# Conservation of stored grain cooling

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## Abstract

A literature review related to stored grain cooling was conducted. It was found that the application of cooling in stored grain is most favorable to assure high quality of the grain. Furthermore, quality and quantity losses of the grain can be minimized. The handling and application of grain cooling simplifies grain storage management and brings additional advantages to grain processing Some advantages are risk-free long-term storage without quality loss, conservation of harvest freshness for outstanding taste of grains and rice and reductions in losses caused by insects and fungal mycotoxins.

Keywords: grain cooling, grain storage, grain quality

## 1. Introduction

Worldwide conservation of grain is a must in order 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 underestimates its potential not only for the storage of grain but also for processing as well as maintaining food quality.

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

## 2. Materials and Methods

### *2.1. Grain cooler*

The grain cooler 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 air passes 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 in order 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.


**Figure 1** Grain cooler.

*2.2. 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 turned off 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 Figure 2 and 3.

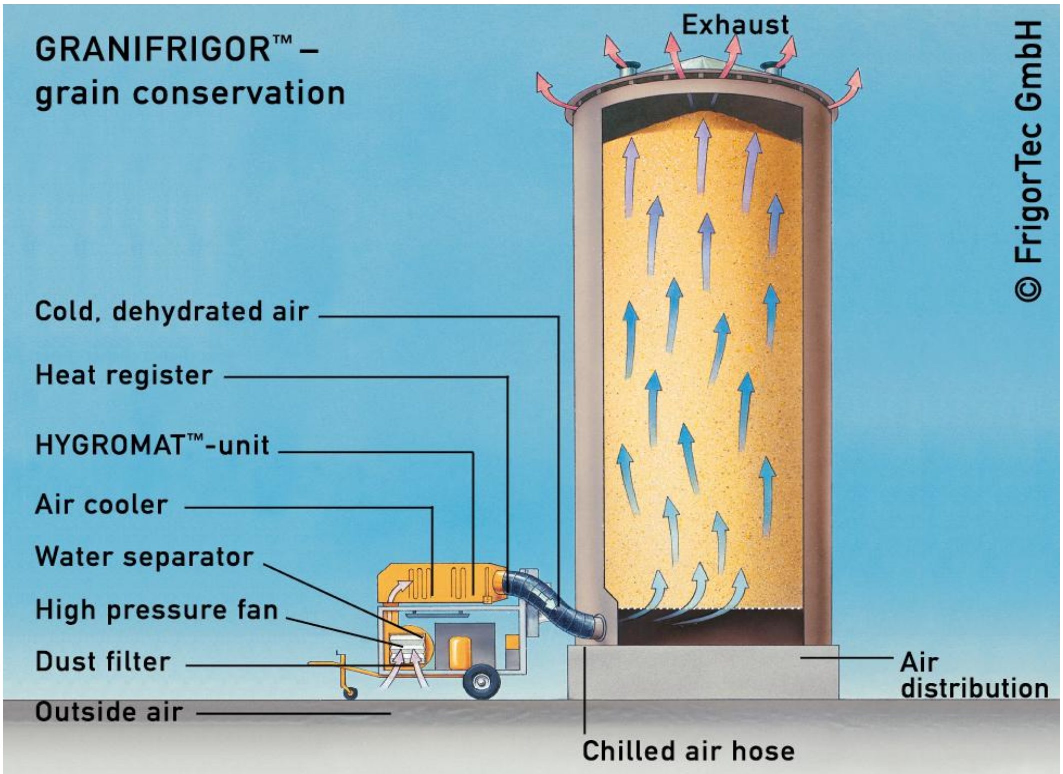


**Figure 2** Application of grain cooler at vertical silo.

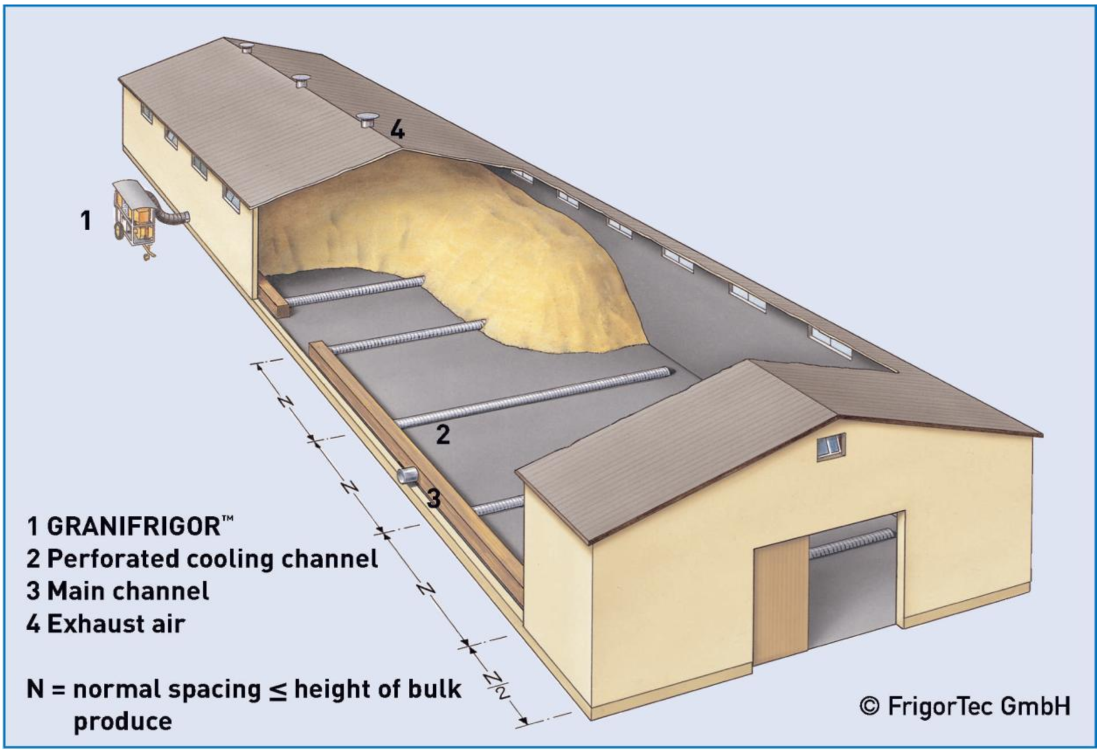


**Figure 3** Application of grain cooler at warehouse.

## 3. Results and Discussion

### *3.1. 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 Figure 4 (Jouin, 1964). Respiration becomes more intensive as the temperature and moisture content of grain increase.

