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INTEGRATED COMMODITY MANAGEMENT

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ABSTRACT

Agricultural produce of all kinds fall within the broad definition of the commodity. Integrated commodity management requires an understanding of the physical and bio-chemical properties of the commodity, storage environment of the commodity, and all tools which can be used to manipulate the storage environment to extend the storage life of the commodity and to maintain the quality of the commodity. Using bulk grain as an example, the relationship among physical properties of grain kernels, grain bulk, environment of stored grain, and methods of managing stored grain was analyzed and an approach to integrated management of grains was presented. The paper highlights the directions for further research for integrated commodity management.

Keywords: Physical and bio-chemical property, storage grain management, commodity.

INTRODUCTION

Agricultural commodities refer to bulk products grown or produced on farms. There are many different types of agricultural commodities, including staple grains and most feed products from plants and livestock and products derived from livestock. Agricultural commodities are usually used to sustain life on the earth.

Under most situations, agricultural commodities are stored, transported, and processed before finally consumed. For example, grain will be stored for several months to one year in Canada. About 900 million tonnes of grains are in storage throughout the world at any given time (Jayas et al., 1995). Grain storage is a repeated interim phase in the complex logistics of moving grain from producer to processor and grain products from processor to consumer. Microorganisms, insects, toxins, chemicals, and heavy metals can contaminate and/or infest the grain and products during this period (White, 1992). Infestation and/or contamination can cause extensive morbidity and mortality, and economic destruction of food manufacturers and agricultural industries. In any country, grain owners (farmer and elevator manager) have a moral obligation to supply grain that are safe, while food processors have a duty to convert those grain into products which can be eaten by consumers without risk of compromising individual health. Therefore, the main purpose of grain storage management is to safely store and transport grain and products to provide a stable and safe food supply on a daily basis to consumers who might live in other villages, towns, cities or countries.

A sound program of commodity management requires an understanding of the characteristics of the commodity, storage environment of the commodity and all tools which can be used to manipulate the storage environment to extend the storage life of the commodity and to maintain the quality of the commodity. From the view of engineering design and economic efficiency, all applied management methods and tools should be based on the physical and bio-chemical property of commodities (Cenkowski and Zhang, 1995) and the property of its storage environment. In this article, we used bulk grain as an example to analyze the relationship among physical and chemical properties of grain kernels, grain bulk, environment of stored grain, and methods of managing stored grain. This analysis should help to understand the integrated approach to grain commodity management.

PHYSICAL CHARACTERISTICS OF GRAIN

Stored grain is bulk granular solids and has flowability under certain elevation potential. Their physical characteristics include the mechanical, thermal, aerodynamic, storage, and quality properties. Data related to these physical properties are required in design and evaluation of machines and equipment used during harvesting, handling, storing, separating, cleaning, and processing of agricultural commodities (Cenkowski and Zhang, 1995; Mohsenin, 1986). During engineering design and evaluation, the limitation to achieve a high accuracy is the availability of adequate data on the engineering properties of grain and oilseeds (Jaros et al., 1992). For example, the geometric properties such as size and shape are one of most important physical properties considered during the separation and cleaning of agricultural grains (Mohsenin, 1986). To a large extent, the geometric properties determine the interactions among and between particles, and with the surrounding air and structures of the machine. These interactions, in turn, influence almost all engineering properties of grain (Cenkowski and Zhang, 1995). In theoretical calculations, agricultural seeds are assumed to be sphere or ellipse. However, the shape of kernels might not be the exact sphere or ellipse and there might be differences between any two kernels (Fortes and Okos, 1980). The shape and size of the seeds affect drying rate, grain and air flow rate, and loads on bin walls (Cenkowski and Zhang, 1995).

To properly use these physical characteristics, each term of the physical characteristics of bulk and kernel of grain should be properly defined and measurement methods should be standardized or described. For example, the term of storage life and germination of grain is well defined and their measurement methods are developed (Karunakaran et al., 2001). However, the definition of storability might be vague even though it has been used in many publications. It is usually used to qualify the storable ability of grain. In most situations, storability might refer to (but not exactly) storage life or vitality (germination). There is also no recognized or described method to determine the storability of grain. There is no method to compare storability of different grain types or the same type of grain at different storage conditions if storage life and/or germination are not used. This unclear definition limits the application of the storability term.

