DESIGN AND DEVELOPMENT OF SMALL SCALE STORAGE SILO OF WHEAT (*T. AESTIVUM*) FOR FOOD SAFETY IN RURAL SECTOR

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by

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DEDICATED TO

DR. YADVIKA

CERTIFICATE

This is to certify that the thesis entitled "**Design and development of domestic grain storage silo for food safety in rural sector"** being submitted by **Ms. Arjoo** to the Indian Institute of Technology, Delhi for the award of **'Doctor of Philosophy'** is a record of bonafide research work carried out by her under our guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology Delhi. The research report and results presented in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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ABSTRACT

Food and nutritional security is an important dimension related to human dignity and societal development. In India wheat is a staple food crop grown and consumed at large scale. The production is seasonal that too affected by a number of factors that makes the storage of wheat an important post-harvest operation. In India ~ 60-70% of the produced wheat is stored at home/farm level. Storage losses is a critical issue and ~10% of the grain produced is lost during storage. Infact type of storage structure plays an important role in protecting the quality of stored grain. The storage structure serves as a barrier between the stored grain and ambient environmental conditions. Present study focuses on developing new suitable efficient storage structures to solve problems faced by the farmers for the storage of wheat.

To begin with, in order to understand the existing grain storage system used by the farmers, a field study was conducted in selected villages of Haryana (India). It was found that about 80% of farmers are using conventional metallic bins of different sizes to store their grains. In different structures lot of grain damage was found. Overall, it was noted that the conventional metallic bins were not good enough to provide the complete storage protection. The survey results emphasises on the need of designing new storage structures to minimise the storage losses. For designing the storage structure, various engineering properties of three different wheat varieties (MP- 1106, UP-2254 and WH-542) and their behaviour at four different moisture content (8, 10, 12 and 14%) were studied. Thousand grain weight (TGW), true density, porosity, Angle of repose (AOR) increased with the increase in moisture content whereas bulk density, hardness, Initial cracking force (ICF) decreased with the increasing moisture. The knowledge about the various physical, gravimetrical, frictional and flow properties is important for designing process.

Temperature and moisture content are the most important factors affecting the quality of stored grain. Sometimes, the gradients caused due to the difference in temperature of stored grain and the ambient conditions are enough to form a ‘hot-spot’ inside the grain mass. A study was conducted to see the emergence of ‘hot-spot’ inside the small metallic bin (100 kg capacity) and its effect on the quality of stored grain was investigated. The results confirmed that even in small scale bins, temperature and moisture migration takes place which can form ‘hot-spot’. During the summer season, moisture migration is more at the top and bottom of the bin and a ‘hot-spot’ was found near the bottom of bin. Whereas during the winter season, moisture accumulation is only at the top of the bin and the ‘hot-spot’ is also

near the top surface of grain mass. The formed 'hot-spot' had a strong bearing on the quality of stored wheat. Maximum changes in quality of stored wheat were observed during the summer season and near the 'hot-spot'. Protein content was decreased by 21.77 %, fat content by 64.05%, germination by 84.34% etc., other quality parameters also showed significant changes. The study clearly indicates the need of new storage material and design to protect the stored grain from the changing environmental conditions.

A comparative study of different types of materials for grain storage bags was also done. During the field survey different types of bags used for the purpose of wheat storage available in local market were collected. The bags used were jute bag with or without plastic lining, polypropylene bag, Hermetic bag and Eval bag. These bags were then compared for their thermal, mechanical and barrier properties. The results indicate the superiority of Eval and hermetic bags in terms of low thermal conductivity (0.054 and 0.062 W/mK) and good barrier properties (WVTR- 3.56 and 2.16 g/m^2/24 hrs, OTR- 3.45 and 4.28 cc/m^2/day) but have low mechanical properties that can be improved by using jute bag as a cover lining. Hence Eval and Hermetic bags can be used as an alternative to other commonly used bags to store grains.

Finally, based on the experimental findings, design of four new bins were developed and tested. The designs include- (i) bin with horizontal partition, (ii) bin with special provision of having perforated pipe for keeping the fumigant tablets, (iii) bin with perforated empty space at the bottom and (iv) double wall bin with insulation. After evaluating the change in quality parameters and change in moisture contents during the long storage period of nine months, it was found that out of these four new designs, the bin with special provision of centrally located perforated pipe for keeping fumigant tablets was found to be best for wheat storage. The best bin was not only best in terms of maintaining the quality of stored wheat but the curved plates in the central pipe were acting as an insect-pest trap thus reducing the infestation and also for their monitoring without disturbing the biological system. Wheat straw was found best in terms of low thermal conductivity (0.04 W/mK) and can be used as an insulating material in double wall metallic bin. Overall, the final novel design integrating double wall concept with metallic bin having special provision for keeping fumigant tablets will solve the storage problems of farmers in rural habitat. Infact popularisation of such a simple design of grain storage bin which can be fabricated by local artisans will go a long way in achieving food safety in rural India.

