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Fabrication of a hydro cooling system to mitigate dry matter loss of stored wheat grains in silos

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Abstract - A prototype hydro cooling system was developed using fourteen copper and five Polyvinyl chloride (PVC) tubes, length and diameter of these tubes were 914, 8mm & 914, 12.5mm respectively. All copper tubes were wrapped individually with linen cloth properly and kept them together horizontally in a cylindrical manner while leaving a 0.7-10mm gap between all tubes using pieces of hollow metal sheet to facilitate movement of air currents over the linen cloth wrapped copper tubes. The underside of the all PVC tubes were made perforated with small openings (0.25mm) and these tubes were also inserted horizontally between copper tubes in a manner to damp the linen cloth when water is running through the PVC tubes. All tubes were housed horizontally again in a large PVC tube with an adequate space between tubes and the housing. Two axial blowing fans (230v, 2800rpm) were attached to the hydro cooling system to blow air over and through the copper tubes. When water was flowing through the PVC tubes, tiny water droplets are coming out and drench with the linen cloth, wrapped over the copper tubes.

Two prototype silos, height and diameter were 1600, 400mm respectively, were fabricated using tin sheet with the capacity of 150kg each and fabricated hydro cooling system was attached to the aeration duct of one of the silos (Test silo) while leaving the other(Control silo) without a cooling system. 150kg of initial moisture content known wheat grains were loaded into each silo and hydro cooling system was operated (During day time only) for a period of 10 weeks. When ambient air was blowing over the damped linen cloth, rate of evaporation of water was increased; consequently, surface temperature of the copper tubes dropped down by around 8-10^{0}C. So also when ambient air was blowing through the cold copper tubes; the blowing air also gets cooled and this air was used to cool the wheat grains in the test silo. Samples of wheat grains and temperature measurements were taken from top, middle and bottom of the two silos weekly for a period of 10 weeks in order to determine mean temperature, mean moisture content and 1000 grain weight, which is the yard stick to measure dry matter loss of wheat grains due to respiration.

Results revealed that mean temperature of test silo was dropped down from 29.1^{0}C to 25.1^{0}C while control silo was showing an incremental trend from 29.1to 34.5^{0}C. In the case of dry matter loss, this was for test and control silos 0.083 and 0.22% respectively, after 10 weeks of storage. Therefore, hydro cooling system was capable to save about 64.37% of dry matter loss comparatively control silo within a matter of 10 weeks period. Nevertheless, this cooling system is a productive option for controlling of dry matter loss of grain due to global warming as well as for food security while using solar energy to operate the blowing fans.

Index Terms: Hydro cooling, Dry matter loss, thousand grain weight, global warming, food security, wheat grain, wheat silos

Introduction

Controlling of dry matter loss of cereal grains during storage due to respiration is an important post harvest practice for food security, particularly for countries situated in the tropical region where ambient air temperature is relatively higher than that of the other regions in the world during most of the months in a year. Moreover, this situation can further be aggravated by global warming and it may be vulnerably affecting to the third world developing countries again because most of these counties are also situated in the tropical belt of the globe. Due to global warming the ambient air temperature can be raised more than 33 ^{0}C within next 100 years of period and it will be vulnerably affecting for the third world developing countries "[4]". Since rate of respiration is directly correlated to the temperature in the micro environment of the storage, finding out of ways and means to reduce it, is an important post harvest practice to safe guard the loosing of edible grade dry matter specially carbohydrates. Nevertheless, countries must secure food security with their own produces and if there is a gap between production and consumption which must be bridged by the

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importation. So if there is more respiratory losses of the produce during storage, the gap will be widen and need more resources to replenish it. Hence scope of this study was to fabricate a low cost hydro cooling system to cool the stored grain with a view to impede rate of respiration up to some extent while avoiding water vapor is directly coming into contact with the grains.

Materials and Methods

Fabrication of hydro cooling system for wheat grains

A prototype hydro cooling system was fabricated using fourteen copper and five Polyvinyl chloride (PVC) tubes, length and diameter of these tubes were 914mm, 8mm & 914mm, 12.5mm respectively. All copper tubes were wrapped individually with linen cloth and placed them horizontally in a cylindrical manner while leaving a 0.7-10mm gap between all tubes using pieces of hollow metal sheet and a plastic plate (Figure 1) with a view to facilitate movement of air current over the linen cloth wrapped copper tubes.

Fig. 1: Cross section of the hydro cooling system

The bottom half part of the all PVC tubes were made perforated with small orifices (0.25mm) and these tubes were also inserted horizontally between copper tubes in a manner to damp the linen cloth when water is running through the PVC tubes by gravity from an over head water tank. All tubes were housed horizontally again in a large PVC tube with an adequate space between tubes and the housing (Figure 2).

