Influence of grinding size of the main cereal of the diet on egg production and eggs quality of brown egg laying hens from 33 to 65 weeks of age

J. Herrera, B. Saldana, L. Camara, J. D. Berrocoso, and G. G. Mateos

ABSTRACT The influence of grinding size of the main cereal of the diet on production and egg quality traits was studied in brown hens from 33 to 65 wk of age. The experiment was completely randomized with 6 treatments arranged as a 3 x 2 factorial with 3 main cereals (barley, corn, and wheat) and 2 grinding size of the cereal (6 and 10 mm screen). Each treatment was replicated 11 times (10 hens/replicate). Diets were isonutritive and contained 2,740 kcal/kg AMEn and 16.8% CP. Egg production, ADFI, egg weight, and feed conversion ratio (FCR) were determined by period (4 wk) and for the entire experiment. Egg quality traits (percentage of undergrades, Haugh units, thickness, strength, color of the shell, and proportion of albumen, yolk, and shell) were measured also by period. No interactions between main cereal and grinding size of the main cereal of the diet were observed for any of the traits studied. Feed intake, egg production, and BW gain were not affected by diet or grinding size. Eggs were heavier (P < 0.01) in hens fed barley than in hens fed corn or wheat, probably because of the higher fat content of the barley diets. Also, FCR tended to improve in hens fed barley compared with hens fed corn or wheat (P = 0.07). Diet did not affect any of the egg quality traits studied. In summary, barley and wheat conveniently supplemented with enzymes, can be used in substitution of corn at levels of up to 55% in diets for laying hens, without any adverse effect on egg production or egg quality traits. Moreover, the substitution of corn by a combination of barley and supplemental fat increased egg size. Consequently, the inclusion of one or other cereal in the diet will depend primarily on their relative cost. Within the range studied, screen size (6 vs. 10 mm) of the cereal had limited effects on hen production.

INTRODUCTION

Corn and wheat are the main sources of energy in poultry diets worldwide, although barley is also of common use in laying hens (Frikha et al. 2009; Jacob and Pescatore, 2012). Barley and wheat contain variable amounts of non-starch polysaccharides (NSP) which increase digesta viscosity and reduce nutrient absorption and performance in broilers (Edney et al., 1989; Wang et al., 2005; García et al., 2008) and laying hens (Lázaro et al., 2003; Mirzaie et al., 2012). In layers, diets with a high NSP content are associated with an increase in the incidence of dirty eggs (Bruñau et al., 1994; Francesch and Bruñau, 2004). However, the proportion of dirty eggs decreases and even disappear with the use of convenient enzyme complexes (Lázaro et al., 2003; García et al., 2008; Saki et al., 2010).

Egg weight has been associated traditionally to the level of methionine, the most limiting amino acid in hen diets, as well as to the linoleic acid (LNL) content of the diet (Shutze et al. 1962; Balnave, 1970, 1971). Corn contains more LNL than wheat or barley, which favors its use in laying hen diets (Grobas et al., 1999a, b). However, it is unclear if the increase in egg size observed is due to the LNL concentration per se or to an increase in the level of supplemental fat, because under most practical conditions both factors are confounded (Grobas et al., 1999a,c).

Numerous factors affect voluntary feed intake (FI) in poultry fed mash diets. In this respect, the optimal geometric mean diameter (GMD) of the diet that maximizes FI and hen production is a major challenge for the egg industry. Most studies indicate that when allowed to choose, hens show a clear performance for coarse particles (Isa Brown, 2009). Herrera et al. (2017) reported that feed efficiency tended to improve when diets based on corn or barley were ground with a 6 to 12 mm screen compared with a 4-mm screen but no other production or egg quality traits were affected. The hypothesis of this research was that the size of the screen used to
grind the main cereal of the diet could affect hen production, and effect that could depend on the type of cereal used. The objective of this research was to evaluate the effects of the GMD of the main cereal of the diet on production and egg quality traits of brown-egg laying hens fed diets based on barley, corn, and wheat from 33 to 65 wk of age.