Different procedures and applications impact the physical properties of the agricultural commodity. Moreover, physical properties of the kernels might keep changing during applications (Fortes and Okos, 1980). For example, size and shape of kernels might change during drying, loading, and processing. Size and shape influence the grain bulk density. Different methods for determining bulk density may give different results (Nelson, 1980). In a storage facility, the bulk density is difficult to interpret because the degree of packing depends on the method used to fill the facility (Jayas et al., 1989). Therefore, to properly use the data of the physical properties, measurement condition should be well described and should be close to its application condition.

Any tools, machines, and equipment used should fit well with the physical property of the material. For example, bulk grain can be loaded or unloaded by applying its flowability. When grain is bagged, the bagged grain becomes un-flowable and can be transported inside bags. Even though both methods of grain handling (transfer grain in bags or in bulk) have advantages and disadvantages, it should be used at different stages with different applications. For example, bagged grain is best transported in a small amount and usually used in the retail handling, while bulk grain is handled in large amounts (e.g. 100 t) during harvesting, storing, and processing. Some countries currently handle bagged grain instead of bulk grain. This degrades the handling capacity and efficiency when a large amount grain is transported. Both bags and bag storage space are also expensive, particularly where manpower costs are high. Therefore, some countries have been gradually converting their handling system from bag system to bulk system over the last 20 years. For example, China converted from the bag storage system to the bulk system in the 1990s. India and Brazil currently used both systems.

BIO-CHEMICAL CHARACTERISTICS OF GRAIN

Grain consists of carbohydrates (starch, sugar, and cellulose and non-cellulosic polysaccharides), lipids, fats, protein, vitamins, fibre, minerals, and water. Just as the various cereal species differ in appearance at the macro and micro levels (such as their size and shape), so these differences in chemical composition. These differences influence their storage life, milling and baking quality, and govern the procedure of processing and handling (Wrigley and Batey, 2010). The chemical components are also a source of biological available energy making it susceptible to consumption by animal and microorganisms and damage by insect pests and microorganisms (White, 1995). These bio-chemical composition differences govern their suitable storage environment. For example, different insect species have different preferences on different types of grain. Different chemical components provide different water activity and this explains why different crops have different storage life under the same temperature and moisture content.

Grain at harvest and during parts (if not all) of its storage periods are living, albeit quiescent, organisms that respire and age. After they lose germination ability or are broken, they lose the protection of their structure or of their immunity. Changes in grain components during storage could be seed dormancy, lipids, carbohydrates, proteins, nutrition and feed quality (thiamine, niacin, pyridoxine, inositol, biotin, and vitamin E), and water (Serna-Saldivar, 2010). Therefore, management methods should also be based on the bio-chemical characteristics of the stored commodity.

Agricultural commodities usually consist of certain amounts of water and also usually absorb water when under high RH environment and lose water when under dry conditions. Their chemical activities during storage and transportation are influenced by water activity and temperature (Tipples, 1995). Therefore, controlling water activity and temperature of stored commodities is the basic requirement of integrated commodity management. Universal guidelines for controlling temperature and humidity conditions to suit the various food commodities are impossible because these conditions and the operating environments vary from place to place and commodity to commodity. However, some basic instructions can be followed such as keeping all food commodities in dry conditions, storing wet and dry foods separately, cross-ventilation in the warehouse, sun roofs and covering food commodities during transportation.

GRAIN STORAGE ENVIRONMENTS

Storage environment includes its physical, chemical, and biological environment. These three parts interact with each other (Fig. 1). There is a high risk of grain deterioration due to chemical reaction and infestation of insects and microorganisms when the storage environment is under optimum physical, chemical and biological conditions (White, 1995). For example, insects will infest the grain only when the physical and chemical environments are in their development and multiplication zones (Fields, 1992). Biological and chemical environments are usually subordinate to the physical environment, but in their turn exert a great influence on the physical environment (Fig. 1). Therefore, the efficient way of controlling the bio-chemical environment is to control the physical environment.

