Bulk Density of Bio-Fuel Byproducts

A.S. Leaflet R2459

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Summary and Implications

Pig diets in Iowa have historically been formulated using corn and soybean meal and the physical characteristics of that type of diet are well known. Virtually all feed storage, handling, and delivery systems found in Iowa are designed considering corn-soybean meal diets. Bio-fuel co-products are increasingly being included in pig diets. The bulk density of bio-fuel co-products is not well known. The purpose of this study was to determine the bulk density of 12 individual co-products, 12 grains, oilseeds, and other pig diet ingredients, and 11 mixed pig diets using established measuring apparatus and procedures. An alternative apparatus was designed and evaluated for measuring bulk density of pig diets, grains, oilseeds, and bio-fuel co-products.

Diet formulation affects bulk density with most diets examined differing in bulk density from ground corn. All co-products examined have a bulk density less than whole corn or ground corn. Incorporating co-products into pig diets will result in a more bulky feed. The precise relationship between co-product inclusion and the bulk density of the final diet remain to be determined. In general, adding co-products from bio-fuel production to swine diets results in reduced bulk density. Bulk density measurements are affected by measuring device used, but the differences are consistent. For the fabricated device described in this report, a correction factor of 66-67% may be appropriate. Calibrating a fabricated device with a USDA tester is critical for accurate bulk density measures.

Introduction

Iowa leads the United States in corn, pigs, and ethanol production. There are multiple approaches to ethanol production currently used in Iowa. Each process results in a co-product with different physical characteristics and nutritional value. Pig diets in Iowa have historically been formulated using corn and soybean meal and the physical characteristics of that type of diet is well known. Virtually all feed storage, handling, and delivery systems found in Iowa are designed considering corn-soybean meal diets. Bio-fuel co-products are increasingly being included in pig diets. With increasing price competition for corn and other traditional feedstuffs it is likely that using co-products in pig diets will continue to expand. Pig diets are formulated based on the nutritional needs of the pigs. Pig feed is most commonly ordered on a weight basis. Farmers and feed mill operators are familiar with the mass-to-volume ratio, or bulk density, of typical pig diets. However, if physical characteristics of co-product ingredients differ from corn and soybean meal, the bulk density of formulated diets will also differ. This may require modification of planned ingredient storage areas, feed mixing equipment, bulk bins, and feeders in order to optimize use of these feed ingredients.

Materials and Methods

In 1953, the USDA developed a weight per bushel tester to quickly and accurately determine the test weight of various grains (Figure 1). This apparatus has a stand, measuring cup, weighing beam, filling hopper, stroker, and overflow pan. Grain is allowed to flow from a hopper into a measuring cup with a standard volume (1101.2 cm^3 or 1 dry quart). Grain fills the cup to overflowing and excess material is leveled off. The measuring cup and grain are weighed, and the weight of the grain per unit volume is calculated.

The 35 feedstuff samples were divided into three groups—common ingredients, co-products, and mixed diets. Samples were randomly ordered within a group for testing purposes. The testing apparatus was calibrated prior to testing the samples by filling the measuring cup with water and weighing the cup on a scale. The weight was converted to volume, using the conversion factor of 1.0 g water = 1.0 cm^3. For each sample 3 mass and 3 dry matter measurements were taken. Dry matter measurements were calculated following 24 hours of drying in an oven at 105°.

Mass was determined following USDA standards. The measuring cup was placed directly under the filling hopper. The distance between the top of the measuring cup and the bottom of the filling hopper was set at 5.08 cm (2.0 in.). Samples were individually poured into the filling hopper. The filling hopper slide was opened and the sample was allowed to flow into the cup. Samples were allowed to flow until the measuring cup was completely filled with a cone of accumulated material on top. A straight edge stroker was used to level the top of the measuring cup. The measuring cup and sample were weighed.

Bulk density is equal to mass over volume (g/cm^3). The mass of water held by the measuring cup was 1102.125 g. Using the conversion factor of 1.0 g water = 1.0 cm^3, the volume of the measuring cup was 1102.125 cm^3. The bulk density of each sample was calculated by dividing the mass of the measured sample by 1102.125 cm^3. Sample dry matter was calculated using the following formula: Dry matter = 1 -[(wet sample weight - dry sample weight) ÷ wet sample weight]. LS Means were calculated and compared for each sample using SAS JMP 7.0.

The USDA standard weight per bushel tester may not be available and so an alternative apparatus was fabricated

(Figure 2). The alternative apparatus was made using 1 × 4 in. lumber for the base and attached vertical struts. Bolts and washers were used to secure an 8 in. length of 3.5 in. diameter PVC tubing to the vertical struts. The PVC tube was reduced down to a 1 in. opening. Sample flow out of the PVC holding tube was regulated by a rotating piece of metal that was attached to the bottom of the tube. The measuring cup was 3.5 in. diameter PVC pipe with an end cap. The volume of the PVC measuring cup was 694.56 cm^3. Bulk density measurements of selected feeds and feedstuffs were made using the fabricated apparatus following USDA protocol. The PVC holding tube was 2 in. above the measuring cup. Nine feeds and diets were selected to compare the two devices. Three bulk density measurements of selected samples were taken using both the USDA and the fabricated PVC device.

