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Comprehensive review about grain cooling as total solution for protection of stored commodities to maintain quality and quantity under humid tropical condition

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ABSTRACT

Storage of grain, oils seeds and pulses requires a continuous management effort to maintain quality and quantity of the stored commodity. Furthermore the expenses for the protection of the goods as well as the harmfulness to the environment are an additional burden in storage management. The use of GRANIFRIGOR^{TM} grain cooling is an alternative to the usual approach of protection of grains, oil seeds and pulses. Grain cooling prevents not only physiologic degradation and spoilage of grain but also protects from hazards like fungi development, weevil infestation and water condensation. The paper will give a comprehensive review about grain cooling as total solution for protection of stored commodities to maintain quality and quantity under humid tropical condition.

Key words: Grain cooling, grain storage, grain quality

Worldwide conservation of grain is a must to preserve harvested grains from being damaged during storage due to the fact that not all grain can be processed in a short time. Thereby various technologies are utilized to maintain best quality of the commodity before it is processed. Most common is to dry the grain to reach a moisture content which allows a safe storage when the harvested grain does not have a safe level of moisture content after harvest. Other postharvest processes are aeration and fumigation among many others. Often a combination of practices are applied to prevent loss of grain.

For more than 50 years commercial grain cooling has been a postharvest technique which is applied (Kolb, 2013). In the beginning it was mainly used to extend the storage life of moist grain before drying (Brunner, 1986) but now it is part of a comprehensive approach for preserving grain during storage. Often grain cooling is seen only as a side method of postharvest management, which is underestimating its potential not only for the storage of grain but also for processing as well as maintaining food quality.

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The review of the literature regarding grain cooling showed the potential of grain cooling for the conservation of grain and incorporating this strategy into postharvest management.

MATERIALS AND METHODS

Grain cooler

The grain cooler (Fig. 1) uses a refrigerant to achieve a cooling force by a compressor during a cooling cycle. Ambient air is sucked into the system by a blower and the airpasses by a heat exchanger where the refrigerant is evaporated. The passing ambient air is cooled down to the desired temperature and the air becomes saturated. Afterwards the relative humidity of the saturated air needs to be reduced to match to the moisture content of the grain to prevent moistening of grain. This is done by a slight increase of the air temperature whereby an electric heater or heat exchangers of condensing refrigerant is used.

The grain cooler is PLC controlled to achieve a constant air temperature and relative humidity throughout of the operation. It is usually mobile, however, a fixed installation is applicable as well. The operation is weather independent.

Fig. 1. Grain cooler

Application of grain cooling

The grain cooler is connected to the grain storage by a flexible hose. The treated air is blown into the grain bulk. The air flow passes the grain and removes the heat of the grain. The air becomes humid and warm and exits the storage bin through vents at the top. The grain cooling continues until the entire bulk is cooled to the desired temperature, usually in a range of 10 to 18°C depending on the storage time. Afterwards the grain cooler is turnedoff and the air inlet and vent openings are closed. The cooled grain remains in the silo until it is removed or cooled again if the temperature will increase after several months of storage. Pictures of the application at a vertical silo and warehouse are shown in Figs 2, 3.

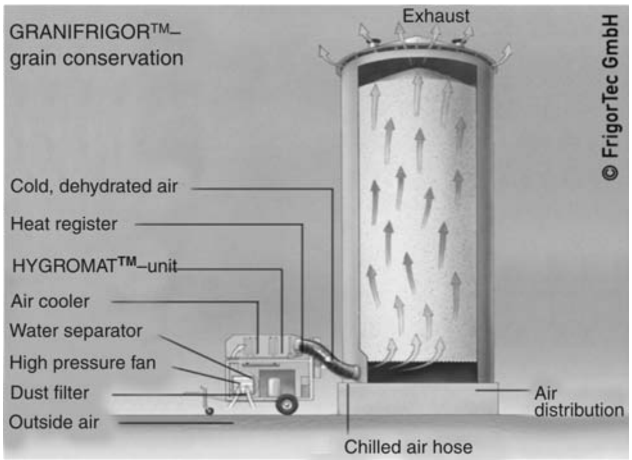

Fig. 2. Application of grain cooler at vertical silo

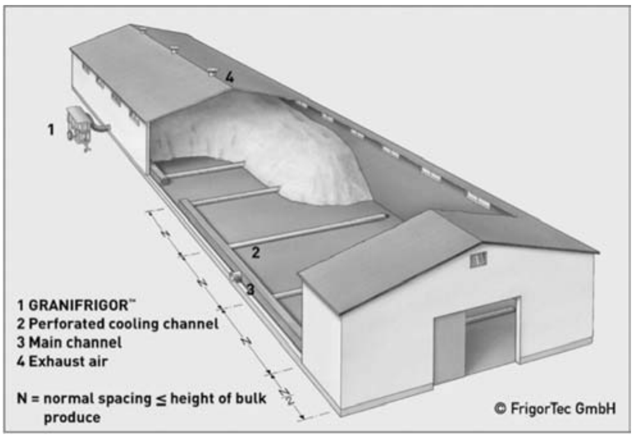

Fig. 3. Application of grain cooler at warehouse

RESULTS AND DISCUSSION

Prevention of respiration loss

Grain continues to respire after being harvested. Losses in freshly harvested grain are primarily caused by its cellular respiration and its heating. The rate of the activity is dependent on the grain's moisture content and temperature as shown in Fig. 4 (Jouin, 1964). Respiration becomes more intensive as the temperature and moisture content of grain increase.

