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Influence of Grain Handling Equipment on Commingling and Residual Grain

Maria Elena Ingles
ASAE Student Member, Grad. Research Assistant, Kansas State University, Manhattan, KS

Mark Casada, P.E.
ASAE Member, USDA-ARS Grain Marketing and Production Research Center, Manhattan, KS

Ronaldo G. Maghirang
ASAE Member, Associate Professor, Kansas State University, Manhattan, KS

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Abstract. *Concern about the possible effects of genetically modified crops has increased the demand for segregating grains during handling and processing operations. Research on the amount of commingling of different grains in an elevator is limited. This study evaluated the level of commingling at a grain flow rate of 51 t/h (2000 bu/h) at the research elevator facility of the USDA-ARS, Grain Marketing and Production Research Center (GMPRC), Manhattan, Kansas. White corn was first loaded in the elevator followed by yellow corn. Samples were taken after the yellow corn had passed the elevator boot, weighing scale, and grain cleaner. Samples were sorted by color and components were weighed to determine commingling, defined as the percentage of unwanted grain in the total grain mass. Residual grain was also collected from each piece of equipment after each replication. Commingling for the first 380 kg (15 bu, approximately 1% of the leg rate per hour) was approximately 4%; it decreased to 0.5% within the first metric ton of load (2% of the leg rate per hour). Residual grain in the dump pit and elevator boot amounted to 0.24% and 1.41% of the total load, respectively. The process commingling after the receiving pit and elevator boot amounted to 0.15% while commingling percentages with weighing scale, grain cleaner and grain scalper were 0.18%, 0.28% and 0.01%, respectively.*

Keywords. elevator, identity preservation, grain segregation

Introduction[1]

The introduction of transgenic crops into the U.S. grain handling system has highlighted the difficulty of preserving the identity of specialty grains with the current infrastructure. Some European countries demand food products with a maximum transgenic level of 1%; above this threshold, the food has to be labeled accordingly (EU Committee, 2001; Food Standards Agency, 2001). Japan, the largest export market for US corn, requires 95% purity for identity preserved traditional corn and sets a zero tolerance for unapproved genetically modified corn varieties (Zinkand, 2000).

Every sector of the food chain is investigating the possible areas where commingling of grains is likely to occur. At the farm level, recent studies include the potential effects of cross-pollination (SIU-Carbondale, 2000), planting distances (Nielsen, 2000; Petty, 2000), and cleaning procedures of harvesting equipment on the percentage mixing of unwanted grain (Greenless and Shouse, 2000).

In the processing chain, grain elevators play a major role in grain segregation and identity preservation (IP). The American Corn Growers Association's (ACGA) 1999 survey of grain elevators in the US showed that of the more than 700 elevators that participated in the survey, 91.4% did not consider segregation as part of their operation (Natural Foods Merchandiser, 1999). An American Corn Growers Foundation's (ACGF) 2000 survey of 1,107 elevator facilities revealed that 30.5% of the respondents did segregation at their gates and 41.6% required segregation be done on-farm (ACGF, 2000). This low percentage might be influenced by the complexity entailed in the segregation process (Hurburgh, 1994). The increase in the varieties of crops to be handled and the higher required levels of purity brought about by the introduction of transgenic crops and specialty products are a few of the many aggravating factors.

The majority of grain elevators in the country were constructed more than 30 years ago and were originally designed to handle commodity crops. Little or no consideration was given to handling specialty crops. Except for a few facilities that dedicate their operation to handle specialty varieties, regular cleaning of the elevator is the only option for facilities to prevent commingling of grains. Cleaning in and around elevator facilities combined with clean harvesting equipment and delivery trucks would ensure IP. However, this is not always economically feasible and has not been common in the industry. Grain receiving pits, augers or conveyors, elevator legs, dryers, and bins are some of the areas in the elevator facility where commingling can occur (Thelen, 1999). Because the issue of grain commingling and more stringent IP is new to the broader grain industry marketplace, limited research has dealt with postharvest operations minimizing commingling. Some studies have investigated the operational effects and economics of grain segregation and IP in elevators (Berruto and Maier, 1999, 2001; Herrman et al., 1999; Bullock et al., 2000; Herrman et al., 2001; Huston, 2001); however, limited work has quantified the commingling that may occur during grain elevator handling.