Results and Discussion

Table 1 presents the bulk density and dry matter of common swine feed ingredients. As expected, the determined bulk density of grains closely matched the published standard bushel weights. Grains fed to pigs are typically ground. Grinding feed reduces particle size and improves digestibility. Grinding also reduces the bulk density of a material, for example ground corn has a bulk density 21% less than the bulk density of whole corn. As expected soybean hulls and vitamin mix are less dense than other ingredients. Mineral components—dicalcium phosphate and ground limestone— were the densest ingredients examined.

Table 2 details the formulation of selected swine diets. Diets are primarily ground corn plus 9 to 25% soybean meal. Other ingredients include dicalcium phosphate, ground limestone, trace minerals, and vitamin mix. Table 3 presents dry matter and bulk density of mixed diets. As expected the most dense mixed diet was the pelletted starter diet. Interestingly there are differences ($P \leq 0.05$) between mixed diets. In general adding DDGS to diets resulted in a lower bulk density of the final diet. Adding glycerol to the control diet also reduced the bulk density of the final diet. Adding both glycerol and DDGS resulted in a diet that was denser than diets containing DDGS alone. Diet formulation affects bulk density with most diets examined having a bulk density different from the bulk density of ground corn.

Table 4 reports the dry matter and bulk density of 12 bio-fuel co-products. Bulk density of the co-products was compared. Bulk density of the examined co-products range from 0.330 g/cm^3 to 0.604 g/cm^3. All co-products examined have a bulk density less than whole corn or ground corn. Incorporating co-products into pig diets will result in a bulkier feed. The precise relationship between co-product inclusion and the bulk density of the final diet remain to be determined, however in general, adding co-products from bio-fuel production result in reduced bulk density. This may warrant further examination as use of co-products increase.

Table 5 reports the comparison of two devices for measuring bulk density of feeds and feedstuffs. Bulk density is affected by measuring device but differences were consistent. For the fabricated device a correction factor of 66-67% may be appropriate. Calibrating a fabricated device with a USDA tester is critical for accurate bulk density measures.

Acknowledgements

The authors gratefully acknowledge the following individuals and organizations for their assistance with this project: Dr. Brian Kerr, NSIRC-USDA; Dr. Carl Bern, professor of agricultural and biosystems engineering; the many ethanol companies providing co-products for testing; ISU Department of Agricultural and Biosystems Engineering; ISU Swine Nutrition Farm; Martha Jeffries, lab manager; and the ISU Science with Practice Program.

Table 1. Bulk density and dry matter of common swine feed ingredients[1].

Item	Dry Matter %	Bulk Density[2] g/cm^3	Imperial Units lb/ft^3	Imperial Units lb/bu
Corn	86.31	0.721 ± 0.002	44.99	55.99
Soybeans	93.32	0.745 ± 0.002	46.47	57.83
Oats	91.12	0.437 ± 0.002	27.27	33.93
Barley	91.91	0.601 ± 0.002	37.46	46.62
Winter Wheat	92.43	0.777 ± 0.002	48.48	60.33
Spring Wheat	91.59	0.757 ± 0.002	47.20	58.74
Ground Corn	85.79	0.594 ± 0.002	37.08	46.15
Soybean Meal	88.35	0.658 ± 0.002	41.02	51.05
Soybean Hulls	91.85	0.371 ± 0.002	23.14	28.80
Ground Limestone	99.98	1.366 ± 0.002	85.23	106.07
Dicalcium Phosphate	98.08	0.934 ± 0.002	58.25	72.48
Vitamin Mix	90.14	0.443 ± 0.002	27.61	34.35

[1]Whole grain unless noted.
[2]LS Means ± SEM.

Table 2. Formulation of selected complete swine diets.

Component	Diet: Gestation	Lactation	Finishing Pig 1	Finishing Pig 2
Corn, %	78.7	71.2	71.0	78.7
Soybean Meal, %	9.0	19.5	24.7	15.0
Other, %	12.3	9.3	4.3	6.3
Total	100	100	100	100

Table 3. Dry matter and bulk density of complete swine diets.

Item	Dry Matter %	Bulk Density[1] g/cm^3	Imperial Units lb/ft^3	Imperial Units lb/bu	Tukey HSD[2] 0.05
Ground Corn	85.79	0.594 ± 0.002	37.08	46.15	CD
Gestation Diet	86.51	0.596 ± 0.002	37.17	46.26	C
Lactation Diet	85.76	0.602 ± 0.002	37.53	46.70	CD
Finishing Pig Diet 1	86.43	0.578 ± 0.002	36.08	44.90	F
Finishing Pig Diet 2	86.05	0.617 ± 0.002	38.47	47.88	B
Starter Pig Pellets	86.43	0.629 ± 0.002	39.26	48.86	A
Control Corn-Soybean Meal	85.31	0.612 ± 0.002	38.17	47.50	B
Control + 15% DDGS	86.05	0.569 ± 0.002	35.47	44.14	G
Control + 25% DDGS	86.38	0.547 ± 0.002	34.12	42.47	H
Control + 10% Glycerol	84.66	0.590 ± 0.002	36.79	45.79	DE
Control + 10% Glycerol + 15% DDGS	84.45	0.585 ± 0.002	36.48	45.40	EF
Control + 10% Glycerol + 25% DDGS	85.64	0.570 ± 0.002	35.55	44.24	G

[1]LS Means ± SEM.
[2]LS Means not sharing a common letter are different ($P \leq 0.\ 0.5$).

