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MiniReview

Application of color sorter in wheat milling

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Abstract

The color sorting machines inspect grains by means of digital cameras and remove contaminants by a short burst of compressed air by using the colour difference. This machine has been successfully used in the rice milling industry for long time. Recently color sorters have begun to find their way into durum semolina milling and also into wheat flour mills.The color sorter are used in the wheat cleaning to remove ergot wheat, black tip, fusarium, burnt, other discolored grains and other inner contaminants. Today's advanced color sorters are robust, compact, requires less maintenance and consumes very little energy. The color sorting has come of age and should be considered for inclusion in any modern wheat cleaning plant. Optical sorters are taking the place of traditional disc and indented separators in the wheat milling process. In the present review the use and integration of color sorter in wheat cleaning flow sheet were discussed in details.

Introduction

Wheat is one of the most important cereal crops, cultivated in about 120 countries and provides nearly one-fifth of the world's calorie requirements. The major wheat producing countries are China, India, Russia, USA, France, Australia and Canada. In Asian countries wheat, rice and maize are the major food grains contributing over 90 percent of the total food grains. As per Food & Agriculture Organization of the United States (FAO) statistics about 701 Million Metric Tons of wheat was produced globally. Wheat is processed to get flour in a roller flour mill. Roller flour milling process fractionate wheat into different products like wheat flour, semolina, germ and bran by gradual reducing system using series of chilled cast iron break and reduction rolls.

Wheat kernel structure consists of three main constituents: Endosperm, bran and germ. Endosperm is the major constituent and contains mainly starch granules embedded in a proteinaceous matrix and accounts for 81–84% of the grain. Germ contains embryo and scutellum and amounts to 2–3% of the grain. Bran, which forms 14–16% of the grain, consists of all outer layers including the aleurone layer, which is usually removed along with the other bran layers during milling, although botanically the aleurone layer is the outer layer of the endosperm (MacMasters *et al*., 1964). The roller milling process involves cleaning and conditioning of wheat to prepare it for milling. The wheat is then milled by roller mill into different finished products.

When wheat received at the mill, usually contains foreign matter such as sand, dust, sticks, string, straw, iron impurities, stones, part of bags, metal, stones, etc. in varying amount depending on the agricultural practices, environmental conditions, harvesting methods and further handling and storage conditions. These foreign matters must be removed from the wheat before further milling. The wheat also contains other cereal grains, pluses and seeds of weed. In addition wheat always contains damaged wheat kernels. The damaged wheat kernels are those which may be undesirable for milling because they have been damaged physically, biologically, by insect infestation or by disease. The cleaning section in the mill should be designed in such way that, it can handle any wheat arriving at the mill.

Kozmin (1979) classified all the impurities present in the wheat into three groups. First group contains poisonous admixtures and that also causes the deterioration in quality of flour color and baking. Ergot, cockle belongs to this class. Second group contains those impurities, which reduces the quality of flour such as the seeds of non-poisonous plants, dust, dirt etc. and third category that may do some damage to the machinery such as stones and pieces of metal.

Cleaning of wheat

The foreign materials are removed in the cleaning section by multiple methods based on different principles. The various machine used to separate impurities from the wheat are based on one or more of

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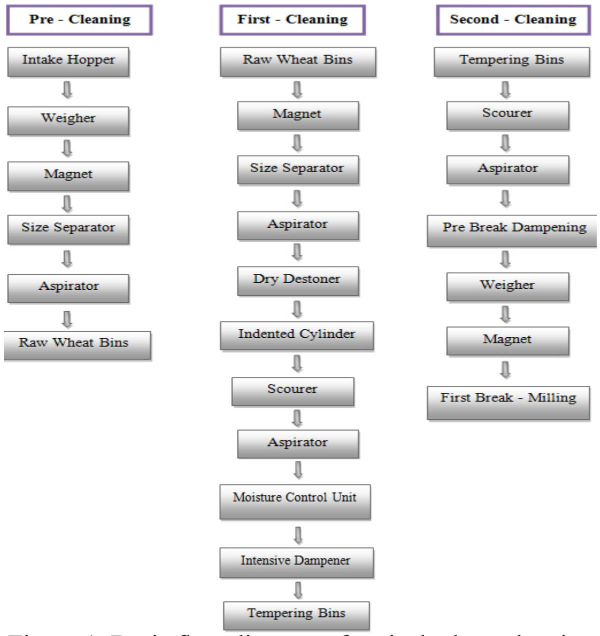

Figure 1. Basic flow diagram of typical wheat cleaning section prior to milling

the following characteristics of either the impurities or the wheat. These are magnetic properties, size, shape, specific gravity, air resistance, surface friction, friability, impact, etc.