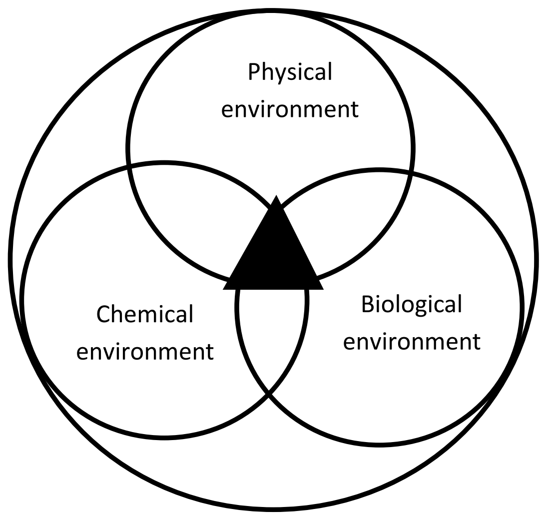

Fig. 1- Environment of stored grain. The triangle shows the high risk of grain deterioration due to chemical reaction and infestation of insects and microorganisms. The edge of the largest circle shows the zones of low chemical reaction and biological multiplication.

Bio-chemical activity of commodities is directly influenced by the water activity and temperature of the commodity. Therefore, managing temperature and moisture content of stored commodities will control both the bio-chemical activity and the environment of the commodity. For example, key issues with grain storage are infestation with microorganisms and insects. Infestation by microorganisms and insects can be controlled by manipulating temperature and moisture content (or relative humidity) (White, 1995). Maintaining these at optimum levels inside and outside of the grain is the secret to successful and cost effective storage. Both temperature and moisture control have advantages and disadvantages (Table1). Theoretically, moisture control will be easier (Serna-Saldivar, 2010) and last longer than the temperature control (Table1). Therefore, the first option for proper grain storage should be the control of grain moisture to safe levels.

Table 1. Comparison of temperature and moisture control of stored bulk grain in bins

	Temperature control	Moisture (RH) control
Control methods	Aeration, chilling (refrigeration)	Drying, mixing, airtight
Limitation of the control methods	Ambient temperature is the limitation under most situations	No limitation if grain will be dried to desired moisture content
Influenced by ambient condition inside bins	Influenced by ambient temperature and follows seasonal temperature	Exchange with ambient air or get wet from precipitation
Prevention from ambient influencing	Difficult to prevent	Can be prevented by good storage facilities
Persisted time	Can keep grain at modified temperature for a short time period (say few days)	Can keep grain at modified moisture for a longer time (say few months)
Total grain mass	Not influenced	Influenced by removing or adding water

The stored grain environment is not a closed system. Its environment is always influenced by ambient environment (Jian et al., 2009). When the environment of the grain is different than the ambient, exchange always occurs until equilibrium is reached. To prevent any undesired influence by the ambient environment, proper storage facilities and/or structures are required. Storage facilities and structures also provide a suitable tool and environment for the control of the physical environment of the storage grain. Even though grain can be stored at different stages inside different structures with defined units such as silos, warehouses, containers, bags, and even in piles on the ground or underground, storage structures should be suitable for the volume, type, physical and bio-chemical properties, processing stage of stored grain, and the nature of the distribution process from the storage. Good designing of storage facilities is the basic requirement for proper grain moisture control. There is currently a trend to decrease the investment on storage structures by using silo bags or other temporary storage facilities as long-term storage facilities. This trend will sacrifice the tools of physical environmental controlling. For example, there will be a challenge in monitoring the temperature and conducting aeration inside silo bags.

INTEGRATED MANAGEMENT (IM)

Integrated management (IM) of stored agricultural commodities (such as grain) can be defined as the use of available technology and tools with ecosystem approach to cost-effectively minimize the losses caused by pests, fungi, and handling damage. It is the practice of monitoring and treating commodity with the goal of reducing cost and inputs. The concept of the IM should be based on the understanding of physical and bio-chemical properties of the stored agricultural commodity. During handling and storage, IM should take advantage of the physical and bio-chemical properties of the commodities. Cost-effectiveness requires that all costs and benefits, including sociological and environmental effects, should have been taken into account.