सारांश

भोजन एवं पोषण सुरक्षा मानव गरिमा और सामाजिक विकास से संबंधित एक महत्वपूर्ण आयाम है। भारत में गेहूं बड़े पैमाने पर उगाई जाने वाली तथा उपभोग की जाने वाली एक प्रमुख खाद्य फसल है। गेहूं की पैदावार जो मौसमी है वह बहुत सारे कारकों से प्रभावित है। अत: फसल उपरांत गेहूं का भंडारण एक महत्वपूर्ण परिचालन है। भारत में गेहूं उत्पादन का 60-70% घरेलू स्तर पर भंडारित किया जाता है। भंडारण के दौरान होने वाली हानि एक महत्वपूर्ण मुद्दा है जिसमे उत्पादित अनाज का ~10% कम हो जाता है। भंडारण का प्रकार व इसका निर्माण, भंडारित अनाज की गुणवत्ता को कायम रखने में महत्वपूर्ण भूमिका निभाता है। भंडारण संरचना, भंडारित अनाज और परिवेश की पर्यावरणीय स्थितियों के बीच एक अवरोध का काम करता है। वर्तमान अध्ययन गेहूं के भंडारण के लिए किसानों की समस्याओं को हल करने के लिए नए उपयुक्त कुशल भंडारण संरचनाओं को विकसित करने पर केंद्रित है।

किसानों द्वारा उपयोग की जाने वाली मौजूदा अनाज भंडारण प्रणाली को समझने के लिए, हरियाणा (भारत) के चयनित गांवों में अध्ययन किया गया था। यह पाया गया कि लगभग 80% किसान अपने अनाज को भंडारित करने के लिए विभिन्न आकारों के G.I. शीट के बेलनकार संरचना का उपयोग कर रहे हैं। विभिन्न अनाज भंडारण संरचनाओं में अनाज की बहुत क्षति पाई गई। सर्वेक्षण में यह पाया गया कि भंडारण के नुकसान को कम करने के लिए नई भंडारण संरचनाओं को डिजाइन करने की आवश्यकता हैं ।भंडारण संरचना को डिजाइन करने के लिए, तीन अलग-अलग गेहूं किस्मों (MP-1106, UP-2254 और WH-542) के विभिन्न इंजीनियरिंग गुणों और चार अलग-अलग नमी स्तर (M.C) (8, 10, 12 और 14%) पर उनमे आये परिवर्तन का अध्ययन किया गया। हज़ार अनाज का वजन (TGW), वास्तविक घनत्व, छिद्रता (porosity), Angle of Repose (AOR) नमी की मात्रा में वृद्धि के साथ बढ़ गया जबकि bulk density, कठोरता (hardness), प्रारंभिक खुर बल (ICF) बढ़ती नमी के साथ कम हो गया। डिजाइन करने की प्रक्रिया के लिए विभिन्न भौतिक, गुरुत्वाकर्षण, घर्षण और प्रवाह गुणों के बारे में ज्ञान महत्वपूर्ण है।

तापमान और नमी प्रतिशत भंडारित अनाज की गुणवत्ता को प्रभावित करने वाले महत्वपूर्ण कारक हैं। कभी-कभी भंडारित अनाज के तापमान में अंतर के कारण होने वाले ग्रेडिएंट और परिवेशी स्थिति संग्रहीत अनाज के अंदर 'हॉट-स्पॉट' बनाने के लिए पर्याप्त हैं। धात्विक बिन (100 किलोग्राम क्षमता) के अंदर हॉट-स्पॉट' के उद्भव को देखने के लिए एक अध्ययन किया गया और भंडारित अनाज की गुणवत्ता पर इसके प्रभाव की जांच की गई। परिणामों में पाया गया कि छोटे पैमाने पर भी, "तापमान-नमी युग्म" बन जाता है, जिसकी वजह से 'हॉट-स्पॉट' बन सकता है। गर्मियों के मौसम में, बिन के ऊपर और नीचे के भाग में नमी का संचय अधिक होता है जबकि सर्दियों के मौसम में, नमी संचय केवल बिन के शीर्ष भाग में होता है। अनाज द्रव्यमान (grain mass) की ऊपरी सतह के पास गठित 'हॉट-स्पॉट' में संग्रहीत गेहूं की गुणवत्ता पर सबसे ज्यादा असर पड़ा। गर्मी के मौसम में और 'हॉट-स्पॉट' के पास संग्रहित गेहूं की गुणवत्ता में अधिकतम परिवर्तन देखे गए। प्रोटीन, वसा, अंकुरण दक्षता क्रमश: 21.77%, 64.05%, 84.34%, कम पायी गई, अन्य गुणवत्ता मापदंडों में भी महत्वपूर्ण परिवर्तन दिखाई दिए। इस प्रकार यह अध्ययन बदलते पर्यावरणीय परिस्थितियों में भंडारित अनाज की गुणवत्ता बरकरार रखने के लिए भंडारण संरचना के लिए स्पष्ट रूप से नये पदार्थ और डिजाइन की आवश्यकता को इंगित करता है।