This study aims to evaluate the degree of commingling and residual grain during elevator handling. Specific objectives were to: (1) quantify the level of commingling caused by each piece of equipment when handling different varieties of corn in consecutive operations within a grain elevator, and (2) characterize the residual grain left in each piece of equipment in the elevator after handling operations are completed. Data on commingling of grain and residual grain during elevator handling will be beneficial in design and development of strategies and

[1] This article reports the results of the research only. Mention of a propriety product or company names is for clarity of the presentation and does not constitute an endorsement or recommendation by the authors or USDA.

equipment related to grain segregation and preservation of specialty crops and transgenic grains.

Methodology

The study was conducted at the 1400 t (55,000-bu) elevator facility of the USDA-Agricultural Research Service, Grain Marketing and Production Research Center (GMPRC), Manhattan, Kansas. This elevator had a single receiving pit and two bucket elevator legs, each with a maximum capacity of 76.4 t/h (3,000 bu/h). Grain handling equipment included a 0.4 t (15-bu) Automatic Weighing Scale (Howe Richardson Scale Co., Clifton, NJ), Rumba Vibrating Grain Scalper (Hutchinson Mfg. Co., Houston, TX) and Eureka Continental Seed Cleaner (S. Howes Co. Inc., Silver Creek, NY). Figure 1 shows the schematic diagram of the elevator facility.

Prior to each test, the elevator was thoroughly cleaned to remove dust, dirt, and residual grain of previous loading operations. Crevices, corners, conveyor belts, bins, spouts, as well as the loading truck were vacuum cleaned.

Grain Transfer Process

To simulate the operation of receiving different varieties consecutively without cleaning the elevator, two varieties of corn were used: white corn served as the commingled or transgenic material and yellow corn as the preserved or traditional crop. Before each grain transfer operation, the bulk of grain in the truck was weighed on the floor scale in the receiving area. About 7.6 – 8.1 t (300-320 bu) were used for each load per variety of corn. One replication consisted of one load of white and one load of yellow corn. Three replications were done for each piece of equipment. The elevator was stopped when the noise created by the grain flow in the bucket elevator leg and spouting ceased. Each load took about 10-12 minutes. White corn was loaded first and allowed to pass through the handling equipment before storage. Each piece of equipment was sufficiently run long to enable it to self-clean to the degree inherent in its design. Without additional cleaning of the elevator, yellow grain was dumped into the receiving pit and handled through the same grain flow and directed into an adjacent storage bin. Representative samples were collected during the handling operation.

Because facilities are seldom equipped with the same handling machines, separate tests were conducted for each piece of equipment to evaluate its contribution to the total process commingling level.

Sampling Procedure

Representative grain samples were collected from the truck and during grain transfer. Probe sampling of the truck was conducted following the USDA-GIPSA recommendation involving an 11-compartment 1.5-m (5-ft) probe sampler (USDA-GIPSA, 1995). Two additional sampling points were added to the standard 9-point recommendation to ensure representative sampling. The grain collected by probing was assumed to represent the initial grain quality and level of commingling.

During the loading operation, samples were collected with mechanical diverter-type (DT) samplers. A Strand DT sampler (Carter-Day Co., Minneapolis, MN), located directly after the head of the elevator leg (figure 1), was used to gather samples for measuring the commingling in the receiving pit and elevator boot. A Gamet DT sampler (Seedburo Equipment Co., Chicago, IL), located right after the handling equipment and directly above the storage bin (figure 1), was used to collect samples representing the degree of commingling in the scale, scalper, or cleaner.