Basic flow sheet of cleaning section

A typical flow diagram of wheat cleaning section is shown in figure 1. The objective of cleaning section is to clean the wheat and prepare it for the milling by water treatment called as conditioning. Cleaning of wheat is carried out in three stages: pre-cleaning, first-cleaning and second-cleaning.

Intake and pre-cleaning of wheat

The main objective of pre-cleaning is to separate the coarse foreign material, ferrous particles, dust, sand and insect-infested wheat kernels. The pre-cleaning operation is performed at higher capacity to reduce unloading time from grain container. The first machine in the flow is the automatic weighing scale to check the quantity of wheat received or taken into process before removing any impurities. Subsequently wheat is passed over the strong appropriate magnet to remove iron impurities and to avoid damage to any machines. After the magnet is size separator for removal of rubbles by coarse sieve and sand and dust by the fine sieve. Aspiration channel is used to remove light impurities and dust. The cleaned wheat allows more space availability for wheat storage in bins flows more readily from storage bins avoiding the choking of bin outlets and is blended more accurately. Pre-cleaning also allows air to flow more uniformly through the mass of wheat, causing more effective aeration also helps to control infestation during storage (Posner and Hibbs, 2005).

First cleaning of wheat

The first cleaning is through cleaning process, which is aimed to remove damaged wheat, seeds and other extraneous matter by process of separation to maximum extend. First cleaning also aims of removing any dust from the wheat by means of scouring and aspiration. In addition to wheat being cleaned, it also must be prepared so that it is in for milling by conditioning treatment. The first cleaning equipment is magnet to remove iron impurities followed by size separation by separator. The size separator will sieve out the material larger and smaller than wheat. The size separator is followed by aspirator to separate lighter materials than wheat. The next cleaning stage separates heavier impurities from wheat by specific gravity. The indented cylinder contains pocket, into which wheat is centrally fed from one end. Material longer than the pocket designs discharges at the opposite end, whereas the smaller material sits in pockets until it falls from top of it, cycle by gravity into an adjustable angle trough conveyor.

The final cleaning phase is surface cleaning by scourer. Scourer contains a central rotating shaft with inclined beaters surrounded by a jacket of wire mesh. Wheat is fed at one end and repeatedly beaten by the beaters which create the friction between beater and grain, grain to grain and grain to jacket as it travels to the opposite end. Outer bran, crease dirt and small broken wheat go through the wire mesh while sound wheat kernels fed to an aspirator for separation of lighter material.

Conditioning of wheat

Part of the wheat preparation for the milling is conditioning which involves addition of water, followed by resting time to allow the water to penetrate through the wheat kernel (Soder, 1996). Objective of conditioning is to toughen the bran layer. This reduces the formation of bran powder, giving clear break flours and better flour color all through the mill. Conditioning is done to mellow the endosperm with the effect of reducing power consumption for roller mills to enable clear and accurate sifting of mill stocks and flour and to ensure desired moisture content of finished products (Sugden, 1999).

Second cleaning

The second cleaning starts from the outlets of tempering bin to the first break rolls and its aim is to remove the loose bran particles and dirt from the wheat kernel by scouring action and to prepare the bran layer by pre-break dampening whenever

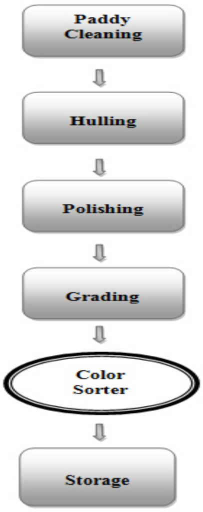

Figure 2. Optical sorting machine location in processing flow of rice milling

required before the surge bin.

Wheat milling

After cleaning and conditioning of wheat, it is milled into the finished products. The wheat flour milling process involves breaking open the grain, scraping the endosperm from bran and germ by break rolls and then gradually reducing the chunk of the endosperm into the flour by the series of grindings at reduction roll system, with intermediate separation of products by sifters and purifiers (Bass, 1988).

Optical color sorter

Optical sorting machines inspect grains by means of digital cameras and remove contaminants by a short burst of compressed air, have been successfully used in the rice industry for long time. The defects removed in the rice mill include black spots caused by insect damage, bran streaks, pale green immature kernels and discolored grains. It has now become requirement for optical sorting machine to remove other contaminants from rice, such as paddy, stones, glass, etc. Optical sorting of rice typically is carried out at the end of milling process as 40% of the weight of paddy is lost during the rice milling process. The amount of rice that reaches the optical sorting stage is considerably less than the input capacity of the processing plant. Today almost all modern rice processing plant uses optical sorting technology to produce high quality rice. The typical location of color sorter in rice processing is shown in figure 2.