Integrated management should consist of many components such as integrated pest management (IPM) and integrated mold management (IMM) without contradiction with each other. Ecosystem approach should be applied when the environment of the stored commodity can be viewed as an ecosystem (Jian and Jayas, 2012). The concept of ecosystem approach is not the same as the IM. The main difference between ecosystem approach and the IM is that the ecosystem approach uses the ecosystem concept to manage the stored commodity and IM uses the ecosystem concept as an option. A program developed based on IM might be adapted and improved using ecosystem approach because many recommendations developed in IM program are also based on the concept of the ecosystem. Therefore, compared with IM, ecosystem approach adds complexity to management but brings additional tools for the task. For example, ecosystem approach should be used to manage the stored grain ecosystem. IM should be used to manage the handling and transportation of the grain.

The key of integrated commodity management is to successfully control the physical, chemical, and biological environment of the stored commodities. For example, even though there are many available methods of handling, safe storage, monitoring, and treatment (Fig. 2), the selection of the applied methods should be based on the physical and bio-chemical property of the grain, the storage environment, and final goal of the storage. Physical environmental control with ecosystem approach should be the primary choice. Controlling both temperature and moisture content or either one would be the basic requirement of a successful IM program.

INTEGRATED MANAGEMENT DURING HANDLING AND TRANSPORTATION

Transport of commodities occurs in many ways, from being hand-carried by individuals to being transported by large bulk carriers. The mode of transport used should be appropriate for the origin and size of a shipment and the distance and terrain over which it needs to be moved. Commodity is usually handled and transported in a short time period. The total mass of the transported commodity is usually smaller than that in storage facilities. Therefore, ambient environment might dominate the environment of the transported commodity. During transportation and handling, commodity might also be in contact with different facilities and tools, and being cut, crushed, impacted, and/or sheared (Fig. 3). For example, grain might gain moisture if it is handled during a rainy day. There is a high risk of contamination, damage, and infestation of pests and microorganisms during handling and transportation (Fig. 3). The integrated management during this time period should focus on the control of the physical environment of the handled grain (such as preventing grain from being in rain) and should eliminate any source of contamination and infestation of pests.

Compared with the storage stage, the advantage of the handling and transportation stage is that grain is usually in a small batch, can be easily moved from one location to another location, will be handled in a few days or hours, can be sampled easily, can be treated in batch or during handling, and insect populations might not have enough time to grow. Therefore, an IM program of grain during handling and transportation should take these advantages and avoid quality and quantity damages.