अनाज भंडारण के लिए इस्तेमाल किये जाने वाले विभिन्न प्रकार की बैग का तुलनात्मक अध्ययन भी किया गया। क्षेत्रीय सर्वेक्षण के दौरान स्थानीय बाजार में उपलब्ध गेहूं भंडारण के लिए इस्तेमाल किए जाने वाले विभिन्न प्रकार के बैग एकत्र किए गए। इनमे जूट के बैग, पॉलीप्रोपाइलीन बैग, हर्मेटिक बैग (hermatic bag) और ईवाल बैग शामिल है । फिर इन बैग की भंडारण गुणवत्ता की तुलना उनके थर्मल, मैकेनिकल और बैरियर गुणों के लिए की गई। परिणाम (thermal conductivity 0.054 और 0.062 W / mK), अवरोधक गुणों WVTR- 3.56 और 2.16 g / m2 / 24 hrs, OTR- 3.45) के आधार पर अनाज भंडारण के लिए ईवाल और हर्मेटिक बैग उत्तम पाए गए। लेकिन बैग की यांत्रिक मजबूती (mechanical strength) कम होने के कारण, इसे जूट को अस्तर के रूप में उपयोग करके सुधारा जा सकता है। इसलिए अनाज भंडारण के लिए आमतौर पर इस्तेमाल किए जाने वाले अन्य बैग के विकल्प के रूप में ईवाल और हर्मेटिक बैग का उपयोग किया जा सकता है।

अंत में, प्रयोगात्मक निष्कर्षों के आधार पर, भंडारण बिन के चार नए डिजाइन का विकास और परीक्षण किया गया। डिजाइनों में शामिल हैं- (i) क्षैतिज विभाजन के साथ बिन, (ii) बिन में फ्यूमिगेंट गोलियां रखने के लिए छिद्रित पाइप रखने के विशेष प्रावधान के साथ, (iii) बिन में नीचे छिद्रित खाली जगह के साथ और (iv) इन्सुलेशन के साथ दोहरी दीवार बिन। नौ महीने की लंबी भंडारण अवधि के दौरान गुणवत्ता के मापदंडों में बदलाव और नमी की मात्रा में बदलाव के मूल्यांकन के बाद, यह पाया गया कि इन चार नए डिजाइनों में से गेहूं भंडारण के लिए, फ्यूमिगेंट गोलियों को रखने के लिए केंद्र में स्थित छिद्रित पाइप के विशेष प्रावधान के साथ बिन सबसे उत्तम पाया गया। यह बिन भंडारित गेहूं की गुणवत्ता को बनाए रखने के सन्दर्भ में न केवल सबसे अच्छा था, बल्कि केंद्रीय पाइप में घुमावदार प्लेटें एक कीट (insect-pest) जाल के रूप में काम कर रही थीं, इस प्रकार कीट संक्रमण को कम करने और जैविक प्रणाली को अव्यवस्थित किए बिना उनकी निगरानी के लिए भी कारगर है । कम तापीय चालकता (0.04 w/mK) के संदर्भ में गेहूं का भूसा सबसे अच्छा पाया गया और इसे डबल वॉल मेटालिक बिन में एक तापरोधी पदार्थ के रूप में इस्तेमाल किया जा सकता है। कुल मिलाकर, दोहरी दीवार वाले metallic bin में फ्यूमिगेंट गोलियां रखने के लिए केंद्रीयकृत छिद्र वाली पाइप के प्रावधान के साथ एक novel डिजाइन ग्रामीण स्थान में किसानों की भंडारण समस्याओं का समाधान प्रस्तुत करेगा । वास्तव में इस प्रकार के सरल व श्रेष्ठ डिजाइन जिसे स्थानीय कारीगरों द्वारा आसानी से निर्मित किया जा सकता है, ग्रामीण भारत में खाद्य सुरक्षा प्राप्त करने के लिए एक महत्वपूर्ण कदम होगा ।

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Abbreviation	Full form
AlP	Aluminium phosphide
AOR	Angle of repose
BD	Bulk density
CAP	Cover and plinth
CI	Compressibility index
CWC	Central warehousing corporation
FCI	*Food Corporation of India*
GI	Galvanized Iron
GDP	Gross domestic product
HDPE	High density polyethylene
HR	Hausner ratio
ICF	Initial cracking force
LDPE	Low density polyethylene
MC	Moisture content
OTR	Oxygen transmission rate
PCA	Principal component analysis
PP	Polypropylene
PPM	Parts per million
RH	Relative humidity
SWC	State Warehousing Corporations
TGW	Thousand grain weight
TD	True density
w.b	Wet basis
WVTR	Water vapour transmission rate