## Abstract

Stored grain losses at the farm level is still a reality, and there is a need for the development of improved grain storage structures for use at farm households. Bamboo based grain storage structures were popular since time immemorial, and this study investigates the feasibility of adopting a bamboo reinforced concrete (BRC) silo for the long-term storage of paddy. A flat bottom BRC silo of 1000 kg capacity was designed, developed and tested at IIT Kharagpur. A unique pattern of stress distribution tends to develop in flat bottom silos during grain filling. The finite element method (FEM) has been used to predict the filling stresses developed in the BRC silo walls as well as on the grain layers. The FEM predictions showed good agreement with the results of the classic theories (Janssen's and Reimbert's) and the Indian Standards (IS 4995: 1974). FEM exhibited the capability to capture the non-uniformity in the stress distribution patterns. The field evaluation was conducted in comparison to the performance of the conventional polypropylene bags. Stored paddy was analyzed for changes in quality attributes for 12 months and at an interval of 30 days. The temperature of stored grains was measured along the silo walls as well as the silo center. Higher temperatures were recorded at the bottom layer of grains along the silo center during the summer months, while this zone shifted to the middle layer on the cooler days. The moisture content of the paddy stored in BRC silo increased from 11.67 to 13.34% (wet basis) towards the end of the storage duration. The interstitial $O_2$ levels showed a declining trend while the $CO_2$ levels increased, with storage duration as well as grain depth. The BRC silo outperformed the bag storage in aspects such as head rice yield, seed quality, insect infestation and fungal load in addition to the protection against rodents. Cooking attributes displayed aging-induced changes in the case of the bag as well as silo stored grains. The defuzzified sensory scores suggested that the rice stored for 270 days in the silo showed the highest preference among the consumers, while the texture was adjudged the most important parameter affecting the rice palatability. Ten strains of fungi with maximum frequencies were identified throughout the storage duration by molecular and phenotypic characterization. Among the isolated fungal strains, *Alternaria padwickii* was the most predominant species in the rice samples during Phase 1 (0-6 months), while the maximum frequency of *Aspergillus flavus* was observed in Phase 2 (7-12 months). Other species encountered and isolated from the rice grains include *Curvularia* spp., *Rhizomucor* spp., *Penicillium* spp., *Hypoxylon* spp. and *Aspergillus* spp.

Though undetectable in Phase 1, total aflatoxin content at the end of the storage period was found to be 0.42 μg/kg grain, indicating the presence of the *Aspergillus* spp. in Phase 2. Insect pests such as *Sitophillus oryzae* and *Sitotroga cerealella* (Angoumois grain moths) were observed during the first three months of storage, beyond which they became undetectable. Temperature gradients tend to develop when bulk paddy is stored in the BRC silo, and it has to be closely observed to detect potential zones of grain deterioration. A 3D – transient computational fluid dynamics model was developed for the prediction of vertical and radial temperature profile that tends to develop in the bulk paddy stored in the BRC silo. The developed model showed satisfactory agreement with the experimental readings. The cost-benefit analysis of the BRC structure for 15 years revealed that it is an attractive option for farmers who encounter storage loss of more than 100 kg per annum. The technology yielded attractive payback when losses to the tune of 150-200 kg can be abated with well acceptable levels of net present value, internal rate of return and cost-benefit ratios above 2.

**Keywords:** Bamboo reinforced concrete silo; paddy; finite element method, fungi, computational fluid dynamics, cost-benefit analysis