A REVIEW ON THE EFFECT OF FUNGI ON THE WHEAT GRAIN UNDER POST HARVEST STORAGE ECOLOGY

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Abstract: *The review paper is aimed to assess the effect of fungi on the wheat grain under the post harvest storage system. It has been observed that very high percentage of wheat kernels has been lost under post harvest storage. The grain quality greatly depends upon the storage conditions. The storage requirement violation can result in grain deterioration. The biotic and abiotic factors influence the various physical and chemical properties of wheat grains under post harvest storage. The fungal ecology present in the stored grain has an important role in spoilage and the production of mycotoxins. The mycoflora of stored wheat grains predominantly consisted of ubiquitous mould genera Aspergillus, Alternaria, Cladosporium, Fusarium, Mucor, Rhizopus and Penicillium possibly because of their omnipresence, capacity to grow on all possible substrates and a wide range of temperature and humidity. The most frequent species observed on the stored wheat grains of Aspergillus were A. niger, A. fumigatus, Alternaria alternata, Fusarium moniliformis, Rhizopus arrhizus and a few Pencillium species. Among these almost all have the capacity to produce mycotoxin which can contaminate and cause spoilage. The various physical, microbial and biochemical analyses of post harvest storage wheat grain is an essential component to evaluate the grain quality in various Indian wheat varieties and also important for facilitating the minimal post harvest food grain loss.*

Keywords: *loss, biotic factor, abiotic factor, mycotoxin, infestation.*

1.1 Introduction

The grain production varies from year to year and hence the grains should be stored strategically from years of overproduction for the use in year of under production. Stored grains can have losses in both quantity and quality. The wheat grain after harvest is influenced by a wide variety of biotic and abiotic factors and has been studied as a stored grain ecosystem. Losses occur when the grain is attacked by microorganisms and particularly by fungi. The grain losses in quantity and quality can be under the form of depletion in seed viability, hardness, colour, size and shape, grain weight and various biochemical parameters, protein, carbohydrate and vitamins under post harvest storages. The presence of mycotoxins in grains is traditionally regarded as an indicator of poor storage conditions. Mycotoxins may already be present in grains coming into storage or may be produced as a result of poor storage only if there is sufficient moisture. Conversely, not all moulds that grow in stored commodities produce mycotoxins. The metabolic activity of these pioneer species raises the moisture content of the grain, which may allow growth of mycotoxigenic species and ultimately, the formation of mycotoxins. *Alternaria, Aspergillus* and *Penicillium* can act as pre or post-harvest pathogens of grain and may form mycotoxins.

1.1.1 The origin and classification of wheat

Wheat belongs to the genus Triticum of the grass family, Poaceae. This genus is originated in the tropical South west Asia, where it occurs in wild as well as in cultivated forms. Wheat is well adapted to harsh environments and is mostly grown on wind swept areas that are too dry and too cold for the more tropically inclined rice and corn, which do best at intermediate temperature levels. Wheat was first grown in the United States in 1602 on an island of the Massachusetts coast. Man has been dependant upon the wheat plant for thousands of years. Wheat genetics is more complicated than that of most other domesticated species. Some wheat species are diploid, with two sets of chromosomes, but many are stable polyploids, with four sets of chromosomes (tetraploid) or six (hexaploid) set of chromosomes [1-9]. Globally, wheat is the most-produced food among the cereal crops after rice. Table 1.1 shows the taxonomic status of the genus Triticum .

The development of a modern classification depended on the discovery, in the 1918s, of the fact that wheat was classified according to three ploidy levels [10-16]. The classification of Van Slageren (1994) is probably the most widely used genetic-based classification at present. Most species of wheat can be described in Latin binomials, e.g., Triticum aestivum, rather than the trinomials necessary in the genetic system, e.g., Triticum aestivum subsp. aestivum. Both approaches are equally valid and both are widely used [17].