Automatic separation and sorting of grains began in the 1880s. Crude electrostatic methods were employed to light materials from cereal grain. These systems used photodiodes or photomultiplier tubes to discriminate between the overall color of the product and foreign bodies (Bee, 2002). The first generation color sorters used shades of black and white (monochromatic) to remove the defects and impurities. Today due to advances in technology, color sorters are using high resolution bichromatic cameras in addition to monochromatic cameras for inspection of grains in wider color spectrum. Recently, the manufacturers are using infrared and ultraviolet sorting capabilities combined with color detection technology to enable the inspection for foreign material with invisible optical properties (Fowler, 2012). Apart from advancement in cameras, the use of fluorescent or halogen lighting, high speed reliable ejectors, better distribution and uniformity of the feeders have allowed the development of optical sorting machines with much higher operating capacities, more sorting accuracy and yield, consistent sorting performance and high reliability. This has resulted into a much wider application of optical sorting in wheat milling. Optical sorters are taking the place of traditional disc and indented separators in the wheat milling process.

The durum wheat milling color sorter is used to remove discolored kernels and black seeds that spoil the appearance and lower the actual quality of semolina. The color sorting became well established in the durum cleaning section, where objective is to produce semolina for high quality pasta or couscous. The wheat cleaning operation is facing new challenges during recent years, mainly because of changes in consumer preferences, demand for high and consistent quality end products, new regulations regarding food safety and to reduce production costs. After cleaning wheat by traditional cleaning machineries, the defective wheat kernels, which may be undesirable for milling because of badly weather damaged, diseased, heat damaged, germ damaged which causes the discoloration of wheat will remains there.This will cause quality problem in the finished products such as specks in the semolina, color deterioration in the refined flour or whole wheat flour. In order to overcome these issues faced by the millers, the wheat cleaning demands new technologies such as optical sorting machines.

Operation of color sorter

The optical sorter by its feeding system continuously presents the grains to the inspection system and the ejection systems in a controlled manner. The feed mechanism consists of an input hopper to hold the sufficient grains to supply continuously, a feed vibrator and chute. The grains are fed from vibrating hopper onto a flat or channeled, gravity chute. Feeding mechanism should present the grains into the uniform thin layer to inspection zone

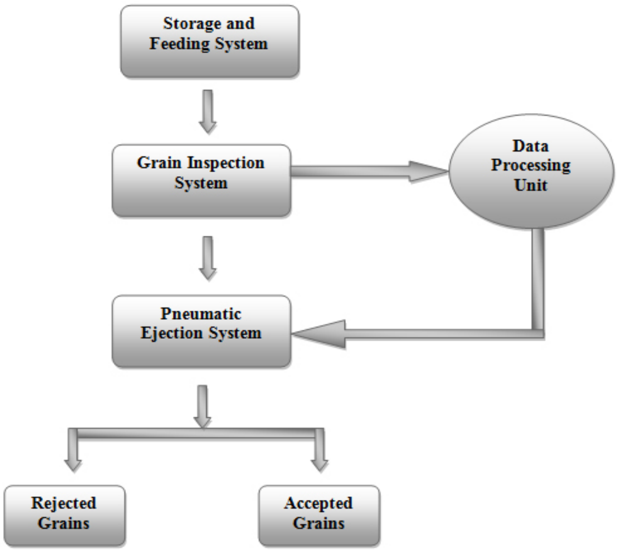

Figure 3. Schematic diagram of a typical optical sorting machine

for efficient separation.

The grains then pass into an optical inspection zone, where the decision on whether to accept or reject each grain is made (figure 3). The grain inspection system comprises of digital cameras, which works in foreground and background lighting. In inspection area, the defects and foreign materials are identified by examining at the color of the product by camera. It requires selectively comparing the magnitude of light that is reflected at certain wavelength band. The color sorting machine rejects dark objects reflecting less than the input threshold value set by the miller. The machine can also be adjusted to reject light objects from dark material. The reflectivity responses of the grains by inspection zone are continuously processed by the data processing unit. The data processing unit identifies defects in the grain stream and location of these defects.