**MATERIALS AND METHODS**

**Husbandry, Diets, and Experiment Design**

The procedures described in this research were approved by the Animal Ethics Committee of Universidad Politécnica de Madrid (Boletín Oficial del Estado, 2007). In total, 660 Lohmann Brown Classic hens were selected at random from an 80,000-bird flock at 30 wk of age and housed in an environmentally controlled barn. Hens were randomly allotted in groups of 10 into 66 enriched cages (120 cm x 63 cm x 45 cm; Facco S.p.A., Padova, Italy) with similar average BW per cage. Then, the hens were fed a common diet based on equal proportions of corn, wheat, and barley for 3 wk and weighed again (1811 ± 31.9 g BW). The cages were provided with an open trough feeder and 2 low pressure nipple drinkers. The lighting program consisted in 16 h light/day throughout the experiment. Room temperature was recorded daily during the experiment with a maximum average value of 26 ± 3°C (June, last period of the experiment) and a minimum of 21 ± 3°C (February). Feed in mash form and water were provided for ad libitum consumption.

Three diets with similar CP (16.8%) and AMEₚ (2740 kcal/kg) contents but differing in the main cereal used (corn, wheat, or barley) were formulated. The diets met or exceeded the nutrient requirements of laying hens as recommended by FEDNA (2008). Two batches of these diets, with same ingredient composition, were manufactured and used from 33 to 44 wk and from 45 to 64 wk of age, respectively. All diets were supplemented with a commercial enzyme complex with xylanase and β-glucanase activity (Roxazyme, DSM S.A., Madrid, Spain). In the formulation of the diets it was assumed that the inclusion of the enzyme complex increased the AMEₚ content of the barley and wheat grains by 2% (from 2800 to 2856 kcal/kg of barley and from 3150 to 3213 kcal/kg of wheat) but had no effects on the energy content of the corn or of the other ingredients of the diet (FEDNA, 2010). Before feed manufacturing, a batch of each of the 3 cereals were divided into 2 portions and ground using a horizontal hammer mill (Mecafa S.A., Ciudad Real, Spain) provided with a 6- or a 10-mm screen and included as such in their respective experimental diets.

The experiment was conducted as a completely randomized design with 6 diets arranged factorially with 3 main cereals and 2 GMD of the cereal. Each treatment was replicated 11 times and the experimental unit was the cage with 10 hens for all measurements.

**Laboratory Analysis**

Representative samples of the feeds were ground using a laboratory mill (Retsch Model Z-I, Stuttgart, Germany) equipped with a 1-mm screen and analyzed for moisture by oven-drying (method 930.15), total ash in a muffle furnace (method 942.05), and nitrogen by Dumas (method 968.06) using a Leco analyzer (Model FP-528, Leco Corp., St. Joseph, MI) as described by AOAC International (2005). Ether extract was determined by Soxhlet analysis after 3 N HCl acid hydrolysis and crude fiber (CF) by sequential extraction with diluted acid and alkali (Boletín Oficial Estado, 1995). Gross energy was determined using an adiabatic bomb calorimeter (model 1356, Parr Instrument Company, Moline, IL, USA) with benzoic acid as the calibration standard. The LNL content of the diets was determined by gas-liquid chromatography (GC-14B, Shimadzu, Kyoto, Japan) as shown by Grobas et al. (1999a) and the amino acid content by ion-exchange chromatography (Hewlett-Packard 1100, Waldbronn, Germany) after acid hydrolysis, as indicated by de Coca-Sinova et al. (2008). Particle size distribution and mean particle size of the diets, expressed as the GMD and geometric standard deviation (GSD; log normal SD), were determined in 100 g samples using a shaker equipment (Retsch, Stuttgart, Germany) provided with 8 sieves ranging in mesh from 5000 to 40 μm as indicated by ASAE (1995). All the analyses were conducted in duplicate except for the GMD of the diets that were determined in triplicate. The ingredient composition and chemical analyses of the diets are shown in Table 1. The GMD and GSD of the two batches of the diets used during the experiment are shown in Table 2.

