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Review Article

Engineering Perspective on Technical Challenges Associated with Corn Grain Storage

Kajal Rajput and Vinod S Amar*

Archer Daniels and Midland Company, Decatur, USA

***Corresponding Author:** Vinod S Amar, Archer Daniels and Midland Company, Decatur, USA.

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Abstract

Grain can also be called food (different names in different regions) being a necessity for any human being to survive on the planet, making us recompense more attention to storage and prevention from impairment to full fill the requirements of mankind. The overall objective of grain storage is to preserve the quality, including nutritive value, and to keep the grains in good condition for marketing and processing, thereby reducing product and financial losses. In this paper, we shall discuss the challenges associated with corn grain storage across the nation and offer solutions to prevent their storage from engineering perspective to satisfy the production demand by meeting the market requirements. We have also identified some factors that can be beneficial to the owner/responsible personnel towards making sure we have demanded grain available desired time and quantity.

Keywords: Corn Grain; Temperature; Moisture Control; Infrastructure; Storage

Introduction

Research shows that approximately 11 million pounds of food every minute is being consumed by the people around the globe which leads to an unearning agricultural demand towards having more land and farm to grow the basic food [1]. However various factors like natural calamity, dryness, bugs, wastage, pollution, and chemical reactions can cause distrust due to misleading efforts aligned for food storage. It is extremely critical to satisfy the food demand with the rate of population growth across the globe by searching for alternates of food or must store enough food for the long run [2]. Urbanization and aging will have important repercussions on the agricultural labor force and the socio-economic fabric of rural communities [3]. Urbanization has been accompanied by a transition in dietary patterns and has had a great impact on food systems. These population dynamics associated with the accelerated trends with the declining growth of population in the rural areas should account for establishing the food security in providing nutritious food grains for oneself in recuperating the total energy required to complete the mental and physical tasks in a day. Carbohydrates [4,5] predominantly being an important component when being consumed, are sourced from the metabolism in the body to be broken down to saccharoidal form of sugars useful for cell growth and repair. Although some carbohydrates are naturally occurring from the whole fruits and vegetables, due to the chemical treatments for microbial inhibition they are stripped along with other nutrients causing the imbalance in the blood sugar levels when consumed. Hence it is imperative to watch out for healthy food sources to minimize or mitigate the chemical treatments such that they can be naturally available for human consumption, unlike relying to processed foods [6] such as pizzas, carbonated drinks, desserts etc.

The primary source of carbohydrates around the world is thought cereals which are harvested from the crops, often referred as grains [7]. Primarily grains could be classified into wheat, oats, rice, and corn. Other grains such as sorghum, millets, rye, and barley are classified as secondary grains. Over 48% of the food consumption to gain the calories useful to meet our daily energy requirements can be obtained through these grains. Apart from the food consumptions [8], these grains or side products obtained from these grain processing for example, via corn processing can be used to obtain cattle feedstock, in pharmacies, commodity chemicals for cosmetics, pharmacies, sustainable biofuels and alcohols etc., Due to the commercial significance of corn [9-11] in obtaining such a value added products, the views presented in this paper will capturing its challenges and possible solutions associated with the corn grain storage industry. In may cultures across the world, grains being the staple part [12] of the diet, when combined with protein rich legumes tend to cater the energy requirements by maintaining the sustainable ecosystem by preserving the food security [13,14].

For a good agricultural practice [15,16], it is imperative to understand the frequency of harvesting the grain bearing crops such that, they could be harvested at the right time of the year and overcome the climatic challenges [17] associated with global warming. Following the grain harvesting, to meet the profitability sellers-market and reputation, farmers must focus critically in maintaining a safe storage conditions [18] to preserve the quality of the grains. Maintaining such a safe storage conditions to exhibit long term stability of the grains is a challenging task and often requires a frequent orientation and awareness among the farmers and grain processing industries. To achieve the safe storage conditions, the grain storage infrastructure [19,20] such as bins, elevators, bunkers, and sheds must be improved. Such an infrastructure used to store the grains must be kept at optimal temperature and air flow needed for the grains to aerate such that they can be free of residual moisture and ensuring such a sanitized environment can prevent the growth of mold and insect population. The optimal conditions [21] required for the specific grain type can be determined by the grain systems specialist for example, they can recommend the aeration [22] fans cannot be operated beyond the range of 150-200 hours to prevent the grains from becoming dry. Performing regular safety checks and frequent improvement to the grain storage infrastructure, allows the farmers, commercial grain storage merchants and commodity end-users be well-prepared during the harvesting time and address the challenges by facilitating other farm activities. Over the past 20 years, from the data released by the USDA National Agricultural Statistics Service (NASS) [23] as shown in the figure 1, in their annual state level grain stock report revealed a substantial transformational growth in the national grain storage capacity due to the increasing demand for the crops such as corn and favorable soil conditions contributing to the crop growth. Janzen., *et al*. has also reported that since the 1990's till 2019, the US grain storage capacity has increased from 19 billion bushels to 25 billion bushels aiming to match the crop production, however it can be realized that the ambitious drive has led to over-building the infrastructure, which could be used to store other secondary grains for years to come.

