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Effects of Grinding Almond Hulls with a Hammermill on Particle Size and Bulk Density[1]

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Summary

The objective of this experiment was to evaluate the effects of grinding almond hulls with different screens on subsequent particle size and bulk density. Twenty pounds of almond hulls from the California Central Valley were ground with a laboratory-scale 1.5 HP Bliss Hammermill (Model 6K630B) using a 7⁄16 in., ¾ in., 1 in., or no screen. Each screen size treatment was ground at three separate time points to provide three replications per treatment. For each replication, two samples were collected and analyzed for particle size geometric mean and standard deviation and bulk density. Geometric mean particle size was greater ($P < 0.01$) when no screen was used to grind almond hulls compared with ¾-in. and 1-in. screens; moreover, particle size was decreased ($P < 0.01$) when ground with a 7⁄16 in. screen compared to all other treatments. Particle standard deviation did not differ ($P = 0.13$) between treatments. Bulk density of almond hulls tended to be greater ($P = 0.07$) when a 7⁄16-in. screen was used as compared to no screen, a ¾-in. screen, and a 1-in. screen. Overall, unground almond hulls had a bulk density of 14.1 lb/ft^3. Therefore, grinding almond hulls using a 7⁄16 in., ¾ in., 1 in., or no screen led to an increase in their bulk density by 140, 115, 114, and 111%, respectively. Particle size was also evaluated using the Penn State Particle Separator.[3] Grinding almond hulls with no screen tended ($P < 0.01$) to increase proportions of medium (i.e., 0.31 to 0.75 in.) particles and decrease ($P \le 0.02$) proportions of fine (i.e., < 0.16 in.) particles compared to grinding with a 7⁄16-in. screen. In conclusion, decreasing hammermill screen size reduced particle size from 2217 µm to 1324 µm but did not impact particle size standard deviation. In addition, grinding almond hulls increased bulk density by 111 to 140%. A live-bottom trailer with a load capacity of 2,835 ft^3 could transport approximately 20 tons of unprocessed almond hulls. Conversely, the same trailer could transport 25 to 30 tons of ground almond hulls, thus, reducing transportation costs by 20 to 33% per ton, respectively.

Introduction

The Almond Board of California estimates annual almond hull production will reach 2.26 to 2.40 million tons within the next four years. Almond hulls contain soluble

[1] Appreciation is expressed to the Almond Board of California for partial financial support of this study.

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[3] Heinrichs, J., and P. Kononoff. 2013. The Penn State Particle Separator. Penn State Extension. DSE. 186:1-8.

sugars and fibers and are primary used by local dairy farms; however, increased regulations have resulted in a decline in the California dairy cattle inventory. Increased production combined with a reduced dairy herd may decrease almond hull demand. Almond hulls are marketed based on crude fiber concentrations. Prime hulls contain less than 15% crude fiber and are primarily used by local dairies. Almond hulls that contain 15 to 29% crude fiber are marketed as hulls and shells and could be incorporated as a feed ingredient in growing beef cattle diets; however, the bulk density of almond hulls make transporting them long distances a costly undertaking. Grinding almond hulls is a potential solution to increase bulk density and may also improve digestibility, reduce sorting, and improve feed aggregation. Therefore, the objective of this experiment was to evaluate the effects of hammermill screen size on almond hull particle size and bulk density.

Materials and Methods

Almond hulls in this experiment contained 20% crude fiber and were considered hulls and shells. Almond hulls were ground to determine the effects of hammermill screen size on particle size and bulk density. Treatments included grinding with no screen, a 7⁄16-in. screen, a ¾-in. screen, or a 1-in. screen. For each treatment, 20 pounds of almond hulls were ground using a laboratory scale 1.5 HP Bliss Hammermill (Model 6K630B). Each treatment was ground at three separate time points to provide three replications.

A subsample of each treatment was analyzed for particle size according to ASABE 319.2[4] methods using a 13-sieve stainless steel sieve stack. Each sample (100 g) and a flow agent was placed in the top sieve and sifted for ten minutes using a Ro-Tap machine (Model RX-29; W. S. Tyler Industrial Group, Mentor, OH). Bulk densities of the initial unground almond hulls and ground samples were measured.[5] Particle size was also evaluated using the Penn State Particle Separator. Two hundred grams of sample was placed in the top sieve. The box was then shaken in one direction five times, rotated a quarter turn, and repeated 7 times for a total of 40 shakes. Sieves were then individually weighed to determine the amount of sample remaining.

Data were analyzed using the MIXED procedure in SAS (v. 9.4, SAS Inst. Inc, Cary, NC). The experimental unit was grind run and each treatment was replicated three times. When protected by a significant *F*-test ($P \leq 0.05$), treatment means were separated using the method of least significant difference; tendencies were declared at $0.05 \leq P \leq 0.10$.

