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HYDRODYNAMIC SEPARATION OF GRAIN AND STOVER COMPONENTS IN CORN SILAGE

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Abstract. *The objective of this work was to evaluate the potential of hydrodynamic separation with water to sort corn grain from stover after ensiling. In a first experiment, the specific gravity of dried intact grain was found to be significantly higher (1305 kg DM/m³) than that of dried chopped stalk and leaf (average 635 kg DM/m³) or dried chopped husk and cob (average 826 kg DM/m³). However, when all material was ground, there was no significant difference between the five components (average 1546 kg DM/m³). In a second experiment, mixing fresh silage in water resulted in partial segregation of grain from stover, achieving a grain concentration as high as 75% in the sunk material when silage had a relatively low moisture content (64% MC) but as low as 41% when silage was relatively wet (74% MC). In a third experiment, partial drying to remove 20 percentage units of moisture prior to water separation increased grain concentration to 92% while complete drying increased grain concentration to more than 99%. Sieving increased grain concentration to 79%. In an industrial setting, hydrodynamic separation of silage with minimal pre-treatment could provide a feedstock with a high concentration of grain (75 to 80%). In a laboratory setting, hydrodynamic separation with prior oven drying could provide a method to separate grain from stover in corn silage by reaching a grain concentration higher than 99%.*

Keywords. Corn silage, corn grain, stover, separation, biomass, sieving, drying.

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Introduction

Various methods to separate corn grain from stover have been proposed. One approach is to shell the grain with a combine and to subsequently harvest the residual stover either with a forage harvester or a baler (Richey et al., 1982). Another approach is to harvest, chop and ensile the whole crop, and to separate components at removal from storage (Jenkins and Sumner, 1986). Advantages for separation after storage include fast and efficient harvest in a single stream, low-cost storage in high capacity bunker silos without the need for grain drying, and separation throughout the year at relatively low work rates, with small size equipment, compared to the high rates handled during the short harvest season.

After ensiling, grain has been sorted from stover, at least partially, by mechanical sieving (Ganesh and Mowat, 1983) or aerodynamic separation (Bilanski et al., 1986). Hydrodynamic separation has not previously been reported for corn silage but it is used industrially to separate heavier particles such as phosphatides from corn oil in the wet milling process (Corn Refiners Association, 1996).

Hydrodynamic separation of grain from stover could be feasible if a difference exists between the specific gravity or the buoyancy of components. The specific gravity of corn grain has been observed to range from 1278 to 1380 kg/m^3 (Gustafson and Hall, 1972). The specific gravity of corn stover components (stalk, cob, leaf, husk) is less well documented. Meanwhile, the specific gravity of forage particles is in the order of 1500 kg/m^3 (Pitt, 1983). This would suggest poor hydrodynamic separation of grain from stover in water because both components would sink. However, empirical evidence shows that grain sinks more rapidly than stover which tends to float because of buoyancy.

The objective of this work was to evaluate the potential of hydrodynamic separation with water to sort grain from stover after ensiling. New data are presented on the specific gravity of corn grain and stover components, after coarse chopping or grinding. Factors considered include harvest conditions (chop length and processing) and pre-treatment of the silage (partial drying, sieving) prior to hydrodynamic separation.

Methods

First experiment: specific gravity of corn components

Several stalks of whole-plant corn were cut with a scythe at 10 cm from the ground at full maturity (early December 2002) near Madison, WI. Plants were separated manually into five components: grain, stalk, leaf, husk, and cob. The components were oven-dried at 103°C for 24 h (ASAE, 2002a) to estimate moisture content and the respective proportions of DM. Specific gravity was estimated by a PMI Automated Gas Pycnometer (Porous Materials Inc., Ithaca, NY) which measured the pressure change of helium gas as it surrounded the crop component in an enclosed volume (ASTM, 2003). Three iterations were done for each sample in the pycnometer, and three replications were done for each component in two states: coarse components (intact grain or coarsely chopped stover) and ground components. Coarse chopping was done with a laboratory chopper set at 13 mm theoretical length-of-cut. Grinding was carried out with a Model 4 Thomas Wiley Mill using a 1 mm screen (Thomas Scientific, USA). The specific gravity was corrected to a dry basis by mass balance:

$$\rho_{DM} = \frac{\rho_{WM}\ \rho_{H_2O}\ (100 - MC)}{100\ \rho_{H_2O} - \rho_{WM}\ MC} \quad [1]$$

where ρ_{DM} is the corrected specific gravity on a dry matter basis, ρ_{WM} is the wet matter specific gravity as measured experimentally, ρ_{H2O} is the specific gravity of water (1000 kg/m³) and *MC* is the moisture content on a wet basis (%).