**Measurements**

**Hen Production** Egg production, feed disappearance, and BW of the hens were determined by cage at 4 wk intervals. Eggs produced the last 2 d of each week were weighed, and the average value of the 4 wk was used to estimate egg weight by period. From these data, ADFI, egg production, egg weight, egg mass, feed conversion ratio (FCR) per kilogram and per dozen of eggs, and BW gain of the hens were calculated for each of the 8 periods and for the entire experiment (33 to 65 wk of age). Any mortality was recorded and weighed as produced.

**Egg Quality** Undergrades (dirty, broken, and shellless eggs) were recorded daily by replicate in all eggs produced. An egg was considered as dirty when a spot of any kind or size was detected on the shell (Lázaro et al., 2003). Other egg quality traits, including haugh units, shell strength, shell color, and shell thickness, were measured in 12 fresh eggs collected randomly from each cage replicate the last 2 d of each of the 8 experimental periods. Haugh units were measured using a multimeter equipment (QCMSystem, Technical Services and Supplies, Dunnington, York, UK) as indicated by
expressed in g/cm², was evaluated applying increased pressure to the broad pole of the egg using a press meter (Egg Force Reader, SANVO Technology A/S, Odense, Denmark) as indicated by Safaa et al. (2008b). Shell color was measured using a Minolta colorimeter (Chroma Meter Model CR-200, Minolta Corp., Ramsey, NJ) and the Hunter color values, L* (lightness), a* (green to red), and b* (blue to yellow), were recorded (Table 3).

Statistical Analysis

Data were analyzed as a completely randomized design with 6 treatments arranged as a 3 × 2 factorial with cereal and screen size of the diet as main effects using the MIXED procedure of SAS (SAS Institute, 2004). When the model was significant, treatment means were separated using the Tukey test. Results in tables are presented as means and differences were considered significant at P < 0.05.

RESULTS

The GMD was higher for the barley than for the corn diets with the wheat diets being intermediate in both feed batches (Table 2). Also, the GMD of the diets increased as the screen size used to grind the cereals increased. The GSD was lower for the barley diets than for the wheat or the corn diets and decreased in all cases as the screen size increased.

Hen Production and Egg Quality

No interactions between the main cereal of the diet and the screen size used to grind the cereal were observed for any of the traits studied and consequently, only main effects are presented (Table 3).

Main Cereal of the Diet

Egg production, egg mass, ADFI, and BW gain were not affected by the main cereal of the diet in any of the periods considered (Figure 1). Mortality tended to be higher in hens fed corn than in hens fed wheat or barley (4.9% vs. 2.6% and 1.9%; P = 0.06). Cumulatively (33 to 65 wk of age), egg weight was greater in hens fed barley than in hens fed corn or wheat (65.7 g vs. 64.7 g and 64.4 g; P < 0.05). Also, FCR tended to be better for the barley- than for the corn- or the wheat diets (1.94 vs. 1.98 and 1.98; P < 0.05). None of the egg quality traits studied (percentage of broken and dirty eggs, shell-less eggs, Haugh units, strength, thickness, and color of the shell, and percentage of albumen, yolk, and shell of the eggs) was affected by the main cereal of the diet (Table 3).

Screen Size

The screen size used to grind the cereal did not affect any of the egg production or egg quality traits studied (Figure 2).

### Table 1. Ingredient composition and chemical analyses (% in dry matter) of the experimental diets.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Corn</th>
<th>Wheat</th>
<th>Barley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>90.1</td>
<td>90.2</td>
<td>90.0</td>
</tr>
<tr>
<td>Gross energy (kcal/kg)</td>
<td>3601</td>
<td>3601</td>
<td>3572</td>
</tr>
<tr>
<td>Ether extract</td>
<td>3.7</td>
<td>2.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Linoleic acid (C18:2)</td>
<td>2.2</td>
<td>1.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>2.7</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Crude protein</td>
<td>17.3</td>
<td>17.0</td>
<td>17.4</td>
</tr>
</tbody>
</table>