Results and Discussion

Geometric mean particle size was greater ($P < 0.01$; Table 1) when no screen was used to grind almond hulls compared with ¾ in. and 1 in. screens. In addition, particle size was decreased ($P < 0.01$) when almond hulls were ground with a 7⁄16-in. screen compared with all other treatments.

[4] American Society of Agriculture and Biological Engineers (ASABE). 2008. S319.2: Method of determining and expressing fineness of feed materials by sieving, ASABE: St. Joseph, MI, USA.

[5] Clementson, C. L., K. E. Ilelji, and K. A. Rosentrater. 2010. Evaluation of measurement procedures used to determine the bulk density of distillers dried grains with solubles (DDGS). Trans. ASABE. 53:485-490.

Particle-size standard deviation did not differ ($P = 0.13$) between treatments. Conversely, bulk density tended ($P = 0.07$) to be greater when a 7⁄16-in. screen was used compared with a ¾ in., 1 in., or no screen. Bulk densities were 33.9, 30.3, 30.2, and 29.7 lb/ft^3 for the 7⁄16-in. screen, the ¾-in. screen, the 1-in. screen, and no screen, respectively. Initial bulk density of unprocessed almond hulls was 14.1 lb/ft^3; therefore, grinding almond hulls with a hammermill using 7⁄16 in., ¾ in., 1 in., or no screen increased bulk density by 140, 115, 114, and 111%, respectively.

Particle size was also evaluated using the Penn State Particle Separator. Proportions of large (i.e., > 0.75 in.) and small (i.e., 0.16 to 0.31 in.) particles did not differ ($P \geq 0.32$; Table 1) between treatments; however, proportions of medium (i.e., 0.31 to 0.75 in.) and fine (i.e., < 0.16 in.) particles were influenced by screen size. Proportions of medium particles tended to be greater ($P = 0.07$) with no screen compared with the ¾-in. screen and with the 7⁄16-in. screen, whereas proportion of medium particles with the 1-in. screen were intermediate and not different ($P \geq 0.38$) from no screen, the ¾-in. screen, or the 1-in. screen. Proportions of fine particles were greater ($P \leq 0.02$) with the 7⁄16-in. screen compared with the ¾-in. screen, the 1-in. screen, and no screen. In addition, proportions of fine particles tended ($P = 0.07$) to be greater with the ¾-in. screen compared with no screen.

Overall, grinding almond hulls with a hammermill reduced particle size and increased bulk density. Assuming a cost of $5 per loaded mile, a live-bottom trailer with a load capacity of 2,835 ft^3 could transport approximately 20 tons of unground almond hulls 500 miles for $125/ton. Conversely, the same trailer could transport 25 tons of ground almond hulls 500 miles for $100/ton; therefore, grinding almond hulls could reduce transportation cost by 20%. In addition, grinding almond hulls with no screen may be optimal to minimize the proportion of fine particles. Research is currently being conducted to determine the effects of ground and non-ground almond hull inclusion on growth performance of growing beef calves.

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Table 1. Effects of grinding almond hulls with a hammermill on particle size and bulk density[1]

	Hammermill screen hole diameter					
Item	**7⁄16 in.**	**¾ in.**	**1 in.**	**No screen**	**SEM[1]**	**Probability, *P*<**
Particle size,[3] μm	1324[c]	1772[b]	1777[b]	2217[a]	71.2	0.01
Standard deviation	2.53	2.47	2.45	2.18	0.138	0.13
Bulk density, lb/ft³	33.9[y]	30.3[z]	30.2[z]	29.7[z]	1.45	0.07
Particle separator,[4] %						
Large	0.00	0.08	0.09	0.33	0.208	0.46
Medium	0.44[z]	2.81[z]	5.12[yz]	15.00[y]	2.091	0.07
Small	79.59	84.25	83.68	76.50	4.581	0.32
Fine	19.92[a]	12.55[by]	11.66[b]	7.92[bz]	2.152	0.01

[1] Almond hulls were ground with a laboratory-scale 1.5 HP Bliss Hammermill (Model 6K630B) using a 7⁄16 in., ¾ in., 1 in., or no screen. For each screen size treatment, 20 pounds of almond hulls were ground at three separate time points to provide three replications per treatment.
[2] Mixed-model standard error of the mean (SEM) associated with comparison of treatment main-effect means.
[3] Particle size and standard deviation determined as described by ASABE 319.4 methods.
[4] Determined using the Penn State Particle Separator. Large = particles > 0.75 inches, medium particles 0.31 to 0.75 inches, small particles from 0.16 to 0.31 inches, and fine particles < 0.16 inches.
[a,b,c] Within row, means with unlike superscripts differ ($P \leq 0.05$).
[y,z] Within row, means with unlike superscripts tend to differ ($P \leq 0.10$).