Second experiment: sequential water separation

Four silages harvested in fall 2002 were retrieved from the silo in March 2003 for the sequential water separation. The silages were selected to represent four mechanical harvest treatments: short chop and unprocessed, long chop and unprocessed, short chop and processed, and long chop and processed. Processing involved crushing and shearing the chopped whole-plant through a pair of toothed rolls operating at small clearance and differential speed (Shinners et al., 2000). Silages came from two experimental farms (Arlington, Prairie du Sac) and two commercial farms (Binversie, Ziegler) in Wisconsin. A measured mass of 1 kg fresh silage was placed in a water basin containing initially 7 liters of water. After one minute of manual gentle mixing, the material still floating on the water surface was removed by hand. The rest of the basin contents were poured gently over a screen to separate material in three components: the effluent water, the suspended solids retained by the screen and the sunk material that remained at the bottom of the basin after pouring. The latter two components were spread on separate paper cloths to partially dry in ambient air. The floating material was then deposited again in the water basin with the same effluent water. After one minute, the floating and suspended solids were set aside for the next water separation while the sunk material was put on a cloth to dry. This process was repeated until eight water separations had been completed. The 8-step sequential separation was replicated three times for each of the four silages.

The sunk material from each of the eight separations, the suspended solids from the first separation and the residual floating material after the eighth separation (i.e. 10 components) were oven dried at 103°C for 24 h to estimate the proportions of DM at each step. A well-mixed amount of 2 kg of water effluent was also measured after the eighth separation and oven dried to estimate the total DM in the effluent.

For each replication (4 silages x 3 replications), the 10 dried components were hand sorted to separate grain from stover. Sorted grain included full and broken grains, grain hull and grain endosperm pieces that were large enough (1-2 mm) to be clearly identified as starch. The rest was considered to be stover. Because sorting occurred over a period of several weeks after oven drying, rehydration occurred and component masses were corrected to a dry matter basis. Grain concentration was estimated as the proportion of sunk grain over the total of sunk grain and sunk stover.

Third experiment: separation after drying or sieving

Six pre-treatments were done to compare the effect of drying or sieving on subsequent grain and stover separation. They were: 1) a fresh untreated silage; 2) silage that was partially dried until it lost 10 percentage units of moisture; 3) silage that was partially dried until it lost 20 percentage units of moisture content; 4) silage that was oven dried to approximately 0% moisture; 5) silage that was sieved by a standard method (ASAE, 2002b) and whose material from screen number 3 only was hydrodynamically separated (particle size between 9.0 and 18.0 mm); 6) the same sieved material as in 5) that was also partially dried to lose 10 percentage units of moisture. The silage for all six pre-treatments was unprocessed and came from a commercial farm (Manthe) in south-central Wisconsin.

A single water separation was done with these treated silages. Using the same amounts of silage (1 kg) and water (7 liters) as in the second experiment, the material was separated in three components: sunk, suspended and floating material. DM in the effluent was estimated by mass balance. The three measured components were further subdivided into grain and stover by hand sorting after oven drying. The water separation was replicated three times for each of the six silage treatments. In the case of sieved material, 1 kg was placed in the separator, and only the fraction retained on screen number 3 was separated by water.

Physical, chemical and statistical analyses

As indicated previously, moisture was measured by oven drying at 103°C for 24 h (ASAE, 2002a). Three samples from each of the five silages were taken for moisture measurement. Mean particle length (MPL) was measured by the standard separator method using five screens and a pan (ASAE, 2002b). Three samples of about 2 kg each were taken to measure MPL for each of the five silages.

The following components were selected for chemical analyses: five corn components from the first experiment (grain, stalk, leaf, husk, and cob), four whole-plant corn silages from the second experiment, four effluent dry matters obtained from the four corn silages in the second experiment, four components from the third experiment (sunk grain, sunk stover, suspended stover and floating stover). Three replications of each component were analyzed by the UW Soil and Plant Analysis Lab in Marshfield, WI using wet chemistry for acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), minerals (P, Ca, K, Mg) and starch.

