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Biointensive safe storage methods for pulses: Review

J. Alice R.P. Sujeetha[1], C.V. Kavitha Abirami[1] and K. Alagusundaram[2]

ABSTRACT

Pulses are an important source of protein in the Indian diet. Pulses are least preferred by farmers because of high risk and less remunerative than cereals; consequently, the production of the pulses is sufficiently low. To meet the demand of pulses, India is at present importing about 3 million tons. Pulse production systems including pre harvest and post harvest techniques. These techniques are mechanized in developed countries but developing countries still employ traditional techniques which incur losses of about 20–25% post-harvest losses. Drying and conditioning of pulses are mostly done by artificial methods; however, the most common drying method for pulses in the world is open sun drying, particularly at farm level. Drying of pulses is essential because the moisture content at the time of harvesting is on the higher side (18–25%) and for safe storage, the optimum moisture content is in the range of 9–12% to avoid production of mycotoxins. Again storage of pulses is a challenging one since pulses are more sensitive to storage pest *viz.,* bruchids and can easily be attacked by them. Hence safe storage conditions like controlled atmosphere storage (CAS) must be provided for the pulses until they are being consumed. CAS offer a safe and environmentally benign alternative to the use of conventional residue-producing chemical fumigants for controlling insect pests that attack stored grain. Air tight containers or bins offer great protection in controlling bruchids. Hermetic storage (HS) technology has emerged as a significant alternative to other methods of storage that protect commodities from insects and molds. HS is based on the principle of generation of an oxygen-depleted, carbon dioxide-enriched interstitial atmosphere caused by the respiration of the living organisms in the ecological system of a sealed storage. Bag storage is a common method in India. Pulses can also be stored either in metal bins, silo bags of various capacities.

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INTRODUCTION

India is blessed with several pulses and cereals and there are different ways to prepare them. But there are some pulses and cereals that have higher nutritional value. Pulses are rich in proteins and found to be main source of protein to vegetarian people of India. It is also called as “poor man’s meat” (Reddy, 2010). It is second important constituent of Indian diet after cereals. India, the world’s largest producer, importer and consumer of a wide range of pulses, is obviously a focus of attention at such events, especially for exporting countries such as Canada, Australia, US and Myanmar. India’s pulses production in 2012-13 is an estimated 17.7 million tonnes (mt), up from last year’s 17.1 mt. India’s annual imports of pulses are estimated at about 30 lakh tonnes valued at over Rs 9,000 crores. For 2013-14, the Government has fixed a production target of 19 mt, with specific measures including crop diversification and mixed cropping. A steady increase in minimum support price in the last three years has provided some encouragement to growers. Market participants are also wondering as to when India will start exporting pulses in an unrestricted policy environment. South Asian countries such as India, Pakistan, Bangladesh and Sri Lanka are all importers of pulses (Anonymous, 2013). The frequency of pulses consumption is much higher than any other source of protein; about 89 per cent consume pulses at least once a week, while only 35.4 percent of persons consume fish or chicken/ meat at least once a week in India (IIPS, ORC Macro,2007).

Post-harvest losses.

Pulse production systems including pre harvest and post harvest techniques are mechanized in developed countries but developing countries still employ traditional techniques which incur losses of about 20–25% post-harvest losses (Maneepun, 2003). Traditionally, grains are dried in fields which ensure optimum moisture prior to storage but a potential risk is associated quantitative losses due to birds, insect infestation, rodents, *etc*. Threshing of pulses after harvesting is mainly done to separate edible grains from the pod. Threshing should be performed at optimum moisture. Threshing at high moisture content of pulses may pose difficulty in removal of chaffy material during cleaning and may be the source of microbial cross-contamination. Further, granary or bag storage of moist grains will be susceptible to fungal attack leading to qualitative and quantitative losses.

Drying

Drying of pulses takes place immediately after harvesting, before threshing (pre-drying) and during storage and/or primary processing. Drying is an important post-harvest operation for safe storage, processing and grain quality preservation. The sole objective of grain drying is to remove excess moisture. Inadequate drying results in excess grain moisture and coupled with temperature favors microbial growth and enzymatic activity leading to degradation of grain quality. Drying and conditioning of pulses are mostly done by artificial methods; however, the most common drying method for pulses in the world is open sun drying, particularly at farm level. In some tropical and subtropical countries, sun drying is performed, particularly field drying. Carefully controlled artificial drying, as practiced in temperate regions, is an expensive process and its use in the tropics is limited to some export crops (Aidoo, 1993). It is not always feasible to reduce the moisture content of grains to safe levels in the field, which necessitates the artificial removal of moisture from grains (Jayas and White, 2003). Sun drying the pulses can gives substantial protection. Sun drying and also cold temperature (refrigerated) condition for 4h for 3-4 days at bimonthly intervals offered great protection. This method was cheap and low cost technology to store pulses for small and medium scale (Alice and Srikanth, 2013).