The usual method for removing unwanted items from the main product stream is with blast of compressed air from the high-speed solenoid valve, connected to a nozzle. The ejection system comprises of air ejectors which allows good grains to pass straight through the machine, whereas the defects are rejected by the ejection system and collected separately. The ejectors use the location information from the image processor to remove the defects by short bursts of compressed air. Ideally, the ejectors are located outside the optical inspection area because of the action of the air blast on the defects may results into dust and bran particles to blown around and could create false rejections. Electronic circuits generate the appropriate time delay between inspection and ejection points (Bee, 2002; Michael Picalek, 2007).

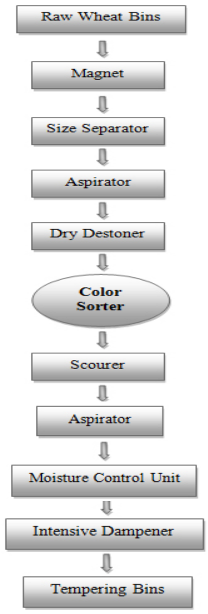

Figure 4. Integration of color sorter in first cleaning section: Location A.

Integration of color sorter in the wheat cleaning section

The optical sorting machine can be integrated in the cleaning flow diagram of wheat mills. Depending on the mill's requirements in terms of cleaning capacity, availability of space and efficiency of existing mechanical cleaning equipment, the optical sorting machines can be integrated in the first cleaning section as well as in the second cleaning section. The optical sorting machine can be integrated along with the existing machineries or instead of certain cleaning machines such as spiral separator and indented cylinders.

First cleaning section

In the first cleaning section the color sorter can be replaced by the indented cylinders (Trier). At this location the total wheat stream passes through the color sorter machine. In this position the color sorter machine is fitted with the maximum of four products feed chutes. Three of these high capacity chutes are used to feed the total load of the section and the fourth one is used to recycle the rejected product from three chutes. The accepted good product can fed back to the original input of the sorter or mixed with the sorted good product. The location of this integration has illustrates in figure 4.

When using the bulk density separator in the first cleaning section (figure 5), the color sorter is fitted with lesser products feed chutes. The bulk density separator is set to deliver about 25-40% of the full feed, which in turns reduces the feed on color sorter. The heavier wheat phase from the density separator

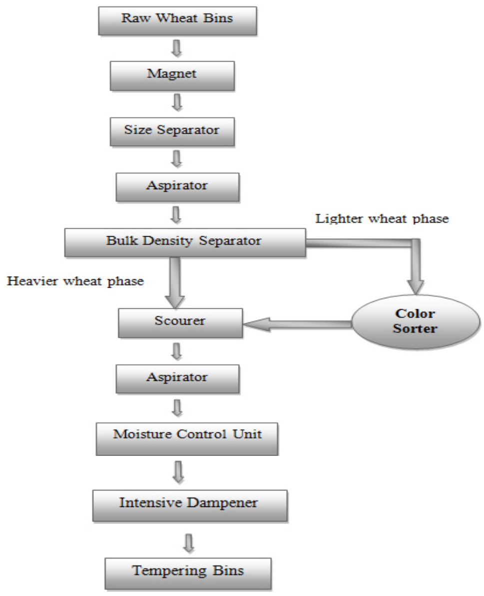

Figure 5. Integration of color sorter in first cleaning section: Location B.

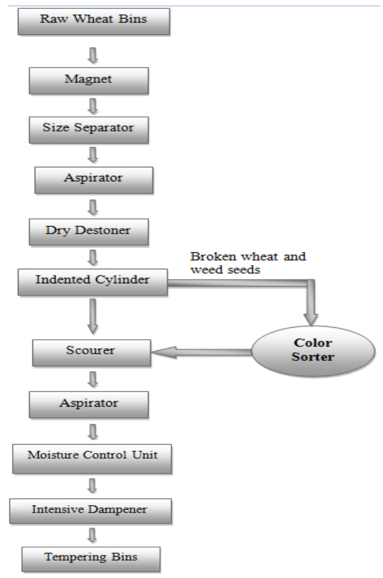

Figure 6. Integration of color sorter in first cleaning section: Location C

is directly sent to the scourer.

In wheat cleaning sections indented cylinders are used to separate the long grains such as oats and round seeds such as weed seeds. The black seeds are smaller than wheat grains, while removing such seeds by indented cylinder, valuable small and broken wheat inevitably get removed. It is then difficult to separate the small and broken wheat from the weed seeds and goes to feed. At this location use of color sorter with single chute can do the recovery of small and broken wheat more effectively and illustrates in figure 6. Round seed separator sends about 1-1.5% of the full feed to the color sorter. The color sorter recovers broken and small wheat of 0.5-0.75% of full feed is returned to the main stream while rejecting the discolored round seeds, damaged small grains (Sugden, 1998). This can improve the yield of the mill. In this location optical sorters reduce the loss of quality wheat as compared to using mechanical shape separation.