Statistical analyses were done using analysis of variance with a single factor. The single factor in the first experiment was corn component at five levels: grain, stalk, leaf, husk, and cob. The single factor in the second experiment was silage source at four levels: Binversie Farm (unprocessed, short), Prairie du Sac Farm (unprocessed, long), Ziegler Farm (processed, short), and Arlington Farm (processed, long). The single factor in the third experiment was treatment at six levels: fresh silage, partially dried to lose 10 percentage units of moisture, partially dried to lose 20 percentage units of moisture, completely dried in the oven, sieved and fresh, sieved and partially dried to lose 10 percentage units of moisture. Analysis of variance was used to determine significant differences. The least significant difference method was used to rank results (Steel et al., 1996).

Results and Discussion

First experiment: specific gravity of corn components.

Table 1 presents the specific gravity of corn components as measured by the gas pycnometer. All components were oven dried prior to measurements. Because of ambient rehydration, the moisture content of components varied between 2 and 8% at the time of measurements. Data presented in Table 1 were corrected on a DM basis using equation [1]. Intact grain was significantly denser (1305 kg DM/m^3) than chopped stalk and leaf (average 635 kg DM/m^3) or chopped husk and cob (average 826 kg DM/m^3). However, when all material was ground through a 1 mm screen, there was no significant difference between the five components (average 1546 kg DM/m^3). The corn used to measure specific gravity was very mature, being harvested in December, and had DM fractions of grain, stalk, husk, cob and leaf of 65, 18, 4, 10 and 3%, respectively. Measures might be different for earlier maturity corn. However, the data show a remarkable homogeneity in specific gravity when material becomes very fine.

The specific gravity of particles changed with their size. Intact grain was much denser than coarsely chopped stover components. When material was finely ground, the internal porosity was largely eliminated, thereby increasing the density of all components. The ground stover components were as dense as the ground grain. Therefore, fine chopping and processing would be expected to contribute to increase the density of all components. This would also lead to a higher proportion of stover sinking with grain in a water separation process.

Table 1. Specific gravity of corn components either coarsely chopped or ground, on a dry matter basis (average of 3 replications).

	Specific gravity (kg DM/m³)	
Component	Chopped	Ground
Grain	1305_a	1486_a
Stalk	606_c	1625_a
Husk	814_b	1606_a
Cob	837_b	1504_a
Leaf	664_c	1510_a
Standard error of means (SEM)	38	67
Least significant difference (LSD)	86	149

Variables with the same letter in a given column indicate no significant difference ($p < 0.05$).

Second experiment: sequential water separation

Table 2 presents the physical characteristics of the four silages used for the sequential water separation experiment. The two processed silages (Ziegler Farm and Arlington Farm) had very similar mean particle length (13 and 14 mm, respectively). They also had a relatively low moisture content; the Arlington silage had the highest DM content (36% DM). The Prairie du Sac Farm silage was unprocessed and had a long particle size (17 mm) while the Binversie Farm silage was unprocessed and had a short particle size (8 mm). The moisture reported for grain and stover in Table 2 may slightly underestimate the actual values because components were exposed to natural air drying for about an hour during manual sorting prior to oven drying.

Table 2. Characteristics of corn silages used for hydrodynamic separation of grain and stover in eight stages in experiment #2 (average of 3 replications).

	Moisture content (% w.b.)			Processed	Mean particle	Geom. SD
Silage source	Silage	Grain	Stover	(Yes/No)	length (mm)	(mm)
Ziegler Farm	67.3	50.3	69.5	Yes	12.9	1.70
Prairie du Sac Farm	73.8	52.8	75.8	No	17.4	1.81
Arlington Farm	63.8	45.8	67.6	Yes	13.6	1.97
Binversie Farm	66.0	46.8	70.7	No	8.1	1.66

Table 3 shows the proportion of grain and stover in the sunk material from the four silages. After the 1st separation, the grain concentration in the sunk material was 75% and highest for the Arlington silage which also was the driest. The grain concentration was only 41% and lowest for the Prairie du Sac silage which was the wettest. The Binversie silage was different from the other three silages because it produced a higher amount of sunk grain (31% of total DM) than the three other silages (19% of total DM). This might be due to a later maturity harvest, a greater presence of fully-formed kernels and the fact that no processor was used, thereby leaving more intact grain.

Table 3. Grain and stover proportions after the first and eighth separations of fresh silage in water (experiment #3, average of 3 replications).