The consequence of heating by respiration is loss of dry weight. Respiration increases as heat increases. Aside from heat,water content rise as result of the oxidation of grain carbohydrates or fats. The water content will decrease the storage life of the grain and render the grain more favorable for infestation of bacteria, mites, insects and fungi. A grain cooler reduces the chances of grains being damaged during storage.

At higher temperatures grain loses more weight during storage time by respiration than when it is cooled (Table 1). Along with the mass loss there is an economic loss, which can be prevented with grain cooling.

Influence of grain cooling on weevil development

Weevils and other insects can damage stored grain and their activity and development is influenced by the temperature of the environment. Maier and Navarro

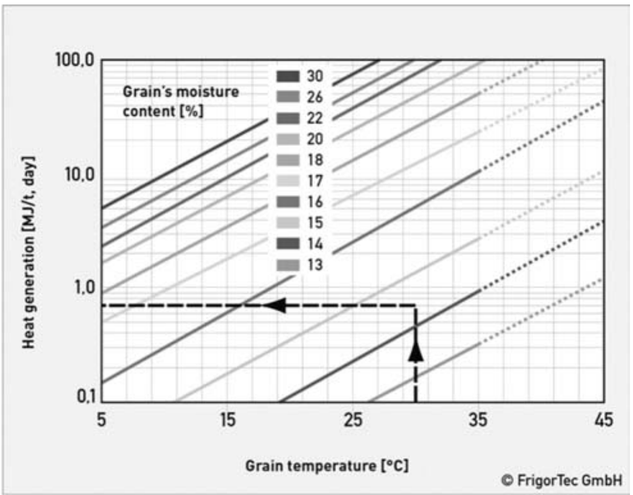

Fig. 4. Heat generation during grain storage modified according to Jouin (1964)

Table 1 Calculation of paddy loss by respiration at different storage temperatures (Sontag, 2014)

Respiration losses – dry substance loss

Given:

Paddy moisture content	14.5%
Paddy temperature	30°C
Paddy price	300 EUR/t
Storage period	8 months
Storage quantity	10,000 t

Formula

$$\text{Substance loss (t)} = \frac{\text{heat generation [MJ/t, day]** } \times \text{ storage duration (day) } \times \text{ storage mass (t)}}{15{,}000 \text{ (MJ/t)}}$$

Result

		Substance loss (t)	Mass loss (%)	Loss (EUR)***
Uncooled at	30°C**	128	1.28	52,650
Uncooled at	25°C	64	0.64	26,325
Colled at	10°C	minimal (≤1)	-	-

*After drying or direct from field in summer; **see Fig. 5; ***grain's moisture content and rice husk taken into account.

(2002) showed that at temperature above 20` to 32 °C the development of the insects is in optimum. However temperature less than 10° to 15°C reduced the activity (Fig. 5). Therefore, the grain is protected when grain is cooled.

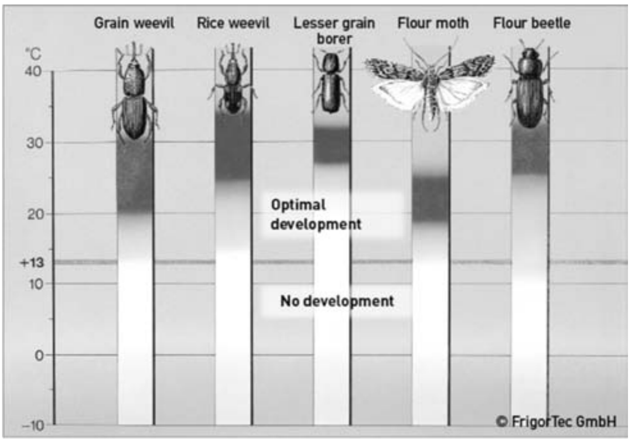

Fig. 5. Weevil development according to temperature (Sontag, 2014)

Prevention of fungi by grain cooling

Microorganisms such as fungi and bacteria adhere to the surface of the grain kernel (Mühlbauer, 2009). The development of fungi depends on the temperature, humidity and the grain's moisture content as shown in Fig. 6 (Lacey, 1980), heirgrowth is prevented in the storage facility by drying and grain cooling. Therefore, it has to be considered that grain is

