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Studies on the selection of plastic woven sacks for storage of food commodities

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ABSTRACT

Mycological and insect penetration studies were evaluated on paddy, rice and wheat stored for six months (at RT and accelerated condition) in Jute, Poly Propylene (PP) and High Density Poly Ethylene (HDPE) woven sacks. Thirty different species of fungi belonging to the genus *Aspergillus, Mucor, Rhizopus, Alternaria, Penicillium, Cladosporium* and some mycelia sterile were isolated by decimal dilution technique. *Aspergillus* Sp. was predominant in almost all the samples analyzed. Total fungal counts varied considerably among the commodity and the paddy harbored higher number of fungal population than rice and wheat. The samples stored at accelerated condition exhibited total deterioration of the commodity within 15days due to rapid fungal growth and at the end of 30days of storage, visible fungal colonies were observed on the surface of the grain. Based on the mycological analysis and insect penetration studies it is evident that the HDPE woven sacks are more suitable for storage of food grains than the traditional Jute sacks.

Key words: Plastic woven sacks, grain-storage, periodical sampling, fungal population, relative humidity (RH), accelerated condition and Insect penetration.

INTRODUCTION

From the early stages of kernel formation on the standing crop until their use and consumption, cereal grains are subjected to damage of several biological agents, mainly fungi (Chirstensen 1991). The fungi colonizing grain have been classified into two groups, known as 'field' and 'storage' fungi (Chirstensen and Kaufmann, 1969). Field fungi characteristically colonize the ripening grain and include *Alternaria, Cladosporium, Helminthosporium* and *Fusarium* sp., but they seldom develop further in storage conditions. In contrast, storage fungi are present in low numbers before harvest but develop rapidly in storage when conditions are favourable, mainly *Aspergillus* and *Penicillium* Sp. Although low levels of storage fungi present during harvest, much is added during threshing, winnowing, frying and when grain is stored in contaminated stores (Lacey 1971; Flannigan 1978). The third and intermediate group of fungi such as Fusarium Sp., which can sometimes develop in most grain during storage (Pelhate 1968). Field fungi require readily available water and therefore seldom develop in storage situation; while storage fungi, specially *Aspergillus* Sp. are able to grow at low water activities (aw, 0.70-0.75) enabling them to initiate grain spoilage. Fungi that infest grains in storage is responsible for decreased in germination, discoloration, heating, mustiness and total spoilage (Lacey *et al.* 1991, Lacey and Magan, 1991). Both storage and field fungi can produce mycotoxins which may cause health hazards to humans and animals after their ingestion (Christensen 1991, Frisvad and Samson 1991 and Miller 1995). Further, these spores are also responsible for respiratory diseases in people handling and transporting them. Although fungal invasion depends on growth and harvest conditions, any such internal mycota may be responsible for

fungal spoilage of the product or more significantly, formation of mycotoxins in the product (King et al. 1986 and Mills, 1989). For all these parameters, the type and number of genera and species present soon after harvest and drying can provide information useful for the control of moulding in store by different processes (eg. Drying, chemical treatment and modification of atmosphere). On the other hand, the Sp. present can give information on the conditions under which grains have been stored. Therefore, it is essential to characterize and identify the spoilage fungi, in order to control and prevent fungal growth and potential mycotoxin formation (Gourama and Bullerman, 1995).

In India, majority of the food grains are stored in jute sacks since ages. This is because the jute sacks are cheap and they are porous in nature. Due to several advantages of polymers, selection of alternatives to jute sacks or most suitable packaging material can ultimately result in improved shelf-life and better quality while reducing costs, particularly by avoiding undue food losses and waste (Elias 1979). A good packaging material should not support the growth of contaminating fungi and insect development. It is important to evaluate the packaging material with respect to microbiological quality during storage of food grains. Therefore, the present study was undertaken to assess the suitability of commodity storage, insect penetration and variation in fungal profile in paddy, rice and wheat stored in three packages such as PP, HDPE and Jute sacks at ambient (RT) and accelerated conditions.