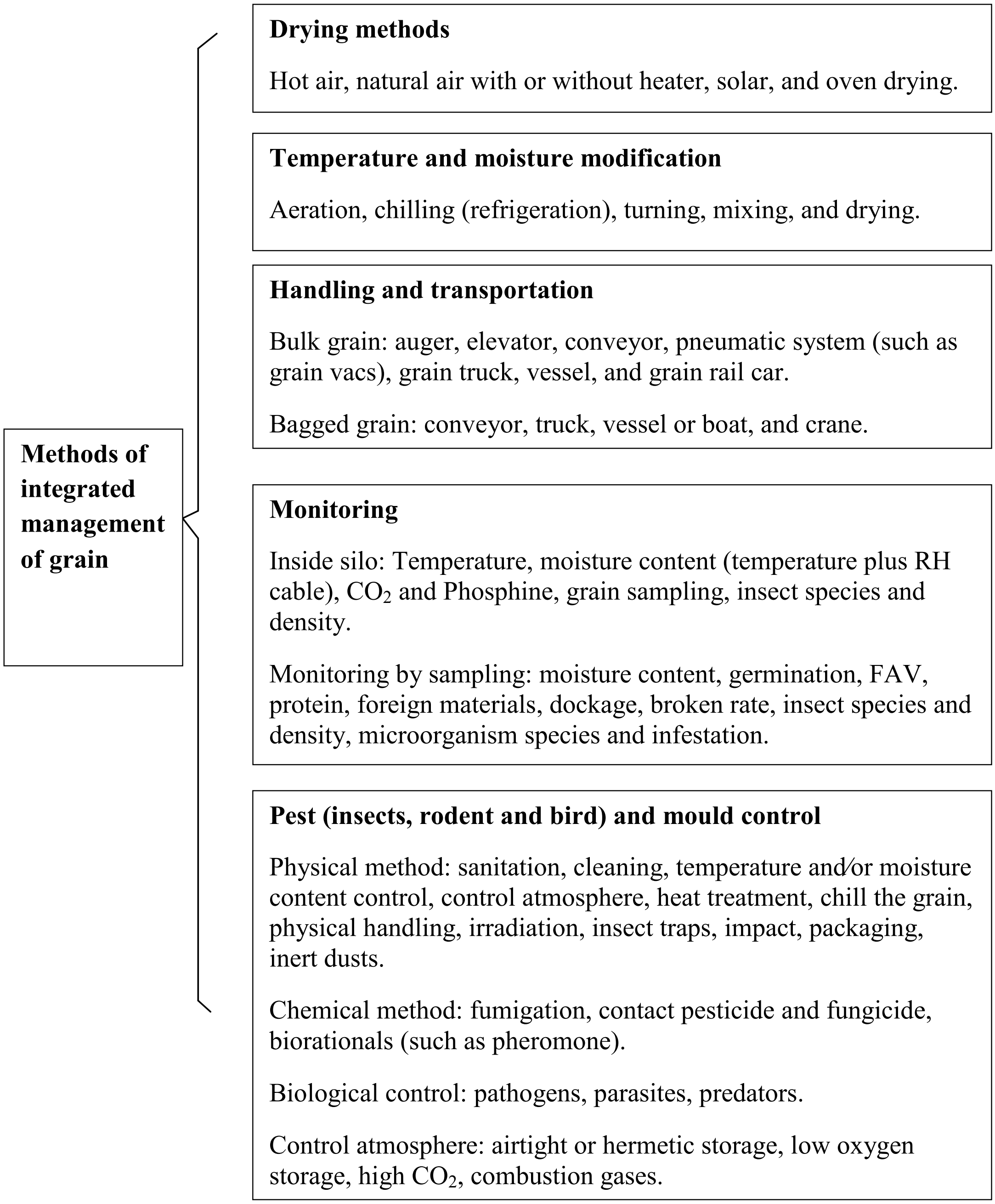

Fig. 2- Available methods of integrated management of grain.