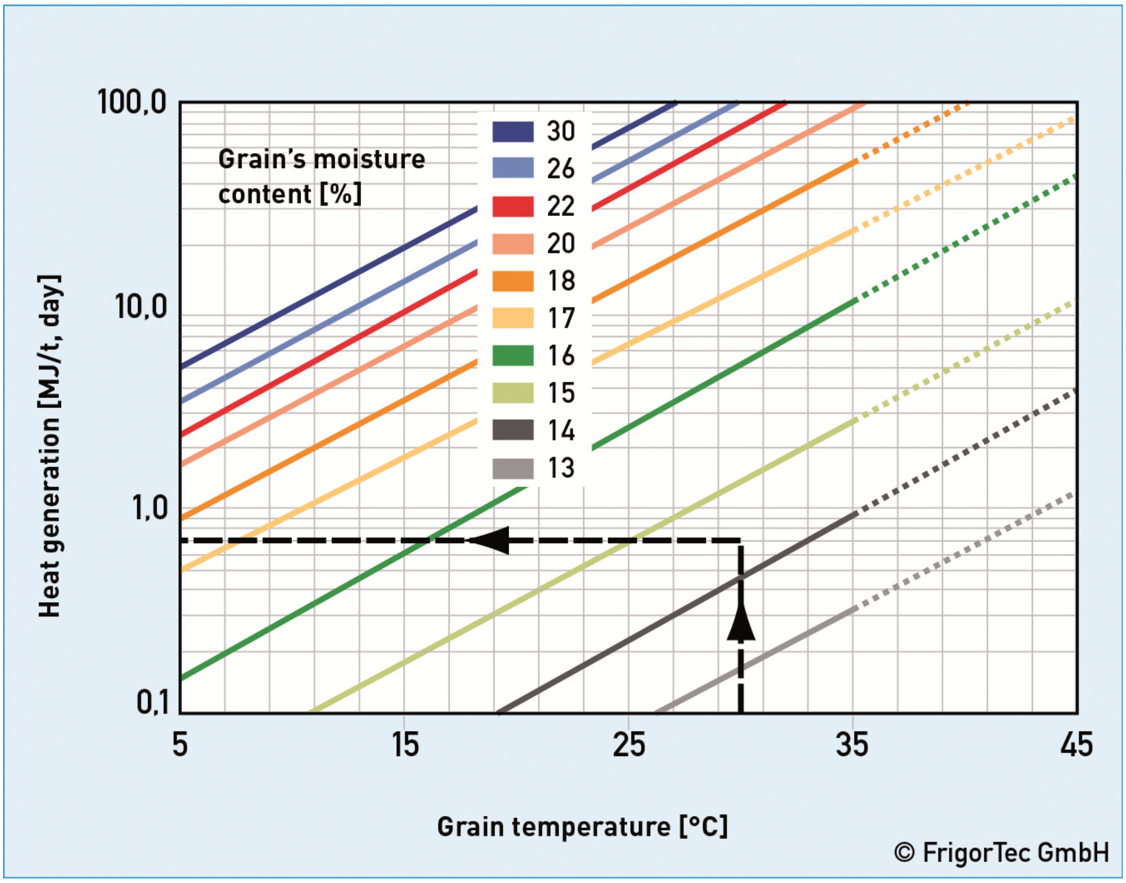


**Figure 4** Heat generation during grain storage modified according to Jouin.

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.

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

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

| Respiration losses – dry substances 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:** | | | | |
| Substance loss (t) = $\frac{\text{heat generation [MJ/t, day] ** x storage duration [day] x storage mass [t]}}{\text{15,000 [MJ/t]}}$ | | | | |
| **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 |
| cooled at | 10 °C | minimal (≤ 1) | – | – |

*after drying or direct from field in summer
**see figure 5
***grain's moisture content and rice husk taken into account

*3.2. 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. Navarro (1975) shows that at temperature above 20 to 32°C the development of the insects is in optimum. However temperature less than 10 to 15°C reduce the activity. Therefore the grain is protected when grain is cooled.

*3.3. 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 (Lacey, 1980) their growth is prevented in the storage facility by drying and grain cooling. Therefore, it has to be considered that grain is biological active and circumstances change over the time. This is certainly true when the respiration activity of the grain is high and water and heat rise. Then moisture content of the grain, its storage temperature and the relative humidity will lead to fungus growth. Thereby the danger of fungal contamination is 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 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.

*3.4. 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 in Figure 5 shows the estimated safe storage 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 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 shows 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.