Storage

Proper post-harvest handling of legumes prevents both qualitative and quantitative losses. Dried seeds with high moisture content increased the rate of mold attack and infestation. Dehulled seeds are often dried to a safe moisture level. There are basically two methods of storage *i.e.*in bags and in bulk. Bags can be stored either in the open air or in warehouses; bulk grain is stored in bins or silos of various capacities. The choice between these methods and the degree of technological sophistication of the storage buildings depend on many technical, economic and socio-cultural considerations. The traditional storage systems used by small farmers is the most widely used structure. These systems are fabricated with the use of artesian construction techniques and local materials.

Jute bags

The jute bag is the most widely used packaging material in the world. It combines good resistance capacities with a relatively moderate cost. It can be re-used several times since it has good inherent toughness, which reduces the risks of tearing. In addition, it protects the grain effectively from sunlight. However, with its relatively heavy fibre with a coarse texture makes it inappropriate for small-size grains. Furthermore, jute easily absorbs humidity and offers little resistance to the attacks of insects and rodents. In order to partially offset the disadvantages of humidity absorption, these bags can be lined with plastic or, if necessary, covered with water proof tarpaulins. Handling jute bags is easy because the material is not slippery. As a result, fairly high stacks can be erected.

PP woven bags

These bags are made of plastic polythene woven fabrics, or of mixed fabrics. Polythene bags are widely used for packaging grains and they seriously rival the traditional jute bag. With good treatment, a polythene bag can be re-used for 6-12 times. They cost less than jute bags and are harder to handle. Their surface is very slippery, and so they cannot be stacked very high. The most commonly used material for such bags is polyethylene and polyester. These bags are not moisture-proof but are moisture resistant. They deteriorate easily if exposed to sunlight, therefore, should be protected from direct sunlight. They are difficult to stack as bags may slide and fall down.

Metal bins

Galvanized silos are used for grain storage. The pulses received in the Silo complex is handled by conveying equipments in bulk and stored in

Galvanized Silos after cleaning. Moisture content in pulses also plays an important role in storage life of grain. Pulses with lower the moisture content and with proper aeration shall be stored in Galvanized Silos for longer period. If pulses are having excess moisture content, it is reduced using drier online after the cleaning and before the storage of pulses inside the Galvanized Silos. Their adaptation is primarily one of installing aeration equipment, modifying unloading if necessary, and making provision for aeration air discharge in the top of normally sealed units.

Silo bags

A Scientific Storage needs to be adopted and implemented immediately for storing all the food grain that is stored in CAP (open), as well as capture further bumper crops and harvests to enable smooth procurement across India as per MSP. Silo Bags Bulk Grain Storage system provides an ideal alternative to CAP (Open) storage. The technology was first developed in Argentina and has since, proved successful in 32 countries over the past 12 years. The Basic principle is to grain in a modified atmosphere, low in oxygen and with a high concentration of carbon dioxide (CO2).Once filled the bag is sealed. The conditions within the bag thereafter control breeding insects and fungi; hence there is no need of any Fumigation. Bags are stored on fields with sufficient drainage and space. All fields are scaled, cleaned and cleared of grass, weeds and rocks thus creating the ideal ground conditions for laying out bags. Each Bag can hold up to 200 tons of Wheat and approx. 10 bags can be stored per acre. Quantity per Bag can vary depending on type of the grain. To keep the grain safe all storage depots are reinforced with suitable Security Systems and cattle, bird and rodent control measures are implemented. A Silo Bag is a co extrusion of 3 layers of PE (Poly Ethylene).The first two layers, White in colour act as a UV filter and reflects sun. The third layer is black and is designed to keep out the Sunlight. Each polyethylene bag (2.7mx60.0m) can store approx 150/200 tons of grain. Once the Silo Bag is sealed and airtight .It has a life of 18-24 months in the open.

Modified and controlled atmosphere storage

Modified atmosphere (MA) offers an alternative that is safe and environmentally benign, to the use of conventional residue producing chemical fumigants for controlling insect pests attacking stored grain, oilseeds, processed commodities, and packaged foods.MA has been researched extensively for more than 30 years (Adler *et al*., 2000; Navarro, 2006) CA is a modified gas composition, usually produced artificially, and maintained unchanged by additionally generating the desired gases (CO2 or N2) or by further purging the storage with these gases, supplied from pressurized cylinders or otherwise. This supplementary introduction of gases is carried out when their concentration in the sealed container falls to below the desired level. In vacuum packed samples, the death of bruchids was immediate after packing in LDPE bags. The mortality also occurred when the infested samples were flushed with 80%CO_2+4%O_2+16%N_2, and mortality occurred at 2 h after flushing (Supriya *et al*., 2013).