Table 1.1:

The Taxonomical status of *Triticum*

Kingdom	Plantae	Plants
Subkingdom	Tracheobionta	Vascular plants
Superdivision	Spermatophyta	Seed plants
Division	Magnoliophyta	Flowering plants
Class	Liliopsida	Monocotyledons
Subclass	Commelinidae	
Order	Cyperales	
Family	Poaceae	Grass family
Genus Species	*Triticum* *aestivum*	Wheat Common wheat

Wheat (the *Triticum* spp.) is cultivated worldwide. Globally, wheat is the most-produced food among the cereal crops after rice. Wheat grain is a staple food used to make flour for leavened, flat and steamed breads; cookies, cakes, breakfast cereal, pasta, noodles; and for fermentation to make beer, alcohol, vodka or even biofuel. Durum is the most commonly used to make pasta. The most common wheat is the hexaploid wheat and includes spelt, modern bread wheat and soft wheat used for cookies and cakes. Wheat is grown to a limited extent as a forage crop for livestock, and the straw can be used as fodder for livestock or as a construction material for roofing thatch. Although

wheat supplies much of the world's dietary protein and food supply, as many as one in every 100 to 200 people suffers from Coeliac disease, a condition which results from an immune system response to a protein found in wheat: gluten [18-20]. Grain fed to livestock whole or coarsely ground. Starch is used for pastes and sizing textiles. Straw is turned into mats, carpets, baskets, and used for packing material, cattle bedding, and paper manufacturing. Some wheat is cut for hay. Wheat grown for grain crop is also used for pasture before the stems elongate and as a temporary pasturage; it is nutritious and palatable.

1.1.2 The effect of stored wheat grains under post harvest storage

The spoilage of grain in storage is brought about by two variables, the biotic and abiotic [21]. Wheats are attacked by many fungi and other organisms. Some cultivars are resistant to the various rusts, smuts, and virus diseases. The most important fungal diseases of wheats are the extension agents which are concerning diseases in an area before growing wheat. Also cvs should be selected for growing as resistant to various diseases. The biotic variables are different types of insects, mites, rodents, birds and microorganisms, i.e., bacteria and fungi. The abiotic variables include temperature and moisture content of the grains; the latter in grains increases due to seepage of moisture from soil or from cemented floor [22]. The micro flora of cereal grains normally includes fungi, bacteria and actinomycetes [23-25]. A number of fungi have been reported to be associated with cereal grains and their milling fraction [26-27]. The majority of mycotoxins are chemically tough, resistant to temperature, conditions of storage and processing technologies. Therefore, detoxication is not always effective. Based on the stages at which invasion and growth occur, the fungi associated with grains can conveniently be divided into two groups i.e., Field fungi and Storage fungi [28]. Spoilage of stored grain by fungi is determined by a range of factors which can be classified into four main groups including (a) intrinsic nutritional factors, (b) extrinsic factors (c) processing factors and (d) implicit microbial factors. The factors produce fungal colonization within the stored grains [29-30]. These reviews examined some important mycotoxins and the post-harvest control strategies which have been developed for effective management to minimize entry of mycotoxins into the food chain. In some cases, pre-harvest decisions can significantly impact the capability for subsequent post-harvest control. The propagates of mould fungi, frequently found in grain and its surroundings, start to develop when favourable conditions emerge. Temperature and substratum moisture are the most significant factors that determine the intensity of micromycete development and grain damage.

1.1.2.1 The effect of fungi on the odour and discolouration of the stored wheat grains

The fungal contamination of the grains is responsible for emitting undesirable odours [31] found that under high moisture condition cereals gave a musty odour. The dark colouration of germs of the wheat grains are due to the damage caused by fungi [32]. This is discoloration of the germ end of the wheat grain. In the commercial grading system, black point involves the germ end only and not extended into the grain crease. If more than half the grain is damaged and well into the crease, it is classified as smudge. It has been also observed that if the wheat grains, with moisture content of 13% or above is kept long enough at a temperature of 35^0C to 40^0C, the grains turn brown even in the absence of storage fungi [33]. Grain itself and the microbial contaminants respire slowly when stored dry. However, if the water availability is increased to 15-19% moisture content (=0.75-0.85 water activity (a_w), wheat) spoilage fungi, particularly *Aspergillus* and *Penicillium* species grow, resulting in a significant increase in respiratory activity [34]. This can result in an increase in temperature and sometimes spontaneous heating from the colonization by a succession of fungi resulting in colonization by thermophilic fungi and actinomycetes [35-37].