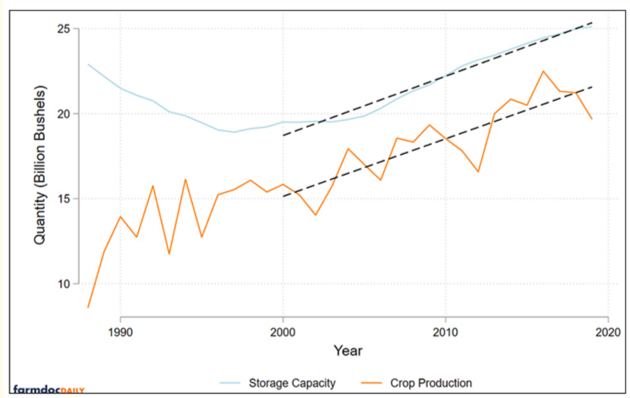

Figure 1: US Grain Storage Capacity and Crop Production from 1988-2019 [23].

A successful grain storage practices often comes from emancipating the risks associated with farming business [24]. However, the inherent uncertainties with unpredictable weather-related incidents could impact the yields and prices associated with the harvested crops and could restrain the government policies [25] and global market ultimately leading to the loss of farmers. In order to better understand the risks, one has to identify weather the risks are caused by human negligence/inefficiencies, or production risks leading to the unnatural consequences in the growth of crops, or financial risks leading to farmers defaulting their borrowed loans [26] due to raising interest rates due to the market or product fluctuations [27] deferring due to change in the commodities, or institutional risks associated with change in the farming laws due to the political concerns.

Current research is not sufficient to explain each phenomenon that occurred in the grain storage. Corn being an excellent source of carbohydrates and its other harvested parts being useful for other global applications, in this paper we present the challenges associated and possible solutions from engineering perspective to preserve the quality of such grains. Some key challenges as discussed here such as insect and pest management can be dealt with comfortably with the help of entomological and biotechnological tools and research. Similarly, the storage environment suitably improves and conveniently changes with the help of modern tools of computational fluid dynamics(CFD). The material properties and their impact in terms of variation of stress during emptying and filling of grain storage can be easily studied through the finite element method (FEM) [28] tool and its related technology.

Corn

Corn is a significant crop across the world which is currently serving as the backbone of agricultural national economy making America a global leader in corn production with over 96 million acres vested towards its production. Hence in section, we shall discuss few critical details about harvesting, end products originating from the grain, storage infrastructure and its challenges and possible solutions to the grain storage.

Harvesting

Over the past decade, the yield obtained from the report released by the U.S. Grains council signifies the trends associated with the corn grain yield per the hectares of land its harvested. It was observed from the figure 2 [29], although the drop in the corn yields dropped significantly in 2012 at a maximum about of hectares harvested, the trends of crop yield has been increasing reaching to 11 million tons per hectare. Although the crop yield is increasing, the average US test weight at 54 pounds per bushel is significantly lower than the preceding years which couldn't meet the superior grade 1 requirements which could be due to the foreign material and broken grain particles resulting from improper handling or storage conditions. This is imperative to realize the warmer conditions for preventing the mycotoxins exploiting the structural integrity and reinforcing the grain quality.

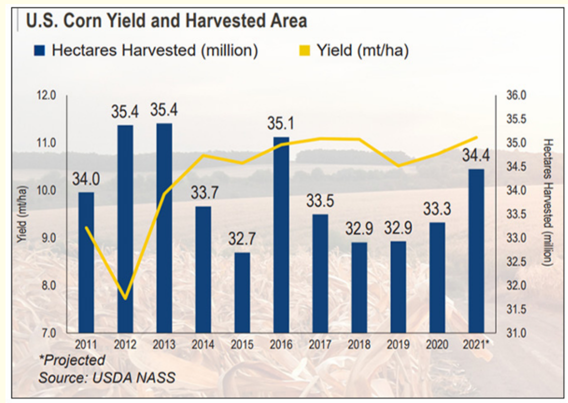

Figure 2: Comparative corn yield for the harvested acres over the decade [29].