Hermetic storage

Cow pea triple bagging

The Purdue Improved Cowpea Storage (PICS) is used to improve cowpea storage in West and Central Africa. It was found to be very successful in African countries. The triple bag consists of 2 layers of polyethylene bag which are expected to be as hermetic as possible and both included in a protective polypropylene woven bag. With triple-bagging, the cowpea seeds are sealed in a series of 2 heavy-grade polyethylene plastic bags. Triple-bagging of cowpeas for 7 months with 2 pieces of HDPE bags of 80 μm wall thickness placed in an additional woven nylon bag tightly sealed has been shown to be effective in controlling pulse beetles, *Callasobruchus maculatus* population. Moreover, the seeds remain undamaged and viable at the end of the storage period (Sanon *et al*., 2011).The Purdue Improved Cowpea Storage (PICS) is used to improve cowpea storage in West and Central Africa. It was found to be very successful in African countries.

Problems encountered during storage of pulses

Biotic

Infestation of *Callosobruchus* spp.

The presence of insect pests in grain has indirect influence on grain respiration. Being living organisms, insect pests in grain also respire, resulting in heat which causes temperature rise in the entire system and moisture which, in turn, wets and increases the moisture content of the grain. Increased heat/temperature and moisture causes an increase in respiration and consequently loss in quantity and quality of the grain. Infested stored seed can be recognized by the white eggs on the seed surface and the round exit holes with the 'flap' of seed coat .Infested seeds lose their viability and are unfit for human consumption. Detection of Insect Infestations by acoustic detection, grain Radiography-X Rays, nuclear Magnetic Resonance, carbon dioxide evolution, near Infra Red Spectroscopy, uric acid test, ninhydrin test and other physical and mechanical methods(traps)

Management

Seed is sun dried before storing in a clean beetle-proof storage container (metal, wood, earthenware, or plastic).Fumigation with aluminium phosphide protects the seed without affecting the viability. Coat the seed with small quantities of vegetable oil or mix neem leaves in the stored grain. Mix the pulses with inert dust diatomaceous earth, activated clay *etc.* Adult emergence of pulse beetle in black gram was less in grains treated with activated clay and with talc powder. Fly ash was also reduced the per cent of grain damage (Alice and Srikanth, 2013). Mendki *et al.* (2001) reported that fly ash effectively suppressed the population of C. *chinensis* for as long as 16 to 18 months. Fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO).

Storage fungi

Storage fungi usually invade grain or seed during storage and are generally not present in large quantities before harvest in the field. The most common storage fungi in rice are species of *Aspergillus* and *Penicillium*. Contamination occurs through spores contaminating the grain as it is going into storage from the harvest, in handling and storage equipment or from spores already in the storage structures. Under high temperatures and moisture this small amount of inoculums can increase rapidly. The development of fungi is influenced by the: moisture content of the stored grain, temperature, condition of the grain going into storage, length of time grain stored and amount of insect and mite activity in the grain.

Rodents

Rodents cause considerable damage to field crops and stored products. There are four ways in which rodents do damage to stored products; they consume a quantity of the product. They spoil part of the product with their droppings. They gnaw holes in the packing material causing waste. Jute bags can be seriously damaged in this way. Products stored in bulk are less vulnerable because rats can only nibble away the surface. Rodents are also carriers of diseases which are harmful to man. Unlike the insects and fungi which infest the storage, rodents will plunder stores whatever the temperature or moisture content of the grain or air.

Abiotic

Moisture

Grain, even after normal drying, still contains a certain degree of moisture. The higher the moisture content the higher the respiration rate and the faster the grain spoils. This is due to the high rate of micro-biological activity then prevalent on the grain due to rapid mould growths. Moulds (fungi) are tiny multi-cellular plants which readily grow in high-moisture products including grain. Moulds being living organisms, draw their food requirements from the product causing loss and deterioration. The higher the moisture level in the mould-affected grain the faster the grain spoils. At a moisture level below 10%, respiration in most food grain almost stops, increasing the grain's storage life. It is always safe to store pulses less than 12 %.