Samples were mechanically collected at intervals of 15 seconds for the first 2 minutes of loading, 30 seconds for the next 3 minutes, 45 seconds for the next 3 minutes, and 60 seconds for the rest of the loading operation. Each sample was placed in separate resealable plastic bags for later analysis.

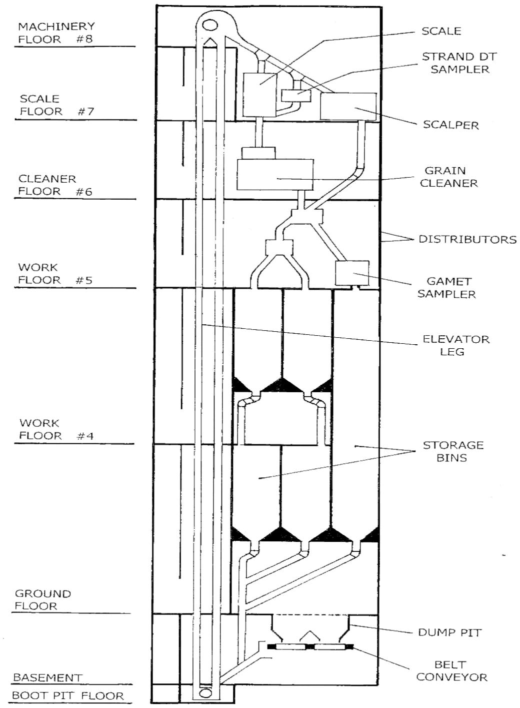

Figure 1. Schematic diagram of the elevator facility at GMPRC, USDA-ARS, Manhattan, KS.

Residual Grain Collection

Residual grain was manually collected from the dump pit, elevator boot, scale, and weighing hopper of the scale, scalper screens, and grain cleaner. Grain was stored in plastic bags and kept for later analysis. The facility was then thoroughly cleaned for the next test.

Sorting Process

Samples collected both from probe sampling and mechanical sampling were analyzed for moisture content, test weight, and sorted to quantify the level of commingling. Moisture content of the grain samples was measured with a Motomco® 919® Automatic Moisture Meter (Seedburo Equipment Co., Chicago, IL), while test weight was estimated based on the weight per Winchester bushel (USDA-GIPSA, 1997). All test weight values were converted and expressed in kg/hl. Commingling was calculated as the ratio of the white corn to the total sample collected expressed in percent.

Separation of kernels was done manually after samples and residual grain were passed through the Carter Dockage Tester to remove the fine material and broken corn less than 4.8 mm (12/64 in. diameter), stalks, and dried leaves. For the large amounts of residual grain gathered from the receiving pit and elevator boot, a Satake Automatic Color Sorter (Satake USA Inc., Houston, TX) was used to assist with the separation of the white from the yellow corn. Final sorting of all samples was done manually. The flow of grain and the activities involved for the test are shown in figure 2.

The process commingling was calculated by taking the percentages of white corn composition for each piece of equipment and normalizing to the feeding rate, that is,

$$C_p = [\Sigma(\text{Load} \times C_s)]/\text{total load} \times 100 \quad (1)$$

where: C_p = process commingling, in percent
C_s = sample commingling, in decimal

Load = feed rate * sampling interval, time

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Results and Discussion

Grain Commingling

The initial quality of the grain used for the tests is shown in table 1. These include the moisture content, test weight, and grade. Both the moisture content readings and test weights were not significantly different between white and yellow corn at the 5% confidence level. The variation of moisture readings was 1.05%, while test weight varied from 76.5 – 78.3 kg/hl for white and 77.1 – 78.4 kg/hl for yellow corn. Purity of yellow grain refers to the percentage of yellow to the total sample collected by probe sampling while purity of white is the percentage of white to the total sample collected. The percentage of purity for white corn was 99.952% and yellow corn was 99.936%. Also, the amount of broken corn and foreign materials (BCFM) was higher for the yellow (3.2%) than white corn (1.6%) samples which resulted in the higher grade for the white corn.