End products of corn and their applications

Being considered as a "yellow gold", almost every products these days available ranging from commodity foods to biofueled gas stationed reserves, the dent corn type [30] is the most sorted grain in the wet-milled process industry to produce value added end products such as corn starch, oil, syrup, animal feedstock and biofuels such as ethanol.

Corn starch

Corn starch also known as amylum, is a water insoluble powdery material rich In polymeric glucose units. Corn starch is the most expensive product sorted by the corn wet-milling industry which could be a main feedstock material for fermentation [32] and other downstream operations to be used for emulsifies, pharmaceutical ingredients, resins and biodegradable plastics etc., [31]. The highly amolosic starch produced by the dent corn could be combined with cellulose, chitosan, gelatin, glycerol, proteins, microalgae etc., to finds its applications in food, pharmaceutical packing and preservatory applications [33].

Corn oil

Corn oil is a germ maize extracted component with a high smoke point finding its application a valuable application for food frying. Refined corn oil contains about 99% of triglyceride molecules among which 55% of unsaturated fatty acids and 15% of saturated fatty acids [34]. Constituting almost 2.8% oil in one bushel of corn and lesser margarine content, makes it a viable source for biodiesel production although not universally accepted by growers. Although there seemed to be a vested research interests on the agronomists developing a high-oil variety, other ready uses could include its industrial applications in textiles, fertilizers, and pharmaceutical preparations [35].

Corn syrup

The sugar components modified by processing the corn starch could result in the corn syrup which could be used as flavor enhancer in foods or drinks. A healthy grade dent corn can yield about 33.3 pounds of corn syrup which in-turn could consist about 42% fructose which is obtained by enzymatic processing of glucose. The glucose could be converted into fructose using isomerase-based enzymes to produce the artificial sweeteners which are commercially used by replacing the traditional cane sugar [36,37].

Storage infrastructure challenges and solutions

For recent years being more favorable for the corn crop yields, the harvest season seems to pose grain storage issues to the corn farmers. Making room for new crop and improving the grain storability could be an exclusive tool to control the mycotoxin growth. Blooming aflatoxin levels and mold increase could severely impact the regulatory and compliance requirements for exporting the stored grains [38,39]. Space issues [40,41] for getting rid of old grains could exponentially increase the land demand to lead the price requirements and deterioration of the kernels. Finding alternatives could encourage the farmers to mix the old grains with freshly harvested grains or pilling up the old grains could lead to overall deterioration of the crop quality ultimately hurting the nation's reputation. As its evident that maintaining optimal moisture and temperature requirements for the grain storage serve as a key performance indicator, the biggest challenges is to recognize the signs for grain damage. A damaged grain [42] could result in musty odor, crusty top, bridged up grains and evident movement of insects in the grain silo. Hence, before inspecting the grains utmost care should be taken by wearing masks, wearing clean-room designed clothing and boots and seeking professional help to clean the grain build-up or clogs [43]. If the moisture content in the grains reaches more than 15% or higher drying temperatures could lead to grain fracture at its kernel portion which is the primary cause of grain clogs in the bins leading to frequent maintained of the storage facilities. Also, several grain cleansing gadgets and machines are offered by companies such as Borghi, Pfeuffer, Akyurek, Metra etc., uses rotary cleaner, vibrating screen based patented technologies, could be aided to cleanse the damaged grains without affecting the composition of the grains [44,45]. The temperature inside the bins could be efficiently controlled by laying electric cables inside and introducing automated sensors to the facility which can have control sensing to make up the fluctuations [46]. Currently research efforts are focused on controlling the quantities of mold growth inhibitors or finding food grade friendly chemicals to reduce the fungi spores and findings will be presented in upcoming studies relating to various grains.

Conclusions

Food grains such as corn, sorghum, wheat, oats etc., cater the needs of growing hunger and energy demands of global population. Corn being the most abundant and most favored harvested crop in the country, in this review we presented the grain storage infrastructure, challenges associated with the storage and offered possible solutions to enlighten the reader and scientific community about the state of art developments in the grain industry, so that they one can be well prepared to enact proper channels to improve the grain quality. We understand that storage temperature and moisture are the leading causes for the aftermath of grain damage and hence, more resources need to be invested to improve the grain quality without damaging their kernel.

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