Second cleaning section

Color sorter can also be integrated in the second cleaning section. It can be integrated between the scourer and the first break bin as illustrated in the figure 7. In this location the color sorter would be with either three or four products feed chutes depending on the mill capacity. It can be very effective as the flow rate of wheat stream is steadier and little lower in capacity.

Other applications of color sorter in wheat processing

Separation of wheat, based on color parameter is important because milling and baking characteristics

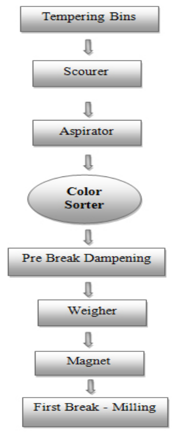

Figure 7. Integration of color sorter in second cleaning section

of wheat vary according to the color properties. Wheat color varies from pale yellow to red brown, influenced by the presence of red pigmentation in the seed coat and also by growing conditions. The color characteristic of wheat is generally considered for wheat classification for grading purposes. Red and white wheat shows different milling, baking and taste properties (Paulsen and Heyne, 1981; DePauw and McCaig, 1988; Bason *et al*., 1995; Dowell, 1997). Color class in wheat market plays important role, a premium may be paid for a particular color class on the basis of nutritional and end-use values (Ronalds and Blakeney, 1995). When a mixture of two or more contrasting classes occurs, such that, a lot is less than 90% pure, it is classed as mixed and its price is reduced. Mixing of different class of wheat can occur if classes are not kept properly segregated during storage and handling, or if lots are incorrectly classed at marketing. Wheat color class can also determine wheat market price, with domestic and foreign buyers sometimes paying a premium for wheat of a preferred color class. Hence sorting of wheat according to color class is important in its marketing and use. The color sorter can also be used to separate healthy dark kernels of common wheat from light kernels. The darker kernels tends to contain more protein, therefore are of higher value (Sugden, 1998). Pasikatan and Dowell (2002) evaluated a high speed commercial color sorter for the segregation of red and white wheat, using single and double pass procedures. The results of the study showed that, red wheat was segregated better than weathered red wheat because of its distinct color contrast with white wheat. However, blends with weathered red wheat were also segregated well when a substantial contrast was provided by the white wheat.

Kernel bunt is caused by the smut fungus *Tilletia indica*, infected wheat kernels are partially or fully replaced with black spore masses of the fungi. The fungus generally causes the yield losses of less than 1%, but flour milled from infected grain with more than 3% bunted kernels can be unfit for human human consumption because of the unpleasant, fishy odour associated with thefungus (Mehdi *et al.*, 1973). The color sorter could be used to remove the infected kernels with *Tilletia indica* (Karnal bunt) from large seeds wheat lots destined for the mills or export (Dowell *et al.*, 2002).

Fusarium contamination is most commonly associated with soft wheat or spring wheat, but can affect all types of wheat. The disease causes yield loss, low test weights, low seed germination and contamination of grain with mycotoxins. A vomitoxin called deoxynivalenol (DON) is considered as the primary mycotoxin associated with fusarium. Fusarium disease in wheat reduces its density as well as giving the wheat kernels a slightly pink tint. Advanced optical sorters have effectively removed fusarium affected wheat kernels from quality wheat. This will allow wheat miller to recover a portion of quality wheat from fusarium contaminated wheat lot (Fowler, 2012)

The use of color sorter is growing in the whole wheat processing, where whole wheat kernel is processed and used for the human consumption. The color sorter is used to remove discolored or partially discolored wheat kernels caused by a phenolic compound produced by the grain in response to injury or fungal attack. The color sorter can also found in system in which wheat is processed into flakes and other breakfast cereals (Posner and Hibbs, 2005).

Conclusion

In order to meet complex market requirements, wheat millers need the new advanced technologies such as color sorter machines. The optical sorter machine has captured the interest of wheat processors who earlier had to rely on the traditional mechanical cleaning methods. The optical sorter not only used for the better quality it provides, but also color sorting machine save energy as it uses electronics rather than heavy motors. The color sorter requires reduced wear and tear maintenance. The color sorter first adopted in the durum milling process for the effective removal of ergot and black seeds contaminants to produce high quality, safer and cleaner semolina. Today, application of color sorters becomes wider in wheat flour milling to produce high quality and safe flour. The color sorting should be considered as a better option for inclusion in any modern wheat cleaning plant.

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