**Calculated analysis**

- **AMEn (kcal/kg)**: 2740, 2740, 2740

**Digestible amino acid**

- Lys: 0.76, 0.76, 0.77
- Met: 0.39, 0.39, 0.42
- Met + Cys: 0.62, 0.62, 0.62
- Thr: 0.55, 0.50, 0.53

- Total ash: 11.8, 12.1, 11.8
- Crude fiber: 2.7, 3.6, 3.4
- Crude protein: 17.3, 17.0, 17.4

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1Provided the following (per kilogram of diet): vitamin A (trans-retinyl acetate), 10,000 IU; vitamin D3 (cholecalciferol), 3750 IU; vitamin E (d-alpha-tocopheryl acetate), 10 mg; vitamin B1, 1.3 mg; vitamin B2, 5 mg; vitamin B6, 2 mg; vitamin B12 (cyanocobalamin), 15 mg; niacin, 25 mg; pantothenic acid (d-calcium pantothenate), 10 mg; folic acid, 1 mg; biotin, 15 mcg; choline (choline chloride), 250 mg; manganese (MnO), 90 mg; iron (FeSO4.H2O), 40 mg; copper (CuSO4.5H2O), 8 mg; iodine [Ca(IO3)2], 0.7 mg; selenium (Na2SeO3), 0.3 mg; Roxazyme, 200 mg (1600 U of endo-1,4-β-glucanase (EC 3.2.1.4), 3600 U of endo-1,3 (4)-β-glucanase (EC 3.2.1.6), and 5200 U of endo-1,4-β-xylanase (EC 3.2.1.8)) supplied by DSM S.A., Madrid, Spain; Natuphos 5000 (300 FTU/kg supplied by Basf Española, S.A., Tarragona, Spain), 60 mg. All diets included 0.18 g canthaxantin/kg. The barley- and wheat diets included also 0.18 g/kg and 0.16 g/kg, respectively, of the ester of β-apo-8-carotenonic/kg (supplied by Basf Española, S.A., Tarragona, Spain).

2Prepared following the recommendations of FEDNA (2010).

3Data correspond to the average of duplicate analyses of the 2 diets differing in the GMD of the cereal used in the 2 batches manufactured (33 to 44 wk and 45 to 64 wk of age). Within each cereal type, the determined chemical analyses were similar for the 2 diets in the 2 periods (CV below 4%).

### Figure 2

Perez-Bonilla et al. (2012). Shell thickness, was measured at the two pole ends and at the middle section of the egg shell with a digital micrometer (model IT-014UT, Mitotuyo, Kawasaki, Japan). The average of the 3 measurements for each of the 12 eggs was used for further analyses (Safaa et al., 2008a). Shell strength and shell color were measured in 6 eggs collected randomly from each replicate on the same days. Shell strength, expressed in g/cm², was evaluated applying increased pressure to the broad pole of the egg using a press meter (Egg Force Reader, SANVO Technology A/S, Odense, Denmark) as indicated by Safaa et al. (2008b). Shell color was measured using a Minolta colorimeter (Chroma Meter Model CR-200, Minolta Corp., Ramsey, NJ) and the Hunter color values, L* (lightness), a* (green to red), and b* (blue to yellow), were recorded (Table 3).
The GMD of the diets was higher for the barley- than for the corn diet with that of the wheat diet being intermediate, consistent with data of Herrera et al. (2017). The differences reported were expected because the barley grain had very flexibles glumes and contain more neutral detergent fiber than corn and wheat grain. Consequently, more barley particles pass intact through the screen, increasing the GMD of the diet. The GMD and the GSD of the diets increased as the screen size used to grind the cereal increased. Similar results comparing these three cereals were reported by Perez-Bonilla et al. (2014) and Herrera et al. (2017), indicating that feed structure depends not only on the size of the screen used but also on the characteristics of the grain.