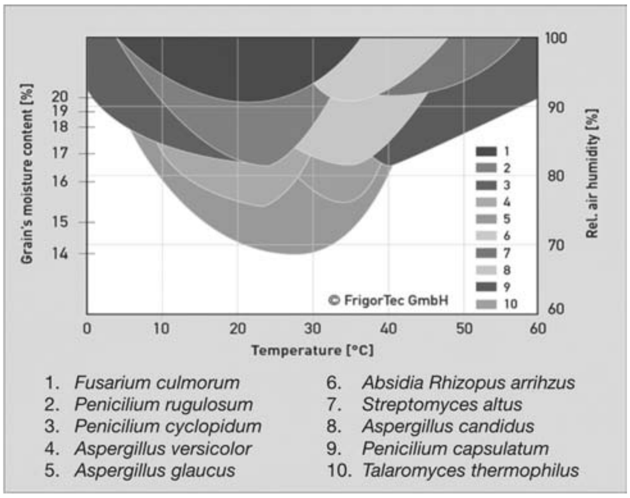

Fig. 6. Development of fungi at grain storage (Lacey, 1980)

biologically active and circumstances change over the time. This is certainlytrue when the respiration activity of the grain is high and water and heat rise. Moisture content of the grain, its storage temperature and the relative humidity will lead to fungus growth. Thereby the danger of fungal contaminationis not only the deterioration of the grain but the increase in mycotoxins which have toxic effects on humans and animals. Most mycotoxins are heat-stable and can persist through grain processing. For this reason, the formation of toxins must be prevented by preventing harmful fungi (Rodemann, 1999). Grain cooling can decrease damage from fungi.

Extension of storage time of cooled grain

The safe storage time of grains depends on the moisture content as well as on the storage temperature of the grain (Agena, 1961;Wimberly, 1983). The storage period timer (Fig. 7) showed the estimated safestorage time for grain according to its temperature and moisture content (Sontag, 2014). The safe storage time for any particular condition of grain can be read by matching the grain's moisture content against its

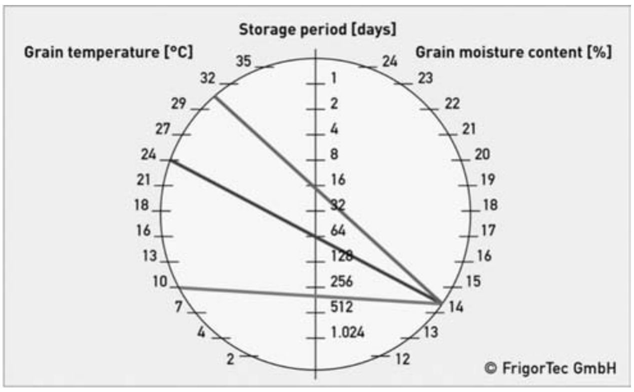

Fig. 7. Storage timer of grain (Sontag, 2014).

actual temperature. The section of the line on the vertical axis of the storage period gives the possible safe storage time of the grain. It is obvious what grain cooling does for the extension of safe storage life of grains particularly in tropical environments. The example showed that for a moisture content of 14.5% the safe storage life at 31°C is around 18 days while at 10°C it is increased to around 300 days.

Improving of postharvest management

Storage management is responsible for maintaining the quality of grain before processing and for keeping any losses to a minimum. Grain cooling prevents condensation inside the bulk storage. The grain is cooler than the tropical climate and water rise by respiration is reduced to the lowest throughout the storage time. The grain quality is stabilized and its moisture contant remains constant (Kanlayakrit and Maweang, 2013; Parnsaktron and Noomhorm, 2012).

Common techniques include aeration, fumigation and moving the grain to avoid any heat, insect or fungus damage. When aerating the grain, temperature and relative humidity of the ambient air must be observed to avoid or minimize damage ofthe grain. This is difficult to achieve throughout the year in the tropical region. It leads to limited operation of aeration system to prevent warming and moistening of the grain. Grain cooling conservation, being independent of the weather, represents an easier option and does not lead to a degradation of the grain quality.

Taking a look on fumigation leads to several constraints for an easy postharvest management. Adequate protection of human health and of the environment is a must if fumigation is applied. A sealed storage facility is required or regular re-gassing is unavoidable but couldlead to developing a resistance to a number of fumigants at low effectiveness. Grain cooling is safer than using fumigants.

Moving grain is sometimes used to deal with the issue of hot spots in grain caused by insects and fungal infestation. This requires investment in equipment for additional storage capacity and transport equipment, incurring laborand energy costs. The management must also be able to react quickly and effectively. This technique is applied for many grains but leads to as grinding losses of up to 0.06 % caused by the conveyor equipment (Boac, 2010) and in rice it leads up to 3 % more broken kernels (Zareiforoush, 2010),for each turn. When grain cooling is applied no moving of the grain is required at any time which spares cost and losses.

CONCLUSION

Grain cooling is a comprehensive solution for postharvest management and conservation of dry bulk commodities. It brings benefits which keep quantity, quality and the processing of a crop in the most economic condition. Its implementation in the tropics and subtropics will lead to essential improvement of grain handling, loss reduction and good management practice, which has been proven in moderate climate already for more than 5 decades but also in the tropics since 1980.

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