Silage source	After first separation			After eighth separation				
	% of DM		% grain	% of DM				% grain
	Sunk grain	Sunk stover	Conc. in sunk material	Sunk grain	Sunk stover	Floating stover	DM in effluent	conc. in sunk material
Ziegler Farm	18.5_b	11.4_{bc}	62.0_b	20.0_c	36.3_b	17.6_b	26.0_a	35.6_b
Prairie du Sac Farm	19.1_b	27.1_a	41.3_c	19.5_c	53.2_a	6.7_c	20.7_b	26.8_c
Arlington Farm	19.3_b	6.6_c	75.2_a	25.2_b	29.6_c	23.8_a	21.6_b	45.9_a
Binversie Farm	30.7_a	14.7_b	67.7_{ab}	31.6_a	37.2_b	10.2_c	21.0_b	45.9_a
SEM	1.7	2.3	4.9	2.1	2.1	1.7	0.4	3.5
LSD	3.9	5.3	11.2	4.9	4.9	3.9	1.2	7.5

Variables with the same letter in a given column indicate no significant difference ($p < 0.05$).

After the 8^{th} separation, grain concentrations ranged from 27 to 46% and were lower than after the first separation (41 to 75%). At each separation, more stover sank and mixed with the corn grain. Only the Arlington silage released more than 1.5% of total DM as grain beyond the first separation. The actual concentration of DM in the effluent ranged from 0.71 to 1.22%, with an average of 1.01%. DM in the effluent reported in Table 3 represents the DM as a proportion of the original DM in the silage.

Figures 1 to 4 illustrate the curves of sunk grain, sunk stover, DM in the effluent and floating material over the course of the eight water separations for the four silages. The sunk grain and sunk stover reported in the figures were measured at each separation. The floating material and the effluent DM were measured only after the 8th separation. The curve for DM in the effluent was inferred by assuming that 70% of DM in the effluent was released after the 1st separation (see the third experiment for a justification) and by assuming that the release of effluent followed a logarithmic curve as a function of separation number. The curve for floating material was obtained by mass balance. The suspended stover recovered after the first separation was considered to be part of the floating material.

In this second experiment, water separation of grain and stover from fresh silage was best achieved at 75% grain concentration with processed and relatively dry corn silage (64% MC). Short chop material (8 mm) actually had a higher grain concentration (68%) than long material (17 mm) whose grain concentration was only 41% largely because of a high initial moisture (74% MC). The moisture content had a greater impact than the physical form in the range that was observed (8 to 17 mm mean particle length, processed or not processed).

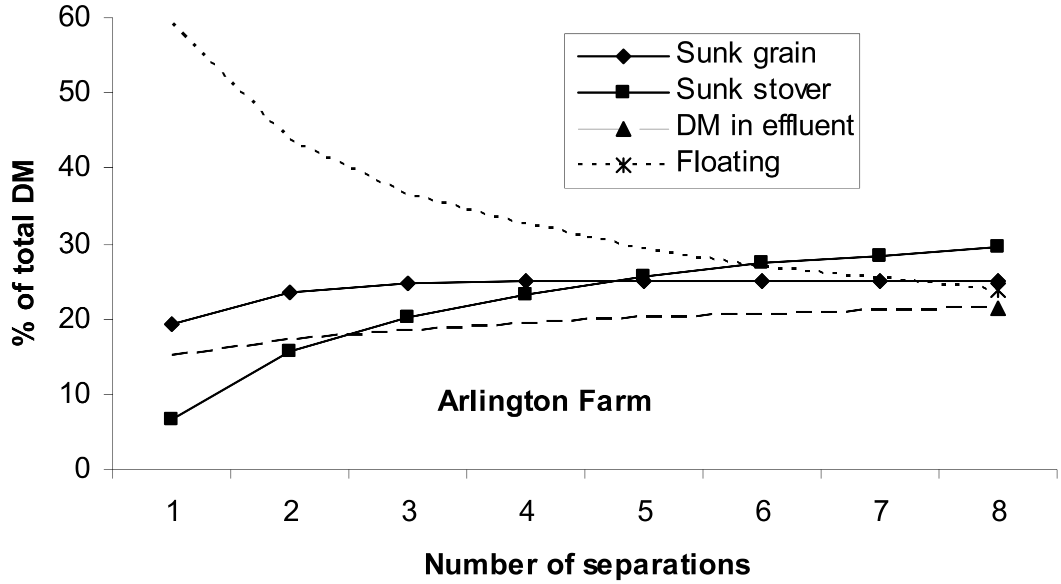

Figure 1. Corn silage components after eight successive water separations. The Arlington Farm silage was processed, had a MPL of 13.6 mm and a MC of 63.8%.