The quantitative grain contamination with micromycete propagules was established by a number of methods given by various scientists [38-44]. The grain colour changes by some micromycetes produced and contaminate it with poisonous substances including mycotoxins [45-52].

1.1.3 The presence of micro flora contaminating the stored wheat grains

Mould contamination of food and feed is a constantly occurring phenomenon but the attitude towards it has been far from consistent [53]. It has been found that fungal damage of grain is caused in various ways. They reduce the grain viability, produce odour, grain discoloration and depletion in food added value (FAV) by the increase in FAV and also produce toxins injurious to the health of consumers. The fungi are responsible for emitting of undesirable odour from stored grains [54]. A number of studies have been reported the loss of dry matter content and visible moulding of stored wheat grains [55-62]. This could be considered as a subjective index of the safe storability of grain. There are problems with the use of visible moulding as a criterion of deterioration [63-66]. Wheat quality loss has been measured and models developed based on germination rates, visible mould growth or respiration of grain and microorganisms. The microscopic growth may be a more effective measurement of initial colonization than visible moulding [67-70]
An extensive micro flora has been found to be associated with stored wheat grains [71-83]. Earlier in the laboratory a number of cereals have been screened with respect to micro flora associated in storage grains [84-87].
The effect of microbial infestation on decrease in the germination of grains is now well known. It has been established in other cereals and especially in wheat. Discolouration of wheat is a common occurrence. During the course of their development breakdown and utilization of the constituents of the seeds occur [88-89]. The dark germs of grains are known to be due to damage by storage fungi [90-94]. The high moisture and temperature conditions for cereals gave a musty odour due to fungi, instead of bacteria [95].

1.1.4 Fungal infestation in post harvest stored wheat grains

The wheat grains come in association with the fungi from the time of grain maturity and also at the time of storage. Some of these fungi are in intimate association and are present as dormant mycelium under the pericarp or dormant spores on the surface of the kernel. However, there is a number of fungi which are only superficially associated with stored grains. Mould growth in grains may cause deleterious changes in addition to the formation of mycotoxins. Many spoilage
fungi cause loss of germination in seed grains, discolouration and darkening of the grains, reduction in protein content, musty odours, and changes in fatty acid profiles and other constituents of the grains. Mould development may also encourage mite and insect infestation. The association of fungi with cereal grains starts from the field itself. Shortly after the grain reaches to maximum size, the lemma and palea protecting it are pushed apart exposing the grain to infection by fungi [96] and their extensive studies have been carried out in the laboratory on these aspects [97-99]. Poor post harvest management can lead to rapid deterioration in grain quality, severely decreasing the germinability and nutritional value of stored grains. Fungal activity can cause undesirable effects in grains including discolouration, contribute to heating and losses in nutritional value, produce off-odours, losses in germinability, deterioration in baking and milling quality, and can result in

contamination by mycotoxins [100-102].
A number of studies have been reported on the loss of dry matter content and visible moulding of stored wheat grains [103-110]. This could be considered as a subjective index of the safe storability of grain. There are problems with the use of visible moulding as a criterion of deterioration [111-114]. Fungi seldom occur on grains in isolation, but usually as a mixed consortium of bacteria, yeasts and filamentous fungi. It is thus inevitable that interspecific and intraspecific interactions will occur depending on the nutritional status of the grain and the prevailing environmental conditions. Wheat quality loss has been measured and models developed based on germination rates, visible mould growth or respiration of grain and microorganisms [114-118] The microscopic growth may be a more effective measurement of initial colonization than visible moulding. Some attempts have also been made to relate dry matter losses to actual calorific losses due to the activity of mycotoxigenic moulds.

