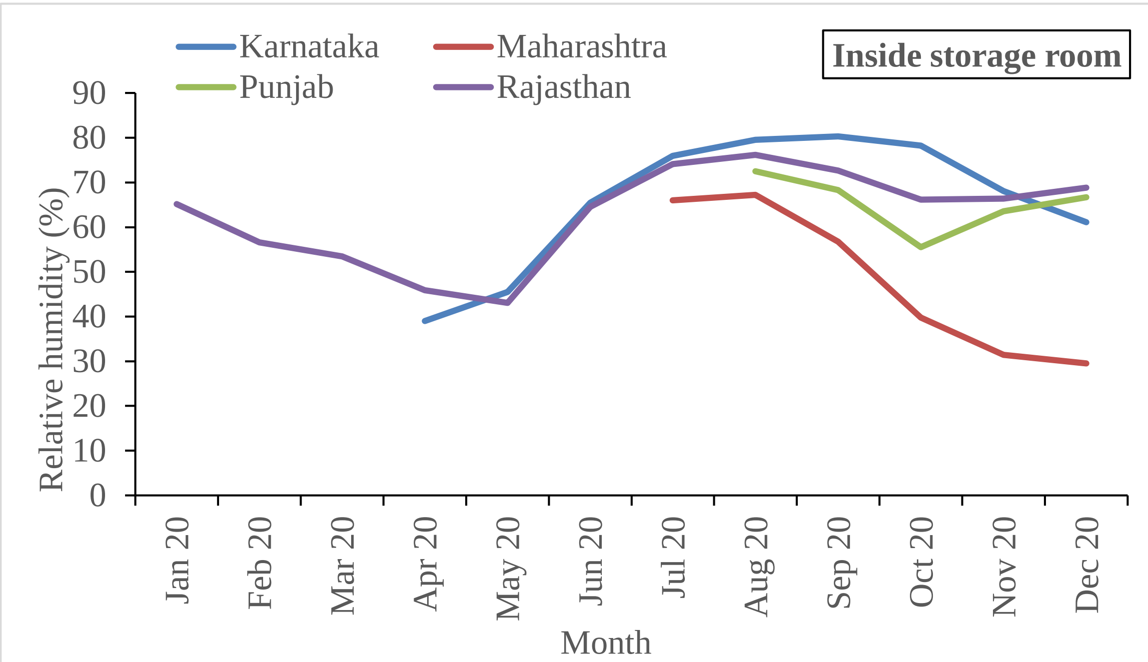
Date: **Signature of Field Investigator**

Signature of CCPI/ CoPI

Environmental Data

A. Average temperature and relative humidity inside the storage room during study in different states





B. Average temperature and relative humidity of environment during study in different states