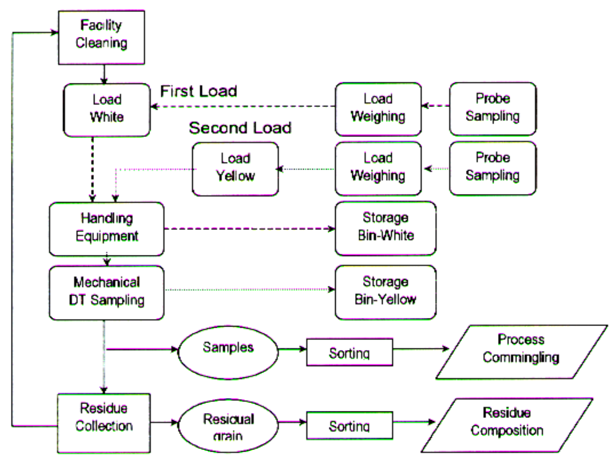

Figure 2. Elevator loading flow chart

Tables 2 shows the average composition of the collected samples during the 10-12 minutes of grain handling. The stalks, foreign seeds, dust, and broken grain passing through the 4.8 mm (12/64-in. diameter) round screen were classified as broken corn and foreign material (BCFM). White and yellow kernels above the 4.8 mm screen were grouped under the sortable grain.

The average amount of samples collected during the loading operation ranged from 348 g for the scalper to 738 g for the scale. The variation in the average amount of samples collected during loading was influenced by differences in the feeding rate. Sortable grain accounted for over 96.7% of the samples collected; BCFM ranged from 0.43 to 3.33% of the samples.

Grain commingling based on the samples collected was initially about 4% during the first 15 sec of grain transfer (197 kg) and reduced to 1.4% after 30 sec (figure 3). The percentage decreased to around 0.5% for the next 60 sec (635 kg) and to 0.2% within the next 2.5 minutes (2.0 t). At the end of the grain transfer, the process commingling after the receiving pit and elevator boot was calculated to be 0.25%.

At a feeding rate of 49.6 t/h (1950 bu/h), the percent of white grain in the samples for the scale started at 1.1% and dropped to 0.2% after the first metric ton (1 minute) of loading (figure 4). Sample commingling dropped to near 0% within 6 minutes, suggesting that after this period, the amount of commingled grain in the preserved grain is negligible. The process commingling with the automatic weighing scale along the grain flow was 0.18% of the total load.

For the grain cleaner with a feeding rate of 48.4 t/h (1900 bu/h), the first 0.25 t gave 2.8% sample commingling (figure 5). The level dropped to 0.5% within one minute (0.8 t) of loading and remained at 0.2% for the next 4 minutes (3 t). The amount of white grain was nearly negligible as loading approached 6 minutes (5 t). The process commingling started at 0.08% and reached 0.28% after 10 minutes of grain transfer.

During the loading operation with the scalper in line with a feeding rate of 43.3 t/h, sample commingling was 1.3% during the first 5% of the total load (380 kg) and declined to 0.3% in the next 5% (figure 6). Unlike the other handling machines, commingling in the scalper approached 0% within the first 3 t of grain transfer (4 minutes). Of the handling equipment used, the scalper had the lowest process commingling at 0.12%.

Table 3 summarizes the overall process commingling for each of the four pieces of equipment. The grain cleaner had the highest process commingling at 0.28%, followed by the automatic weighing scale at 0.18%. The scalper had the lowest process commingling at 0.12%. As such, the existing elevator facility could be used to receive and handle corn with a process commingling less that 0.5% assuming adequate self-cleaning of the equipment takes place between corn types. If the maximum level of commingling from farm to the storage is set at 1.0% and the commingling due to cross pollination and transportation is assumed at 0.5%, the commingling in this elevator would still be within the tolerance level. However, to ensure identity preservation and separation of transgenic crops, various strategies may have to be employed including: cleaning all handling equipment after each load of a different variety, dedicating the facility to specialty crops, and modifying existing equipment in the elevator. For this elevator facility, using self-cleaning and flushing of 1.3 - 2.5 t (50-100 bu) of corn would limit commingling to 0.2%.