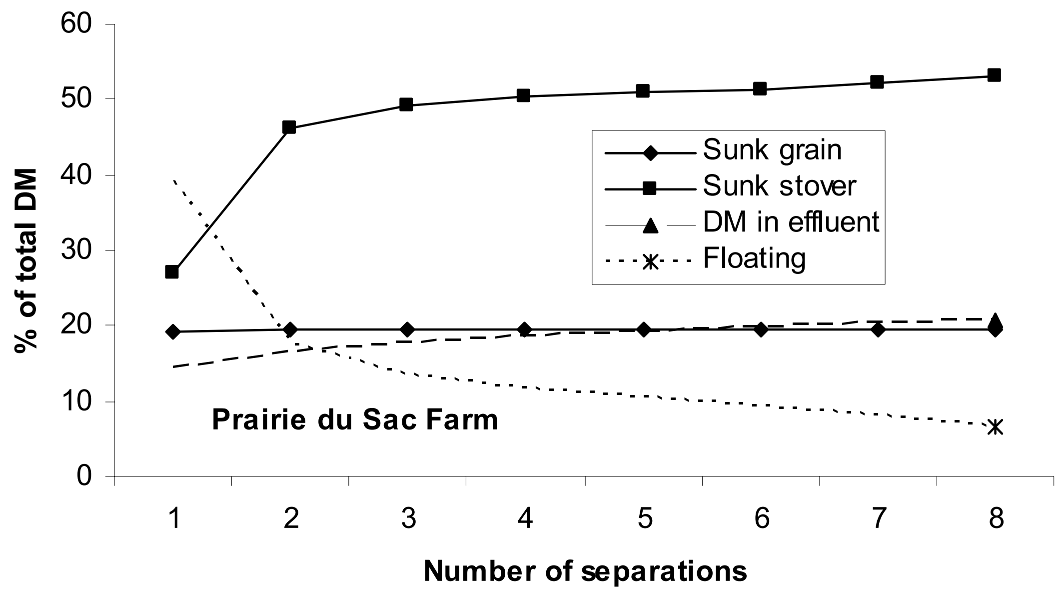

Figure 2. Corn silage components after eight successive water separations. The Prairie du Sac Farm silage was not processed, had a MPL of 17.4 mm and a MC of 73.9%.

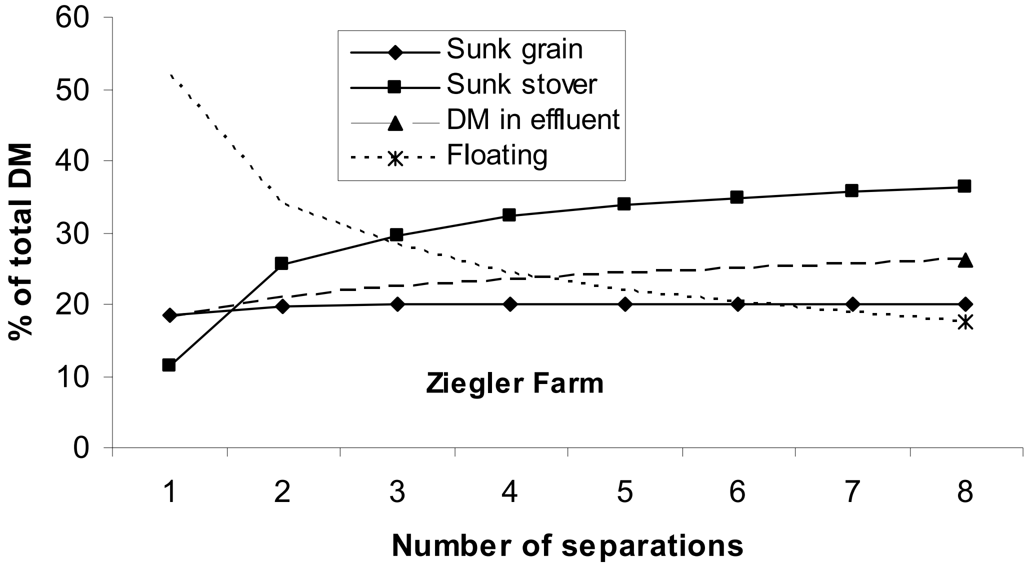

Figure 3. Corn silage components after eight successive water separations. The Ziegler Farm silage was processed, had a MPL of 12.9 mm and a MC of 67.3%.