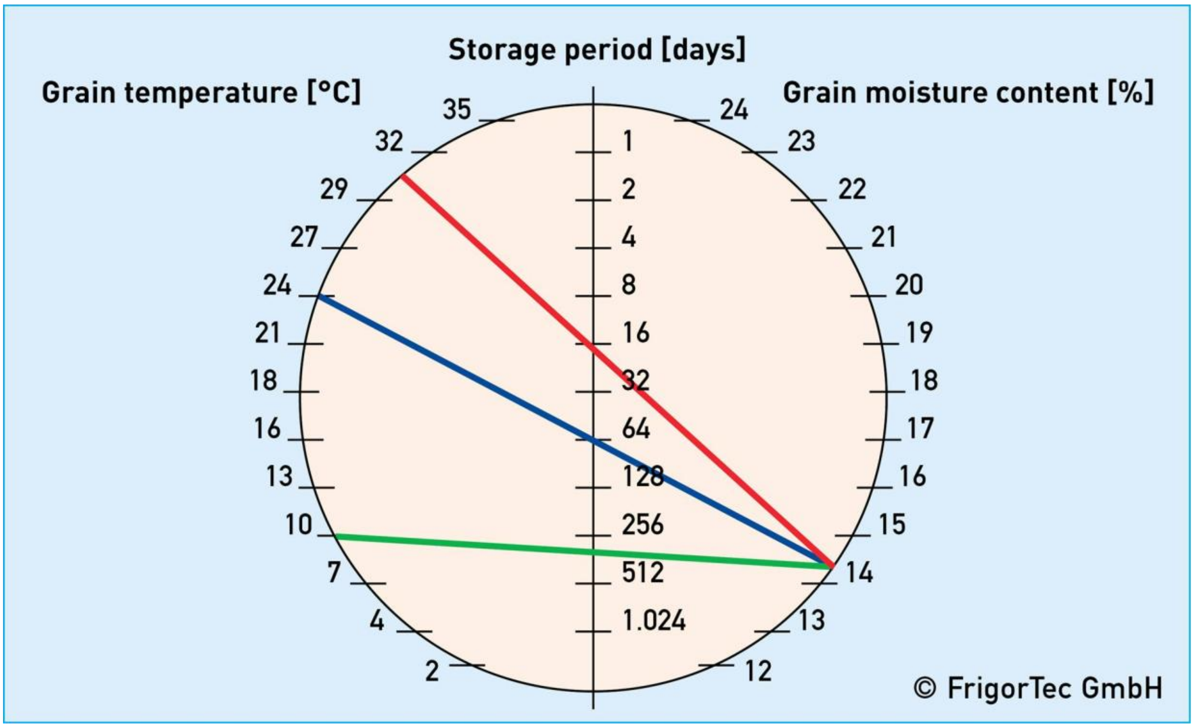


**Figure 5** Storage timer of grain (Sontag, 2014.).

*3.5. Benefits of grain cooling for grain drying process*

During the process of grain cooling the heat of the grain is removed and relative humidity is lowered according to the psychromatic chart. Thus, the air can remove moisture from the grain and during the drying process the cooled grain will lose only 0.5 to 2% moisture content, as function of the initial moisture content of the grain when grain cooling starts (Boser, 1980). Even if the moisture reduction is low it contributes to the drying process of moist grain. A combined process of drying and cooling of paddy rice is shown in Figure 6. It shows that after a three step drying process the moisture content of paddy is reduced from around 23% to 15.5%, and grain cooling will remove another 1.5% afterwards. The paddy can then be safely be stored at a moisture content of 14%. The advantages of the combined process are reduced time for drying, less energy consumption of the dryer, and better grain quality (Barth, 1995). The drying capacity can be increase up to 30 to 40% (Piccarolo, 1988).

When the drying process is stopped before the final moisture content is reached an over drying is impossible and the danger of discoloration for rice by over drying is eliminated. A more important effect is that during grain cooling the drying of the grain occurs very slowly, based on the fact that grain cooling usually takes days to be completed. Paddy has to be dehulled and polished to white rice, thereby the physical stress to the kernel is high and weak kernels easily break to low grade broken rice. When grain cooling is utilized the last part of the necessary paddy drying causes the kernels to remain stronger, which leads to higher head rice recovery (Piccarolo, 1988).