Temperature

The rate of all chemical reactions including respiration increases with temperature. Consequently, respiration and deterioration in grain also increases with temperature. When the temperature and moisture level of the grain are correct, then there will only be enough respiration to keep the embryo alive. The respiration process can continue for a long time if the embryo is not damaged by moulds, insects or rodents. Grain rain stored at high temperatures therefore respires and spoils quicker than well dried grain kept in a cool dry place. Higher temperatures also favour multiplication of insect pests, fungi and rodents. Above 40ºC, most insects die within a day. Most insects breed rapidly at 25–33ºC.Most insect species do not breed below 15ºC but grain weevils can reproduce slowly at 12ºC.Below 5ºC insects cannot feed and slowly die. Mites and fungi can increase down to 5ºC in moist grain. Mycotoxin formation is most likely between15ºC and 25ºC.

Current novel technologies in pulses research for disinfestations

Ionizing radiation

Low-dose applications (less than one kGy) also lead to the disinfestation of insects in stored grain, pulses, and food products. (IR) was one of the first ever emerging technologies used in food products for the enhancement of shelf-life. IR provides numerous technological advantages by minimizing food losses and improving food quality. Irradiation is generally applied in the range of 1.5–7.0 kGy to food materials; this is similar to pasteurization and termed radurization. It has been confirmed that IR is safe for food use within prescribed doses and IR is permitted by all specialized agencies like WHO, FAO, IAEA etc. Radiation treatment at low and moderate doses has been recommended for disinfestation of legumes (Tilton and Burditt, 1983). Radiation processing in legumes, at disinfestations dose (0.25 kGy) and germination (0–2 days), results in rapid degradation of flatulence factors without affecting their sprout lengths; this improves their nutritional acceptability, though subtle varietal differences are noticed. At higher dose (0.75 kGy), considerable reductions in their sprout lengths compared to the control were observed; however, their sensory attributes were unaffected.

Radio frequency (RF)

RE energy offers the possibility of rapidly increasing temperatures within bulk materials. RF energy directly interacts with commodities containing polar molecules and charged ions to generate heat volumetrically, significantly reducing treatment times when compared to conventional heating methods. Many studies have explored the possibility of using RF energy to disinfest insect pests (Hallman and Sharp, 1994; Nelson, 1996). More recent studies demonstrated the potential of RF treatments for industrial disinfestation of in-shell walnuts with acceptable product quality (Wang *et al*., 2007). The demonstrated ability of RF treatments to disinfest low moisture products suggests this method for potential applications in dried legumes. The most important considerations in developing heat treatments using RF energy are the thermo tolerance of targeted insects and treated products, and the heating uniformity of the product. In RF treatments, heating uniformity is largely a function of the dielectric properties of the product and the design of the treatment. This paper presents information on the thermo tolerance of target insects and the dielectric properties of products and target insects. The treatment effect on product quality and heating uniformity of proposed RF treatments will also be discussed. Jhonson *et al.* (2010) reported that chickpeas, green peas and lentils were able to tolerate RF treatments of 60°C for 10 min without adverse effects on quality. The results suggest that practical large scale RF treatments to disinfest pulses may be possible. Wang *et al*. (2010) also studied post-harvest disinfestation of chickpea, green pea and lentil by RF heating.

Micro Wave

Disinfestation of stored grains using microwaves can be an alternative to chemical methods for controlling insects in grains and pulses. Mung bean of 12% moisture content (m.c.) was infested with different life stages of *C maculatus* and exposed to 200, 300 or 400 W microwave power levels for 14, 28 and 42 s. One hundred percent insect mortality for all life stages was achieved with exposure to 400 W power levels for 28 s, which caused a surface temperature of mung bean of 68.1 °C. Eggs were the most susceptible and adults were the least susceptible life stages to microwave treatments. No significant difference was observed between mortality of larvae and pupae stages and their mortality was between eggs and adults. Mung bean temperatures increased and germination decreased with increased power level or exposure time (Purohit, 2013)

Pulses are the cheapest and vital source of protein for vegetarian Indian society. Stagnant production and ever increasing population has lead to declining per capita availability of pulses over the years. As per recommendations of WHO, India will require 38 MT pulses by 2017-2018. With a focused and integrated approach, India has the potential to produce 37 MT of pulses. To bridge the gap between demand and supply of pulses, India needs manifold increase in pulse production. Efforts have to be taken up to set up on farm storage yard for farmers in their village itself. Metal bins will solve the problems encountered during storage. Efforts have to be taken up to minimize the post-harvest losses in pulse crops must be made in the national interest. Use of ecofriendly grain protectants like activated clay, talc and Fly ash will also reduce the pest incidence in pulses. Another cheap method is drying under sun for 4h for 3-4 days will control the pest.

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J. Alice R.P. Sujeetha*, C.V. Kavitha Abirami and K. Alagusundaram

Indian Institute of Crop Processing Technology, Pudukottai Road, Thanjavur-613 005, Tamil Nadu,India.

*Mobile No. 09750968425

E-mail: alicesujeetha@iicpt.edu.in