1.1.5 Decrease in nutritional value as due to myctoxin production in stored wheat grains

During storage, the grains undergo some biochemical changes like the increase in fatty acids. The increase in fatty acid value is chiefly due to storage fungi and not due to the activity of seeds [119]. The stored grain will have quantitative and qualitative losses. Weight loss during storage (not due to a loss of moisture) is a measure of food loss but the latter may be proportionately larger owing to selective feeding by the pests. Rodents and moth larvae may preferentially attack the germ of the grain thus removing a large percentage of the protein and vitamin content, whereas weevils feeding mainly on the endosperm will reduce the carbohydrate content. Many pests may eat the bran of cereals reducing vitamins such as thiamin [120-123]
The quantity and quality of endosperm proteins are the major factors responsible for baking quality, and nutritional value of wheat [140-142]. Various seed storage proteins in wheat are classified upon their solubility in different solvents, such as water, saline solution, 70% aqueous ethanol and diluted acid or alkali solutions and are named as albumins, globulins, gliadins, and glutenins, respectively [126-128].
The other storage factors such as moisture and fungal infection also lead to changes in vitamin content. In beans in particular, loss of protein is very important where there is infestation, as up to 25% of the dry matter may be raw protein. Fungi growth leads to reduced nutritional and technical quality of cereal grains [130-132]. Grain storage conditions affect its quality due to high percentage of mycotoxins [133-137]. Wheat grains are also rich in pantothenic acid, riboflavin and some minerals, sugars etc [138]. The composition of wheat grain and flour is given in Table 1.2.

Table 1.2:
Composition of wheat grain and flour [139]

Parameter	Grain (%)	Flour (%)
Moisture	9 - 18	13 - 15.5
Starch	60-68	65-70
Protein	8-17	8-15
Cellulose	2-2.5	Trace
Fat	1.5-2	0.8-1.5
Sugars	2-3	1.5-2
Mineral matters	1.5-2	3-6

Storage temperature affects the keeping quality of wheat. Increase in temperature accelerates the rate of respiration until it is limited by oxygen supply; build up of carbon dioxide concentration, exhaustion of substrate, and thermal inactivation of essential enzymes. Heat damages the gluten proteins and even discolours the kernels of the stored hard red winter wheat with moisture contents of 10.95% in sealed half gallon glass jars at -1^{0}C and 24^{0}C for two years [140-142]. The grain losses in quantity and quality can be under the form of depletion as mentioned above like that of seed viability, hardness, colour, size and shape, grain weight and various biochemical parameters, protein, carbohydrate and vitamins under post harvest storages. The storage fungi damage the grains in several ways; they reduce the germinability, produce undesirable odour and kernel discoloration, decrease the food value and also produce toxins injurious to the health of consumers.

The effect of mycotoxigenic fungi in post harvested stored wheat grains must be examined in the context of the ecology as a whole in order to understand the dominance of certain species of fungi under certain environmental conditions. Interactions between these fungi and other contaminants are complex and are significantly affected by the prevailing and changing environmental factors. As a conclusion the mycoflora of stored wheat grains predominantly consisted of ubiquitous mould genera *Aspergillus, Alternaria, Cladosporium, Fusarium, Mucor, Rhizopus* and *Penicillium* possibly because of their omnipresence, capacity to grow on all possible substrates and a wide range of temperature and humidity. The most frequent species observed in the stored wheat grains of *Aspergillus* were *A. niger, A. fumigatus, Alternaria alternata, Fusarium moniliformis, Rhizopus arrhizus* and a few *Pencillium* species and some of the fungi have the capacity to produce mycotoxin which can contaminate and cause spoilage.

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