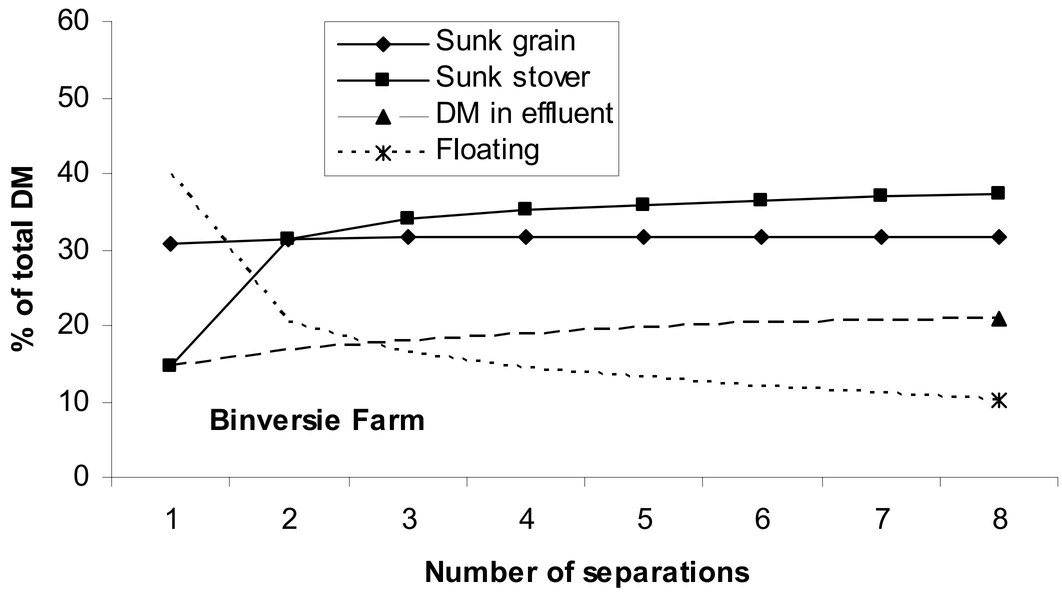

Figure 4. Corn silage components after eight successive water separations. The Binversie Farm silage was not processed, had a MPL of 8.1 mm and a MC of 66.0%.

Third experiment: separation after drying or sieving

Table 4 presents fractions of sunk, suspended and floating material after a single separation. The residual grain represents grain that was hand sorted from either the suspended or floating material. The DM in the effluent was obtained by mass balance after other components had been dried and separated.

Sieving increased the proportion of grain collected (37% vs. 21%, without drying), and improved the grain concentration in the sunk material (79% vs. 72%). However, the total amount of grain obtained in the sunk material was lower after sieving (18.6% vs. 21.3%) because about half the silage remained in the other sieves that were not used for the water separation. The smaller-size sieves would contain a significant amount of broken grain.

Table 4. Grain and stover proportions after one water separation and various pre-treatments (experiment # 3 with silage from Manthe Farm: 64.6% moisture content, unprocessed and 10.3 mm mean particle length; average of 3 replications).

	% of	Moist.	% of DM after one separation						% grain
	silage	content	Sunk	Sunk	Susp.	Floating	Residual	DM in	conc. in
Pre-treatment	used	(%)	Grain	stover	stover	stover	grain	Effluent	sunk material
1. Untreated silage	100	64.6	21.3_{c}	8.4_{a}	7.1_{b}	44.1_{cd}	1.5_{b}	17.6_{a}	71.8_{d}
2. Partially dried to lose 10 units of MC	100	54.8	22.9_{c}	9.5_{a}	5.2_{c}	45.4_{c}	0.5_{c}	16.5_{ab}	70.6_{d}
3. Partially dried to lose 20 units of MC	100	45.3	25.8_{b}	2.2_{c}	2.1_{d}	54.6_{b}	1.0_{bc}	14.3_{bc}	92.3_{b}
4. Oven dried	100	0.0	23.8_{bc}	0.1_{c}	0.6_{d}	62.3_{a}	2.5_{a}	10.8_{d}	99.4_{a}
5. Sieved and fresh	50.3	64.6	37.0_{a}	9.8_{a}	9.5_{a}	29.5_{e}	0.6_{c}	13.6_{cd}	79.1_{c}
6. Sieved, partially dried to lose 10 units of MC	50.3	55.5	34.6_{a}	4.7_{b}	5.1_{c}	41.1_{d}	1.7_{ab}	12.8_{cd}	88.0_{b}
Standard error of means			1.4	1.0	0.8	1.8	0.4	1.3	2.7
Least significant difference			3.1	2.2	1.7	3.9	0.9	2.8	5.8

Variables with the same letter in a given column indicate no significant difference ($p < 0.05$).