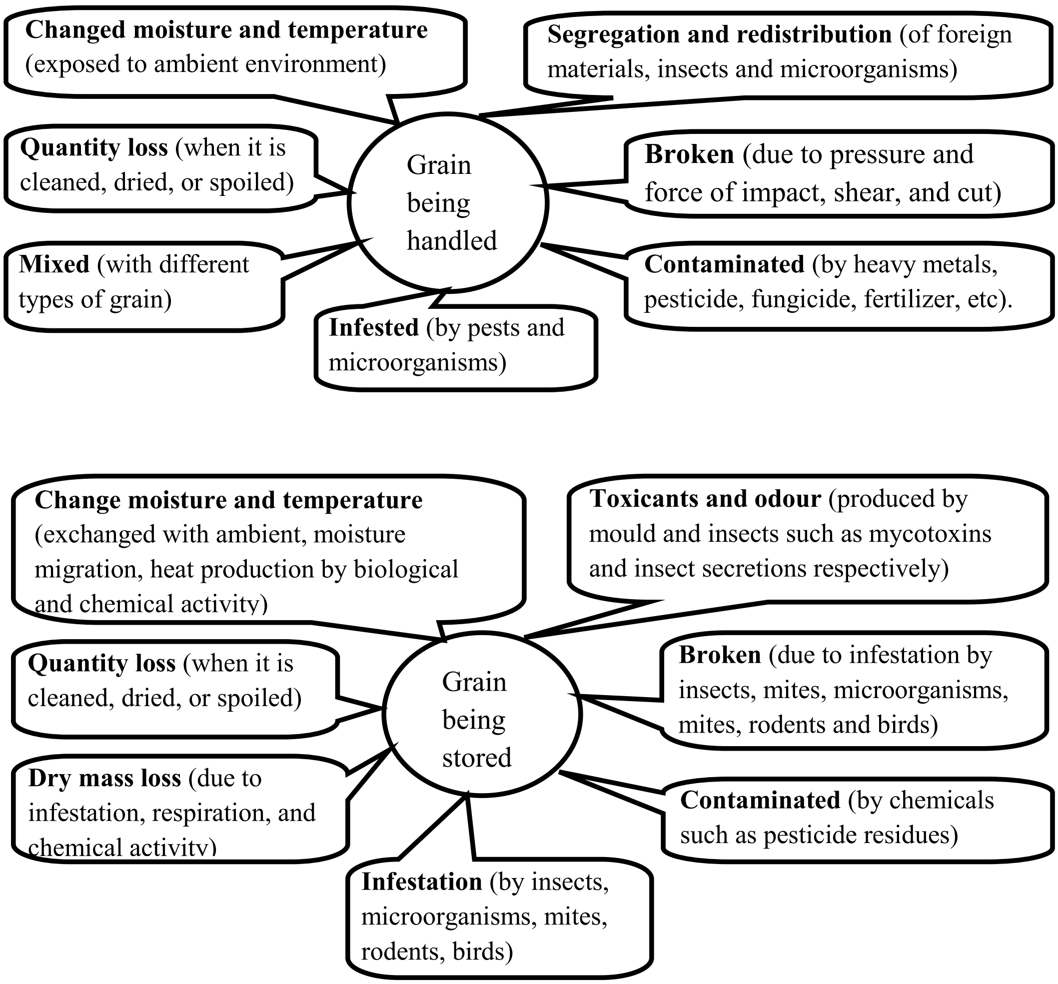

Fig. 3- Sources of quality and quantity change during grain handling (top) and storage (bottom).

INTEGRATED MANAGEMENT DURING STORAGE

During grain storage, there are many sources which will result in the quality and quantity loss of the stored commodity (Fig. 3). Even under “optimized” storage conditions it is impossible to eliminate qualitative changes. They can only be minimized in storage at low temperatures and moisture content. Even though there are management issues causing physical and economical loss of stored grain, key issues are usually mechanical damage due to handling and infestations with microbes, insects, birds and rodents (Jayas et al., 1995). Damage from these factors is inter-related.

Experience has shown that losses during storage are not easily reduced in the absence of well-integrated policies and an IM program. Even though there are many choices to conduct a sound grain storage management, integrated management with ecosystem approach should be the first choice of the grain storage management (Jian and Jayas, 2012). All methods applied should take advantage of the relationship between the physical and bio-chemical environment and fit well with the physical and chemical property of the grain. For example, grain moisture should be controlled during the entire storage period. Sanitation should be practiced throughoutthe entire procedure of handling, transportation, and storage. Any action of treatment should be based on the result of monitoring and inspection.

Coordination between the three principle approaches - physical, biological and chemical - to the protection of agricultural commodities such as grain must be known when a program of integrated pest management is developed. The interaction between living and non-living factors and integration of various control techniques, within the framework of integrated pest management, has become a focus for research in the stored-products field. The importance of a multidisciplinary approach to stored grain research has also been stressed (White, 1992). Entomology, mycology, chemistry, engineering and food science are commonly involved, but effective integration of technical solutions is often lacking. Intergradation of technical solutions requires the thorough understanding of the physical and bio-chemical properties of commodities and their storage environment. Outlining of inner links and inherent laws behind the IM principles might help with the integration. Identification of the basic issues and their control strategies might promote the application of IM. For example, IM of commodity should focus on the physical control combined with ecosystem approach.

FUTURE RESEARCH

Integrated management theory uses the concept of economic control thresholds (ECTs). For example, an ECT of IPM is most simply defined as the level of pest damage which justifies, in cost/benefit terms, the expenditure of resources upon control actions. It is always a variable threshold because the costs and benefits of any action will depend upon the situation and its circumstances. The ECT at different situations should be studied. Losses of quantity and certain quality parameters should be objectively determined. For example, for insect control in grain storage the ECT is likely to be at or very close to zero in most situations. This will limit the application of biological control.

Monitoring is the basic requirement of the sound IM program. However, reliable monitoring applied in grain storage is only the temperature (Neethirajan et al., 2009). Quality of grain inside stored bins could not be determined without sampling. Therefore, affordable and reliable sensors which can be used under different situations should be developed. Relationship among the physical and chemical properties, and the physical and bio-chemical environments of the stored commodity should be used in IM programs. A successful monitoring program can help to reach this goal.

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