Table 1. Initial quality of grain before the loading operation.

Grain Quality	Yellow	White
Grade	U.S. No. 2	U.S. No. 1
Purity, %	99.936	99.952
BCFM, %	3.2	1.6
Moisture content, %	12.66[a]	12.08[a]
Test weight, kg/hl	77.4[b]	78.0[b]

Note: Numbers in a row with the same letter are not significantly different at 5% level of confidence.

Table 2. Average weights and percentages samples collected during grain receiving.

Equipment	Sample Weight (S.D.), g	Sortable Grain (S.D.), %	BCFM (S.D.), %
Pit and boot	612.6 (98.6)	96.67 (1.07)	3.33 (1.07)
Weighing Scale	737.9 (280.9)	97.95 (2.71)	2.05 (2.71)
Grain Cleaner	446.0 (54.8)	99.57 (0.12)	0.43 (0.12)
Grain Scalper	348.2 (46.8)	97.34 (0.55)	2.66 (0.55)

Table 3. Process commingling for each handling equipment.

Elevator Equipment	Total Load (S.D.), t	Feeding Rate (S.D.), t/h	Total Load (S.D.), t	Commingling (S.D.), %
Pit and Boot	8.49 (0.39)	47.3 (0.58)	8.49 (0.39)	0.15 (0.015)
Weighing Scale	8.28 (0.47)	49.6 (2.85)	8.28 (0.47)	0.18 (0.008)
Grain Cleaner	6.93 (2.04)	48.4 (1.66)	6.93 (2.04)	0.28 (0.019)
Grain Scalper	6.11 (2.46)	43.3 (3.74)	6.11 (2.46)	0.12 (0.010)

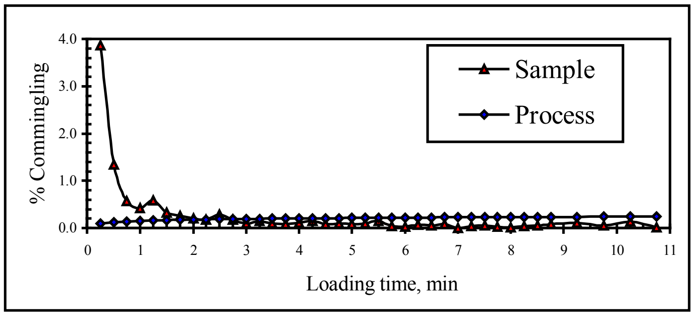

Figure 3. Commingling of white in yellow corn as yellow corn passed through the dump pit and elevator boot and up the elevator leg to the Strand DT Sampler.

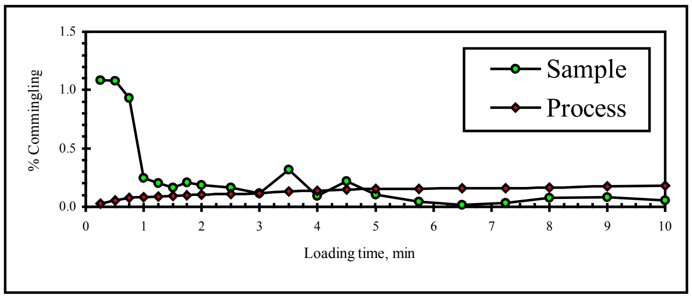

Figure 4. Commingling of white in yellow con as yellow corn passed through the automatic weighing scale.

Residual Grain

The residual grain collected varied from 272 g at the grain cleaner to about 120 kg at the elevator boot. The variation on the amount of residual grain was affected by design of the equipment and the cleaning mechanism of each machine (table 4).