The proportion of sunk stover decreased significantly with partial drying (20 units of moisture loss) and with complete drying in the oven. The grain concentration was enhanced as high as 99.4% for bone-dry material. The proportion of suspended stover was highest for sieved and fresh pre-treatment. This material was of relatively uniform length (between 9 and 18 mm) so grain could sink rapidly in the absence of long stover pieces that tended to float and hinder the descent of smaller grain. The proportion of floating material was significantly higher for dry material. Residual grain was highest also in dry material. The proportion of DM in the effluent decreased as the silage was dried. The reduction of soluble and fine particles after drying might be due to a loss of volatile organic acids.

The effect of moisture content was therefore even more apparent in this third experiment when fresh material was compared to material partially dried (10 or 20 percentage units of moisture removal) or completely dried prior to water separation. Over 99% grain concentration was observed with bone-dry material. This would make the procedure a good laboratory method to concentrate grain from corn silage.

In this third experiment, effluent contained an average of 17.6% of fresh silage DM after one separation. In the second experiment where 8 successive water separations occurred, the effluent water contained between 20.7 and 26.0% of the fresh silage DM. A large proportion of the soluble and fine particles mixed rapidly in the effluent water. These values suggest a range between 68 and 85% for the ratio between DM in the effluent after one separation and DM in the effluent after 8 separations. A value of 70% was assumed above to illustrate effluent over several separations and is within the experimental range.

Chemical composition

Table 5 reports the chemical composition of five components from corn in experiment #1. The levels of crude protein and starch were lower than expected while the levels of ADF and NDF were higher than expected, probably because of the crop's very late maturity. Because of its remarkable difference between grain and stover components, the fiber concentration, either ADF or NDF, is likely to be a good indicator to estimate the proportion of grain and stover in a whole-plant mix.

Table 5. Chemical composition on a dry matter basis of mature whole-plant corn components (average of 3 replications).

Component	% CP	% P	% Ca	% K	% Mg	% Starch	% ADF	% NDF
Grain	4.9_b	0.25_a	0.03_d	0.31_d	0.11_d	42.5_a	2.5_d	21.0_d
Stalk	3.3_c	0.10_{bc}	0.16_b	1.04_a	0.17_b	0.4_b	45.5_b	78.3_c
Husk	3.9_c	0.07_{cd}	0.13_c	0.74_b	0.16_c	1.3_b	42.2_c	84.4_b
Cob	2.8_d	0.05_d	0.05_d	0.60_c	0.08_e	0.1_b	44.5_b	90.6_a
Leaf	5.7_a	0.13_b	0.44_a	0.23_d	0.25_a	1.3_b	46.8_a	77.8_c
SEM	0.3	0.02	0.01	0.05	0.01	2.3	0.8	2.7
LSD	0.7	0.03	0.02	0.12	0.01	5.2	1.8	6.1

Variables with the same letter in a given column indicate no significant difference ($p < 0.05$).

Table 6 shows the chemical composition of the four whole-plant silages prior to water separation in experiment #2. The silages had an average composition of 8.5% CP, 0.26% P, 0.11% Ca, 1.05% K, 0.21% Mg, 19.1% starch, 23.6% ADF and 40.3% NDF. Differences between silages were due to differences in location and harvest dates.

Table 6. Chemical composition of corn silages used in sequential hydrodynamic separation (average of three replications).