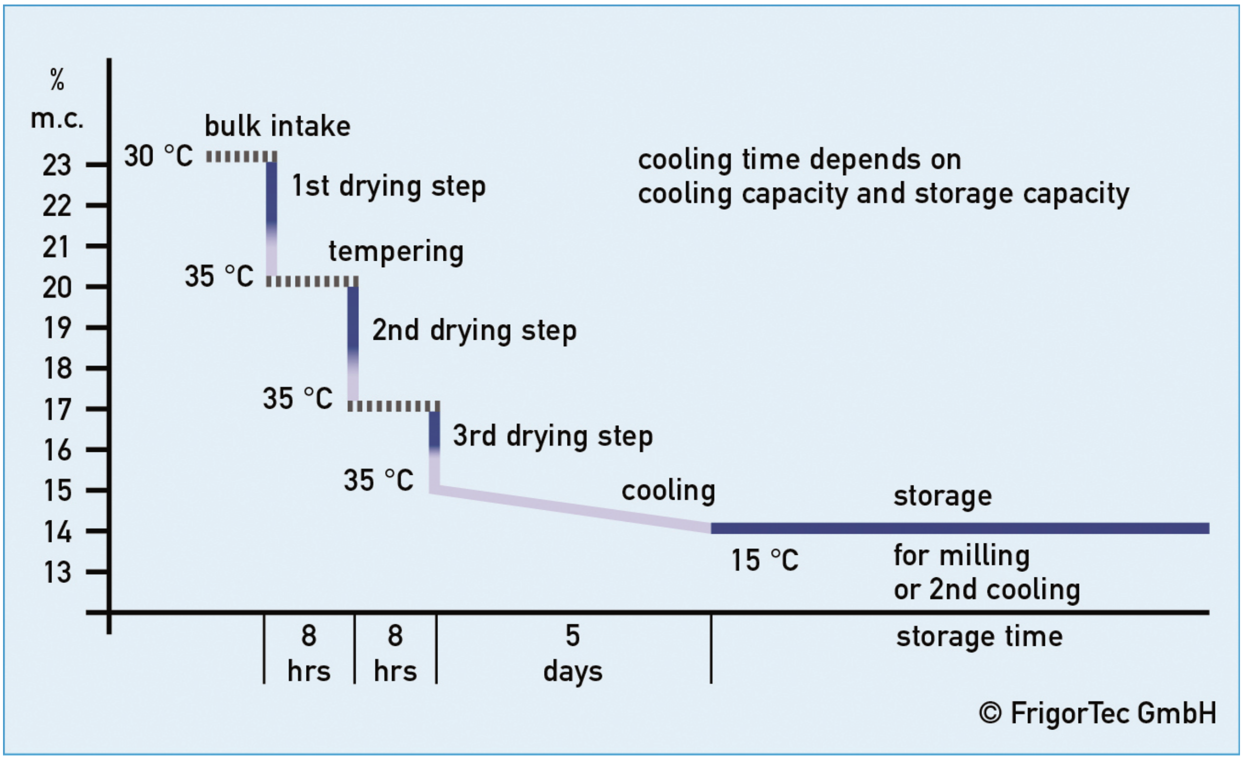


**Figure 6** Combined process of drying and cooling of paddy (Piccarolo, 1988).

*3.6. Improving of postharvest management*

Storage management is responsible for maintaining the quality of the grain before processing and for keeping any losses to a minimum. 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 of the grain. This is difficult to achieve at harvest time when it is warm or humid. 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 could lead to developing a resistance to a number of fumigants at low effectivity. 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 labor and 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.

*3.7. Improving of grain processing by grain cooling*

The effect of grain cooling should not be limited to the storage when it is applied but needs to be observed into grain processing. Mainly grain is milled but there are other processes like parboiling of paddy that would benefit from grain cooling

The milling of grains such as wheat or corn is done by grinding the kernel to flour. The process is done in a highly efficient way but depends on the grain quality and its homogeneity. Therefore grain is graded or sorted before processing. The more homogeneous the grain is the higher the efficiency. When grain is cooled it remains as harvested and there is no change over the storage time. The result is that adjusting of milling equipment is reduced by processing cooled grain. The spared time leads directly into reduced processing time, which increases the efficiency of the process.

Rice processing is different because the result of the milling process is a complete kernel. Due to the combination of drying and cooling the rice kernel remains firmer (Barth, 1995) and can withstand a more efficient setting of rice mill equipment which increase the throughput capacity. Cooled paddy retains better whiteness and will not need to be polished aggressively. A reduction of the polishing degree means more rice remains. In addition, the grain cooling conservation will prevent yellowing of rice (Vasilenko and Sosedov, 1976; Chek, 1989), which will increase the efficiency of color sorting. Taking all this into account, an increase in efficiency in rice milling of up to 5% is possible (Sontag, 2014).

Cooling conservation has a number of advantages for parboiling, thereby soaking of the paddy can be shortened providing an advantage of a greater degree of whiteness of the rice and thus a higher commercial quality (Bhattacharya et al., 1966.). The grain cooler can be used for tempering after parboiling, which reduces the process time of parboiling. The cooled air not only reduces the temperature, but due to its higher drying capacity resulting from its lower temperature and low water content, it can remove more moisture from the paddy. Here the evaporative cooling of the water is additionally used for cooling the paddy, which lowers energy consumption for cooling and even accelerates the cooling.

## 4. Conclusions

Grain cooling is a comprehensive solution for post-harvest 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 many years.

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