The sorting of the residual grain collected after each replication showed that not all white corn kernels were flushed out by the loading of yellow corn. About 20% white corn remained in the receiving pit (figure 7). In the elevator boot, the portion of white corn was significantly higher at 73.6% (table 4). This is affected by the grain transfer procedure. White corn was handled first when the boot was clean, so considerable amounts of white corn filled up the large open volume at the bottom of the boot characteristic of this particular boot design (figure 8). The highest amount of residual grain was gathered from the elevator boot (120 kg), followed by the receiving pit (20 kg) (table 4).

The residual grain from the scale, cleaner, and scalper were much less than those collected from the pit and boot (table 4). Of these three pieces of equipment, the cleaner had the lowest amount at 272 g, followed by the scalper at 482 g and the scale at 532 g. A large portion of broken grain below the 4.8 mm screen (76.6%) was gathered at the scale after the loading operation. Only 23.4% of this sample was classified as sortable grains. In contrast, the sortable portion in both cleaner and scalper were higher as these machines automatically separate broken and fines during grain transfer. Both pieces of equipment had residual white corn of less than 1% (figure 9).

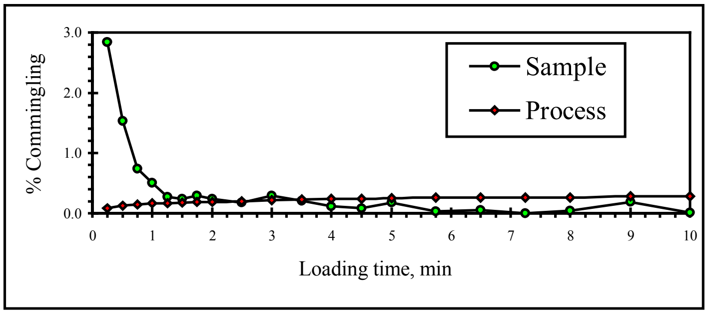

Figure 5. Percent grain commingling with grain cleaner in grain flow.

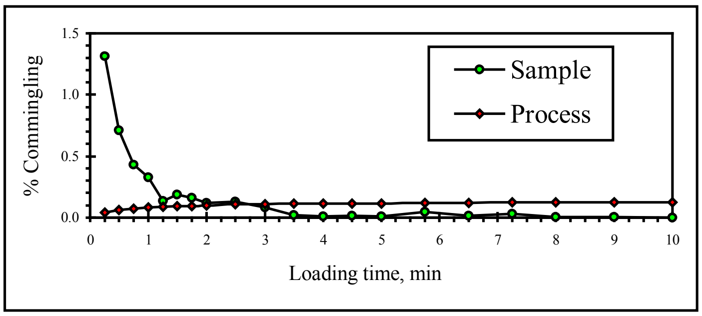

Figure 6. Percent grain commingling with grain scalper in grain flow.

Table 4. Amount and characteristics of residual grain collected in the grain receiving system.

Equipment	Weight (S.D.), g	Sortable Grain (S.D.), %	BCFM (S.D.), %	Percent White (S.D.), %
Dump pit	20,438.0 (1805.2)	84.19 (2.78)	15.77 (2.79)	19.59
Elevator boot	120,115.4 (5382.6)	85.16 (0.54)	11.45 (0.54)	73.64
Scale	531.8 (393.0)	23.40 (1.71)	76.56 (1.71)	2.08
Cleaner	271.9 (146.3)	97.09 (0.13)	2.78 (0.16)	0.85
Scalper	481.6 (51.0)	97.55 (0.01)	2.21 (0.01)	0.55

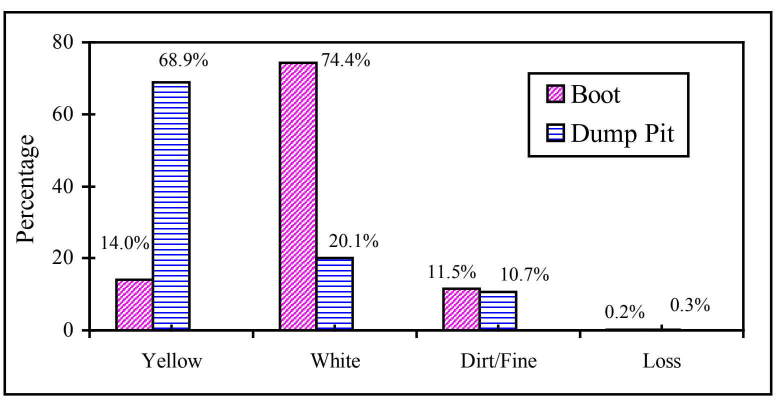

Figure 7. Average composition of residual grain collected from the receiving pit and elevator boot at the end of each replication.