Source	%CP	%P	%Ca	%K	%Mg	%Starch	%ADF	%NDF
Ziegler Farm	8.6_{b}	0.23_{b}	0.04_{b}	0.89_{c}	0.18_{c}	18.6_{b}	22.8_{b}	38.5_{b}
Prairie du Sac	7.4_{c}	0.26_{ab}	0.33_{a}	0.83_{c}	0.27_{a}	23.4_{a}	28.4_{a}	48.2_{a}
Arlington Farm	8.1_{b}	0.25_{ab}	0.04_{b}	1.17_{b}	0.15_{d}	20.0_{ab}	21.8_{b}	36.2_{b}
Binversie Farm	10.0_{a}	0.29_{a}	0.03_{b}	1.29_{a}	0.24_{b}	14.5_{c}	21.4_{b}	38.1_{b}
SEM	0.3	0.02	0.03	0.03	0.01	1.6	1.0	2.0
LSD	0.7	0.05	0.08	0.07	0.02	3.7	2.2	4.7

Variables with the same letter in a given column indicate no significant difference ($p < 0.05$).

Table 7 shows the chemical composition of effluent DM after eight water separations. The effluent DM contained soluble and very fine particles and had on average 15.5% CP, 0.64% P, 0.95% Ca, 3.13% K, 0.73% Mg, 25.9% starch, 3.2% ADF and 5.0% NDF. The effluent DM has a relatively high energy and high protein value. It could be recuperated as an animal feed by-product.

Table 7. Chemical composition of effluent DM after eight water separations in experiment #2 (average of three replications).

Silage source	%CP	%P	%Ca	%K	%Mg	%Starch	%ADF	%NDF
Ziegler Farm	12.0_{c}	0.40_{c}	0.78_{b}	2.17_{b}	0.59_{b}	34.4_{a}	2.7_{b}	4.8_{b}
Prairie du Sac	10.8_{c}	0.56_{b}	1.03_{a}	2.13_{b}	0.61_{b}	34.0_{a}	5.7_{a}	7.8_{a}
Arlington Farm	18.0_{b}	0.73_{a}	0.95_{ab}	4.06_{a}	0.72_{b}	24.6_{b}	1.2_{c}	2.4_{c}
Binversie Farm	21.0_{a}	0.85_{a}	1.05_{a}	4.15_{a}	1.02_{a}	10.5_{c}	3.2_{b}	4.9_{b}
SEM	0.9	0.06	0.11	0.22	0.07	2.4	0.5	1.0
LSD	2.1	0.14	0.24	0.50	0.16	5.6	1.2	2.2

Variables with the same letter in a given column indicate no significant difference ($p < 0.05$).

Table 8 shows the chemical composition of components after water separation. The sunk grain had a level of starch as expected but more fiber than expected. The sunk stover probably contained small fractions of grain that could not be separated manually. The suspended and floating materials also probably contained some small grain particles that had not sunk after the first water separation. A considerable portion of the soluble protein and minerals were removed from these components and found in the effluent SM (Table 7).

Table 8. Chemical composition on a dry matter basis of corn silage components after one water separation in experiment #3 (average of 3 replications).

Component	% CP	% P	% Ca	% K	% Mg	% Starch	% ADF	% NDF
Sunk grain	1.9_d	0.06_c	0.02_c	0.15_c	0.03_d	55.0_a	5.3_c	16.9_c
Sunk stover	4.0_c	0.10_b	0.07_b	0.22_b	0.07_c	16.7_b	29.7_b	50.9_b
Suspended stover	5.1_b	0.11_b	0.18_a	0.23_b	0.09_b	6.8_a	39.0_a	63.4_a
Floating material	6.0_a	0.16_a	0.18_a	0.38_a	0.14_a	9.5_c	36.5_a	61.5_a
SEM	0.1	0.01	0.01	0.01	0.00	1.2	1.6	2.2
LSD	0.3	0.02	0.02	0.03	0.01	2.7	3.6	5.1

Variables with the same letter in a given column indicate no significant difference ($p < 0.05$).

Conclusion

1. The specific gravity of particles changed with their size. Intact grain was much denser than coarsely chopped stover components. However, when material was finely ground, the stover was as dense as the grain. Therefore, fine chopping and processing would contribute to increase the proportion of stover that sinks with grain in a water separation process.

2. Water separation of grain and stover from fresh silage was best achieved at 75% grain concentration with processed and relatively dry corn silage (64% MC). Grain concentration was only 41% in relatively wet corn silage (74% MC). The moisture content had a greater impact than the physical form in the range that was observed (8 to 17 mm mean particle length, processed or not processed).

3. The effect of moisture content was even more apparent when fresh material was compared to partially dried or completely dried material prior to water separation. Over 99% grain concentration was observed with bone-dry material. This would make the procedure a good laboratory method to concentrate grain from corn silage.

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