MATERIAL AND METHODS

Packaging materials

Fresh woven sacks made of HDPE, PP and Jute sacks were used for short duration (6months) storage of wheat (*Triticum aestivum*), rice (*Oryzae sativa*) and paddy. The above three types of sacks were supplied by M/s Indian Centre for Plastics in the Environment, Mumbai.

Storage condition

Paddy, rice (Variety Sona-Mahsuri) and wheat (variety Duram) harvested during December 2003 were procured from one of the local mills of Mysore. Paddy was packed in HDPE, PP and Jute sacks, each containing 35 kg; while rice and wheat were packed in 50 kg sacks (based on their bulk density) and they were machine stitched. Sacks were placed one above the other vertically, wherein each column six sacks were arranged and stored for six months at ambient conditions (RT). The above commodities were also stored in 1 kg pack (25x20 cm, size) of respective HDPE, PP and Jute sacks and were stitched as above. These small unit pack bags were stored at accelerated conditions (38±1°C and at 90±% RH). Sufficient gap was maintained for each set of experiment to avoid cross contamination of insects and rodent interactions, if any during storage.

Withdrawl of sample and mycological analysis

In each withdrawl, the sack was opened and the sample was poured on to an aluminium tray (3 x 6 x 1) and 1 kg sample was taken out after through mixing. Samples stored at RT was withdrawn on monthly basis while other set of samples stored at accelerated condition was drawn after 8 and 15 days intervals. Mycological analyses was carried out in triplicate plates on the same day using Potato Dextrose Agar (PDA), which was purchased from Hi-Media Ltd., Mumbai. The samples were analyzed by decimal serial dilution technique (Harrigan and McCance, 1990). 10gm of appropriate sample was taken into 100ml of 0.1% peptone solution in 250ml Erlenmeyer flasks which were subsequently shaken in a Lab-line incubator-shaker for 30min at 140rev/min. Serial dilutions were made from the stock suspension upto $1:10^6$/ml. 1ml aliquot of appropriate dilution was taken onto sterile petriplate and 15ml of molten PDA was poured over it. The plates were allowed to solidify and incubated at 25±1°C, and the colonies were counted after 5 days. Triplicate plates were maintained for each set. Fungal identification was done based on colony characterization and morphological structures under the microscope (Olympus, Japan) according to Raper and Fennell (1965).

Insect penetration studies

An experiment was conducted at room temperature (25±1°C and 60±5% RH) with a clean and dry dessicators (0.85L cap.) which served as test chambers. The dessicators were filled with 500gm of wheat that was earlier kept in freezer for 24h to kill live insects if any. The packaging materials

such as PP and HDPE were cut into 15cm^2 size and were sandwiched between bottom and lid or the dessicators. Five replicates were maintained for each packaging material with equal number of replications for gunny sacks which served as control. From the established cultures of *R. dominica* (lesser grain borer), *S. oryzae* (rice weevil) and *T. castaneum* (rust-red flour beetle) adults (2-3 days old), 100 per replicate were released on the packaging material through the aperture of dessicator lid and aperture was closed with rubber septum. The rubber septum was opened for 2 min daily for sufficient aeration to the insects. This was continued for 2 weeks. At the end of experiment, wheat kept in the dessicator was sieved to count the insects penetrated if any, through the packaging materials and % insect penetration in each packaging material was calculated.

RESULTS AND DISCUSSION

The results of rice, paddy and wheat stored for six months at RT in different types of sacks such as Jute, PP and HDPE are shown in Table 1. Total fungal counts vary considerably among the commodity tested and paddy harbored higher number of fungal population than rice and wheat throughout the study. The fungal profile in commodity stored at RT has decreased within 3 months, irrespective of type of sacks in which they have stored, although there was a fluctuation in fungal population in paddy samples (Table-1). Data on mycological analysis carried out from initial rice samples yielded 17.1x10^{3}cfu/gm. Subsequent analysis indicated a drastic reduction in population in samples analyzed from 1st and 2nd month and no fungal colonies were isolated from 3rd to 6th month. Contrary to this, the rice samples stored in PP and HDPE sacks, did not support fungal growth throughout the study. The fungal profile in paddy storage was different from rice and wheat. In case of paddy, the population of fungi was observed throughout the study in all three packaging materials. Also, in Jute sacks there was a gradual increase in fungal population upto three months and declined further in subsequent analysis. However, in PP and HDPE sacks although there was an increasing trend initially, further analysis indicated a fluctuation in population. Data on wheat storage revealed a gradual decrease in population within 2 months and no fungal colonies were recorded in the subsequent analysis.