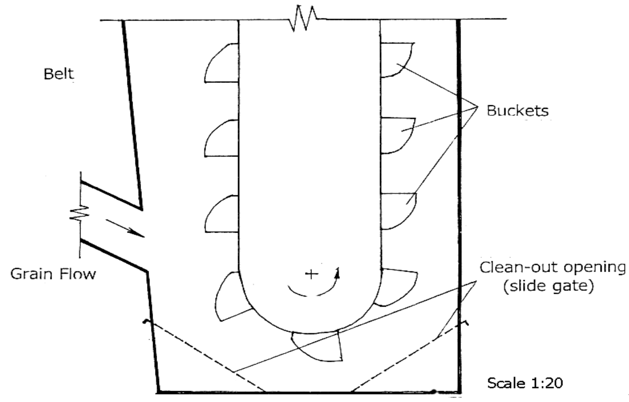

Figure 8. Schematic diagram of the elevator boot.

The amount of grain collected after grain receiving shows that significant amounts of grain are left in the equipment after the grain transfer process. The residual grain in the receiving pit likely influences the level of commingling of the next load of a different variety if the facility is not cleaned properly. The grain at the bottom of the elevator boot may have little effect on the level of commingling as it is unreachable by the scooping action of the buckets. The scale, cleaner, and scalper, designed as self-cleaning machines, left negligible amounts of residual grain.

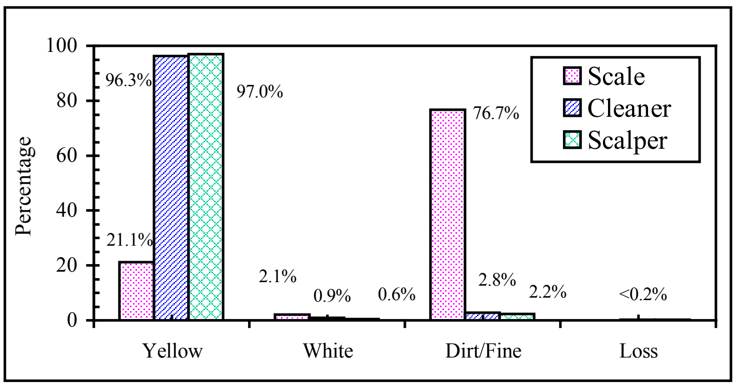

Figure 9. Composition of residual grain collected from the scale, cleaner and scalper after loading.

Conclusion

This research measured the levels of commingling and residual grain during the receiving and handling operation of grain. The following conclusions were drawn from this research:

(1) The grain cleaner had the highest process commingling at 0.28%, followed by the scale at 0. 18%, the receiving pit and elevator boot at 0.15%, and then by the vibrating grain scalper at 0.12%.
(2) The amount of process commingled grain was negligible at the scalper after 4 t (157 bu) of corn load and 5 t (196 bu) for the other pieces of equipment.
(3) The overall commingling effect of the above elevator is about 0.5% for 7.6 t (300 bu) of corn.
(4) The highest amount of residual grain collected after the loading operation was at the elevator boot at 120 kg.
(5) Negligible amounts of residual grain were collected from the scale, cleaner and scalper.
(6) Using self-cleaning equipment and flushing of 1.3 – 2.5 t (50-100 bu) resulted in an IP purity of up to 99.8% in these results.

The results obtained from the tests may not be applicable to elevator facilities with leg rates above 76 t/h (3000 bu/h).

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