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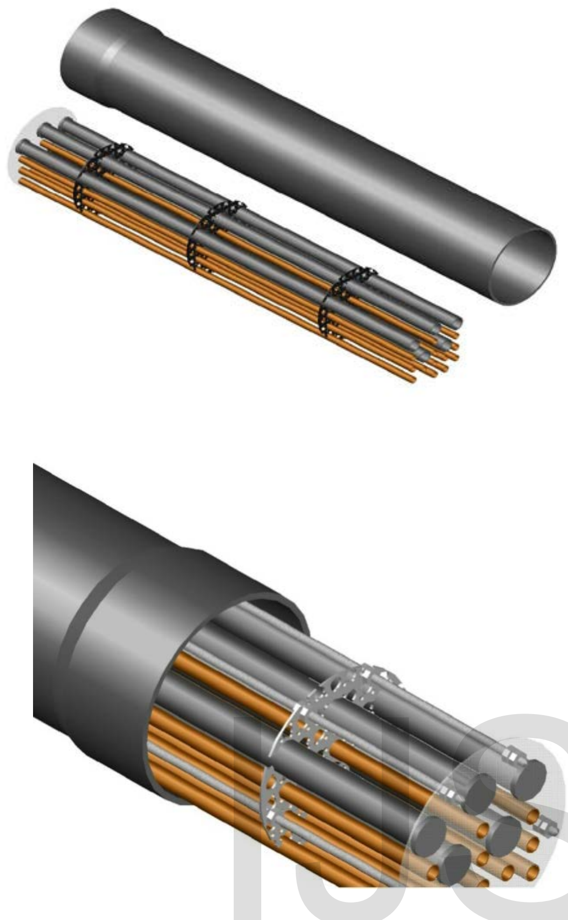

Fig. 2: Copper and PVC tubes Arrangement in the hydro cooler

Two axial blowing fans (230v, 2800rpm) were attached to the prototype design to blow air over and through the copper tubes. When water was flowing through the PVC tubes by gravity, tiny water droplets are oozing out and drench with the linen cloth wrapped over the copper tubes.

Two prototype silos, height and diameter were 1600mm, 400mm respectively, were fabricated using tin sheet with the capacity of 150kg and fabricated hydro cooling system was attached to the aeration duct of one of the silos (Test silo) while leaving the other(Control silo) without a hydro cooling system. 150kg of initial moisture content known wheat grains were loaded into each silo and hydro cooling system was operated (during day time only) for a period of 10 weeks. Samples and temperature measurements were taken from top, middle and bottom of the two silos weekly for a period of 10 weeks in order to determine mean temperature, mean moisture content and 1000 grain weight which was the yard stick, used to measure dry matter loss of grains due to respiration. Moisture content and temperature of wheat grains were measured using a moisture analyzer (Shimadzu - MOC 63u) and thermo couples with 0 to 160 ^{0}C range respectively.

Thousand grain weight and weight loss of wheat grain

In calculating of dry matter loss, the methods described by "[3]" for moisture, "[7]" for germination and "[2]" for 1000 grain weight were taken into account. Therein, 1000 grain weight was determined after drawing samples from top, middle and bottom of silos using a sample Trier and 1000 grain weight was determined with respect to these three places. This procedure was repeated for five times and average 1000 grain weight of fifteen recordings was determined. Same procedure was followed to determine mean moisture content of wheat grains too. Finally, dry matter loss of wheat grains were determined 1st , 2nd , 3rd , 4th , 5th , 6th , 7th , 8th , 9th and 10th weeks after storage. Results obtained from the test silo were subtracted from control silo in order to determine dry matter saving by the fabricated hydro cooling system. Finally, graphs were drawn total dry matter loss and temperature

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variation verses period of storage of wheat grains in test and control silos.

Results and Discussion

Cooling efficiency of the hydro cooling system

When ambient air was blowing over the water drenched linen cloth, rate of evaporation would be increased; consequently, surface temperature of the linen cloth as well as copper tubes was dropped down by around 8-10^{0}C (From 32.89 to 23.56^{0}C). So also when ambient air was blowing through the cold copper tubes; the blowing air also gets cooled (From 32.89 to 26.810C) and finally, this air was used to cool the wheat grains in the test silo.

Pattern of temperature variation of wheat grains stored in test and control silos

Mean temperature variation of wheat grains stored in test and control silos was determined after taking temperature measurements from top, middle and bottom of each silo for a period of 10 weeks and average temperatures of the silos are shown in figure 1.