Table 4. Dry matter and bulk density of bio-fuel co-products[1].

Item	Dry Matter %	Bulk Density[2] g/cm³	Imperial Units lb/ft³	Imperial Units lb/bu	Tukey HSD[2]
Whole Corn	86.31	0.721 ± 0.002	44.99	55.99	A
Ground Corn	85.79	0.594 ± 0.002	37.08	46.15	B
DDGS 1	88.50	0.530 ± 0.002	33.08	41.16	D
DDGS 2	89.51	0.467 ± 0.002	29.15	36.27	E
DDGS 3	89.90	0.470 ± 0.002	29.31	36.48	E
DDGS 4	87.91	0.487 ± 0.002	30.40	37.83	D
DDGS 5	93.19	0.494 ± 0.002	30.81	38.34	D
Microwaved DDGS	86.94	0.396 ± 0.002	24.68	30.71	F
DDG 1	94.37	0.576 ± 0.002	35.96	44.74	C
DDG 2	90.64	0.604 ± 0.002	37.65	46.85	B
Corn Germ	90.70	0.435 ± 0.002	27.12	33.75	G
Corn Bran with Solvent	88.36	0.346 ± 0.002	21.60	26.88	H
Dried Solubles	90.48	0.330 ± 0.002	20.61	25.65	I
Corn Gluten Feed	91.55	0.499 ± 0.002	31.13	38.73	D

[1]All co-products derived from ethanol production processes.
[2]LS Means ± SEM.
[3]LS Means not sharing a common letter are different (*P ≤ 0. 0.5*).

Table 5. Comparison of two devices[1] for measuring bulk density[2] of feed and feedstuffs.

Sample	Apparatus USDA	Apparatus PVC[3]	SEM	*P*-value
Whole corn	0.727	0.484	0.002	< 0.0001
Whole soybeans	0.749	0.501	0.001	< 0.0001
Ground corn	0.554	0.367	0.002	< 0.0001
Vitamin mix	0.443	0.297	0.002	< 0.0001
Finishing pig diet 1	0.569	0.381	0.002	< 0.0001
Finishing pig diet 2	0.613	0.417	0.003	< 0.0001
Corn germ	0.434	0.294	0.003	< 0.0001
DDGS 3	0.466	0.312	0.003	< 0.0001
Corn Bran with Solvent	0.350	0.235	0.004	< 0.0001

[1]USDA = standardized method, PVC = pvc apparatus
[2]Bulk density reported in g/cm³, values reported are LS Means.
[3]By dividing the PVC values by a correction factor 0.665, the bulk density values would be similar to the USDA values.

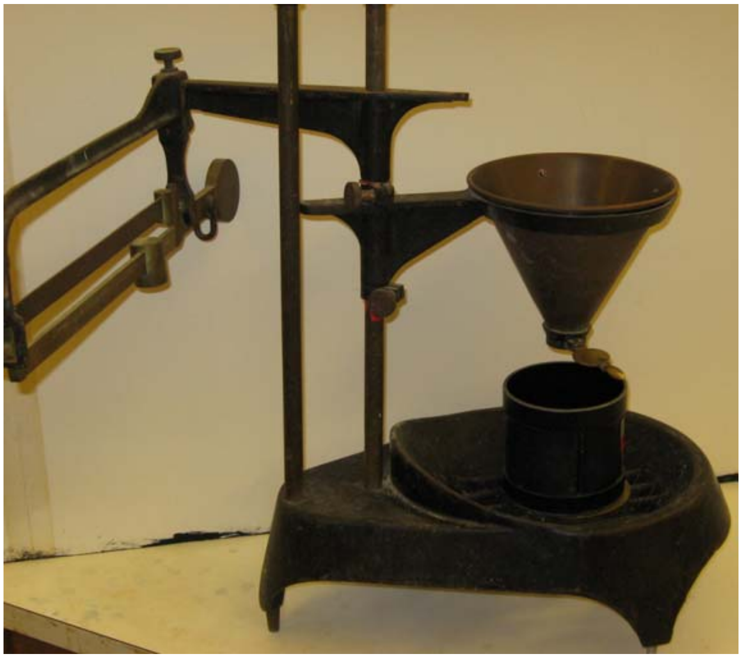

Figure 1. USDA weight per bushel tester.

Figure 2. Fabricated device for measuring bulk density of feedstuffs and diets.