In the present findings, woven PP and HDPE sacks did not show any fungal colonies in rice, and lesser number of colonies in wheat samples. The results obtained here corraborate with Odamtten et. al (1985a), who reported woven PP sacks did not support the growth of fungi in maize stored for 4 months in Jute sacks. Odamtten et. al. (1985b) also stated grain contents stored in PP sacks were of better microbiological quality than those kept in Jute sacks and there was a positive correlation between the final mycoflora on Jute sacks and loss in tensile strength due to the presence of saprophytic fungi such as Sp. of *Aspergillus, Fusarium, Penicillium, Rhizopus* and *Trichoderma*. Jute sacks contain sufficient nutrients to support fungal growth. This implies that fungi can attack this packaging material and cause mechanical and chemical damage and soiling (Hueck, 1965). Fungi therefore play an major role in the reduction of tensile strength of the Jute sacks. Presence of fungal spores on the fabric of Jute sacks, in addition to soiling the sacks it also alters the appearance of the sacks by their colored metabolites.

The fungal species isolated and identified includes Sp. of *Aspergillus: A. candidus, A. speluneus, A. niger, A. fumigatus, A. ochraceous, A. flavipes, A. versicolor, A. ornatus, A. sparces, A. sulphuricus, A. asperescens, A. sydowii, A. terricola, A. biplanus, A. wenti, A. parasiticus, A. flavus, A. alliaceus, A. chevalieri, A. restrictus, A. cremius, A. sclerotiarum, A. thomii, A. tamarii, A. canoyii* and Sp. of *Mucor, Rhizopus, Alternaria, Penicillium, Cladosporium* and Mycelia sterila.

With regard to insect development in paddy and rice stored in Jute sacks exhibited a large number of adult *Carcyra cephalonica* (rice moth) and other insect species from second month and continued till the end of storage. Almost same trend was observed in woven PP sacks, except that the moth development was delayed upto 6th month. Contrary to this, the rice and paddy stored in HDPE sacks and wheat stored in all three types of sacks, neither moths nor insects were developed throughout the study. This indicates that HDPE

Table 1. Fungal population in rice, paddy and wheat stored for six months at ambient temperature (RT)

Duration of Storage	Fungal population (x 10^3 cfu/gm)								
	Rice			Paddy			Wheat		
	Jute	Pp	Hdpe	Jute	Pp	Hdpe	Jute	Pp	Hdpe
Initial load	17.1±3.0	NT	NT	33.0±3.8	NT	NT	124±11.2	NT	NT
1st month	1.4±0.2	0	0	60.4±5.1	46.7±4.4	39.3±3.8	77.0±2.9	41.0±3.4	28.9±2.8
2nd month	1.0±0.2	0	0	68.2±7.2	58.0±5.2	55.3±4.0	10.0±1.4	3.0±0.2	2.0±0.2
3rd month	0	0	0	98.4±13.7	101.4±13.8	86.0±12.1	0	0	0
4th month	0	0	0	60.0±6.6	45.0±9.3	35.0±9.6	0	0	0
5th month	0	0	0	36.3±4.6	20.2±1.8	22.6±1.1	0	0	0
6th month	0	0	0	32.6±3.1	55.1±3.2	71.8±8.3	0	0	0

Values represent the mean ± standard deviation of triplicate plates NT= Not Tested

Table 2: Fungal population in rice, paddy and wheat stored for 30 days at accelerated condition (90±2% RH and 38±1°C)