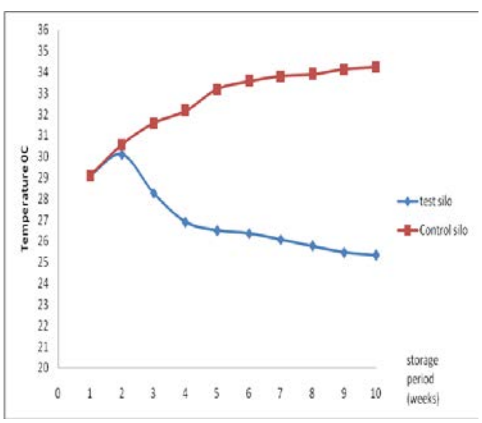

Fig.1. Average temperature of test and control silos

The graphs in the figure 1 indicate that temperature of wheat grains in control silo is continuously increased from 29.1^0 to 34.7^{0}C during 10 weeks period of storage. Whereas, in the case of test silo, this pattern is downward from 29.1^0 to 25.13^{0}C however, showing a little upward trend at the beginning. Reason for the slight increment of temperature in the silos at the beginning is availability of more oxygen among the wheat grains as result of loading process and this free oxygen facilitates for high rate of respiration. Since, heat is a byproduct of respiration; the graphs initially show a slight incremental trend of temperature. Thereafter, due to accumulation of CO_2 gas, rate of respiration declines. However in the case of test silo where contribution by the hydro cooling system as well as low rate of respiration, temperature of the wheat grains declines considerably comparatively control silo.

Moreover, Wheat grains are a living organism and they respire during storage while releasing considerable amount of heat as a byproduct. Since, wheat grain is enveloped with a seed coat and which processes with somewhat heat insulating behavior; there is a possibility to accumulate released heat among the grains themselves. Therefore, temperature of the wheat grains in control silo tends to increase during 10 weeks period of storage because it did not equip with a cooling system as in the test silo. Same finding has been observed by "[5]" in heat resistant behavior of outer coat of cereals particularly for husk of the paddy.

Dry matter loss of wheat grains stored in control and test silos

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Dry matter loss of wheat grains in test and control silos was monitored in terms of 1000grain weight over a period of 10 weeks and results were used to plot graphs, dry matter loss verses period of storage; which is depicting in figure 2.

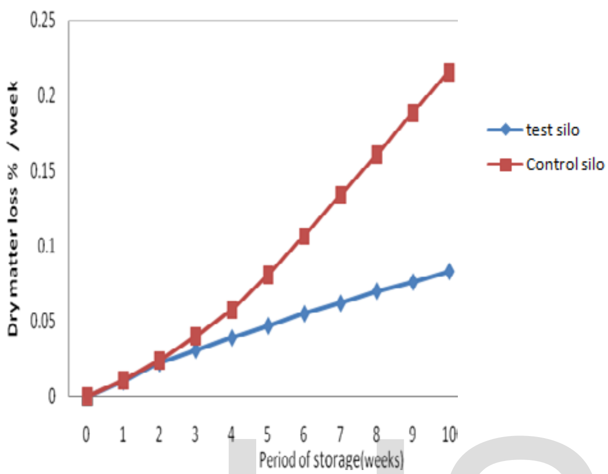

Figure 2: Cumulative dry matter loss of wheat grains

The graphs in the fig. 2 clearly indicate that dry matter loss in control silo is continuously increasing as against period of storage due to elevation of temperature in the stored environment because, high temperature facilitates for high rate of respiration. Moreover, same finding due to respiration of stored cereals has also been reported by “[1]”. Whereas, in the case of test silo, dry matter loss is gradually declined due to decrement of storage temperature as a result of hydro cooling system. The study also revealed, when dry matter loss of control silo for 10 weeks storage per was 0.216g/100g (1.1232% per year) which was for test silo 0.083g/100g (0.4316% per year). Hence, hydro cooling system was capable to save around 0.7% (1.1232% – 0.4316%) of dry matter loss per annum. “[6]”also reported that dry matter loss of stored cereals is directly correlated to the temperature in the storage structure. Finally, a regression analysis was performed in order to determine whether there is a co-relationship between dry matter loss and period of storage of wheat grains stored in control and test silos. Since results revealed that coefficient of correlation for test and control silos was equal to 1.0 & 0.75 respectively; there is a positive co-relationship between period of storage and dry matter loss of wheat grains. To quantify this relationship further, a formula was developed for test and control silos based on the method described by the regression analysis, which was for test silo Y= 0.0045 + 0.0080X and control silo Y = 0.0068 + 0.0174X.

X = Period of storage (Week) and Y = Dry matter loss

Conclusion

The results of the study revealed that hydro cooling system was capable to reduce dry matter loss of wheat grains due to respiration by around 0.7% per annum. Therefore, hydro cooling system is a constructive option to reduce dry matter loss of wheat grains during storage because hydro cooling system was able to bring down the temperature of wheat grains from 32.89 to 26.81^{0}C. Moreover, hydro cooling system can be used as a productive option to secure loss of food the for food security of a nation.

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