Commodity	Duration of storage	Fungal population (× 10^3 cfu/gm) in different packaging material		
Rice	Initial load	JUTE	PP	HDPE
		0	0	0
	8 days	4.1±0.4	3.8±0.5	3.2±0.3
	15 days	214.7±9.9	13.7±0.2	4.1±0.8
	30 days	>300	>300	>300
Paddy	Initial load	24.2±5.1	NT	NT
	8 days	77.2±6.2	74.8±5.9	76.4±5.6
	15 days	196±8.1	140.5±12.4	131.0±12.4
	30 days	>300	>300	>300
Wheat	Initial load	82.7±4.25	NT	NT
	8 days	184.7±19.2	137.6±6.5	101.3±5.8
	15 days	266.3±18.3	179.8±7.4	124.2±5.8
	30 days	>300	>300	>300

Values represent the mean ± standard deviation of triplicate plates NT=Not Tested

Table 3. Insect penetration through different packaging material

Packaging materials	% insect penetration		
	T. castaneum	*R. dominica*	*S. oryzae*
JUTE	98.7±6.3	83.8±7.5	67.0±4.1
PP	0	2.9±0.1	0
HDPE	0	0	0

Values represent the mean ± standard deviation of five replicate samples

sacks are more suitable in preventing the fungal development during commodity storage and thereby protecting the grain quality.

Results of data on rice, paddy and wheat stored at accelerated condition (38±1°C and at 90±% RH) are shown in Table-2. Initially, the fungal population in rice was not observed at 10^3 dilution. Subsequent analysis after 8 and 15 days of storage there was a significant increase in fungal population. At the end of 30 days of storage the population has reached to >300cfu/gm. Paddy and wheat on the other hand, had initially yielded $24.2x10^3$ and $82.7x10^3$cfu/gm, respectively and has reached to >300cfu/gm at the end of 30 days of storage. As expected, the samples exhibited total deterioration within 15 days due to rapid fungal proliferation (black and green spots) and by the end of 30 days visible fungal colonies were also detected.

During storage of commodities, packaging provides a physical barrier that prevents or impedes the infestation by insects. With reference to packaging materials there are three factors that determine the infestation of a commodity. They are insect species, type of packaging materials and type of commodity packaged. Insects may vary in their capacity to penetrate packaging materials. In addition, holes larger than $2mm^2$ will allows most of the stored product adult insects to enter packages, whereas holes smaller than $0.3mm^2$ will prevent entry of most stored-product insects (Cline and Highland, 1981). Most research to determine penetration abilities of various species of stored-product insects were against the packaging films (Cline 1978, Highland 1988), but not with woven plastic packages. There has been no previous reports available on insect penetration of plastic woven packages. The present, study carried out on this aspect revealed that, among the three packaging materials tested, maximum penetration was observed in Jute sacks. The level of penetration in Jute sacks were 98.7, 83.8 and 67% of the tested *T.castaneum, R.dominica* and *S.oryzae,* respectively (Table-5).With the plastic woven sacks, only 2.9% of the tested *R.dominica* were penetrated through polypropylene (PP) woven sacks, while none of the *T. castaneum* and *S. oryzae* could penetrate through PP. Conversely, there was no penetration in HDPE woven sacks by all the three insect species tested. From these results it is evident that the polyethylene woven sacks were more tolerant to insect penetration in comparison with Jute sacks. Therefore, the plastic woven sacks are more safe and advantageous in preventing insect penetration during commodity storage than traditional Jute sacks.

CONCLUSION

In summary, the present findings revealed that there was a significant difference between the higher number of fungal colonies associated with Jute sacks, than woven PP and HDPE sacks. Among the three commodities stored at ambient temperature (RT), paddy harbored higher number of fungal colonies than rice and wheat throughout the storage period. Based on the results of both mycological analysis and insect penetration studies it can be concluded that woven HDPE sacks have many microbiological and physiological advantages over the traditional Jute sacks to merit their use for commodity storage. This would probably save defects and losses due to insects and fungi which were estimated to be over 30% of the annual harvest.

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