### DISCUSSION

#### Main Cereal of the Diet

Egg production, egg mass, ADFI, and BW gain were not affected by the main cereal of the diet, consistent with most published research in which the wheat and barley diets were supplemented with an adequate combination of exogenous enzymes (Pérez-Bonilla et al., 2011; Herrera et al., 2017). However, eggs were heavier in hens fed barley than in hens fed corn or wheat. The information available on the effects of the main cereal of the diet on egg size is scarce. Herrera et al. (2017) observed that egg size was greater in hens fed barley than in hens fed corn or wheat. The combination of exogenous enzymes (Perez-Bonilla et al., 2011; Herrera et al., 2017) observed that egg size was greater in hens fed barley than in hens fed corn or wheat. The reason for the inconsistencies reported among researches is not known but might be related to

### Table 2. Geometric mean diameter (GMD, μm) and geometric standard deviation (GSD) of the experimental diets.

<table>
<thead>
<tr>
<th>Period</th>
<th>Screen size</th>
<th>Corn</th>
<th>Wheat</th>
<th>Barley</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>33 to 44 wk</td>
<td>6 mm</td>
<td>940 ± 2.13</td>
<td>1010 ± 2.14</td>
<td>1131 ± 2.09</td>
<td>1027 ± 2.13</td>
</tr>
<tr>
<td></td>
<td>10 mm</td>
<td>1205 ± 2.38</td>
<td>1270 ± 2.12</td>
<td>1380 ± 2.05</td>
<td>1286 ± 2.12</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>1072 ± 2.17</td>
<td>1140 ± 2.14</td>
<td>1255 ± 2.08</td>
<td>1156 ± 2.14</td>
</tr>
<tr>
<td>45 to 65 wk</td>
<td>6 mm</td>
<td>972 ± 2.21</td>
<td>1116 ± 2.26</td>
<td>1245 ± 2.11</td>
<td>1111 ± 2.19</td>
</tr>
<tr>
<td></td>
<td>10 mm</td>
<td>1123 ± 2.19</td>
<td>1271 ± 2.19</td>
<td>1386 ± 2.02</td>
<td>1260 ± 2.13</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>1047 ± 2.20</td>
<td>1193 ± 2.23</td>
<td>1315 ± 2.06</td>
<td>1185 ± 2.14</td>
</tr>
</tbody>
</table>

### Table 3. Influence of the main cereal of the diet and the screen size used to grind the cereal on hen production and egg quality from 33 to 65 wk of age.

<table>
<thead>
<tr>
<th>Cereal</th>
<th>Screen size (mm)</th>
<th>SD1</th>
<th>Probability2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hen production</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Egg production (%)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Feed intake (g/d)</td>
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<tr>
<td>Egg weight (g)</td>
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<tr>
<td>Egg mass (g/d)</td>
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<tr>
<td>FCRs (kg/kg)</td>
<td></td>
<td></td>
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<tr>
<td>FCRs (kg/dozen)</td>
<td></td>
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<tr>
<td>BW (g)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Shell thickness (mm)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Shell strength (g/cm²)</td>
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<tr>
<td>Shell color (°L)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Egg quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haugh units</td>
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<td></td>
<td></td>
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<tr>
<td>Dirty eggs (%)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Broken eggs (%)</td>
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<td></td>
<td></td>
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<tr>
<td>Shell-less eggs (%)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Egg constituents (% of the eggs)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a,b Within a row, means without a common superscript differ significantly.

1, 2 The interactions between main effects was not significant for all variables (P > 0.10).

2, 3 Feed conversion ratio.

4, 5 Data for these variables correspond to the means of 12 fresh eggs of the 8 periods (28 days each one).

6, 7 Data for dirty, broken, and shell-less eggs correspond to the means of 12 fresh eggs of the 8 periods (28 days each one).

8 Hunter color values, L* (lightness), a* (green to red), and b* (blue to yellow).
Figure 1. Effect of the main cereal of the diet on egg production (A), ADFI (B), egg weight (C), egg mass (D), and feed conversion ratio (FCR) per kg of eggs (E) from 33 to 65 wk of age. NS: $P > 0.1$; *0.1 > $P > 0.05$; **0.05 > $P > 0.01$; ***0.01 > $P > 0.005$; ****0.005 > $P > 0.001$.

In this respect, when corn is substituted by barley, the level of supplemental fat and often the level of LNL content of the diet increases to compensate for the lower $\text{AME}_\text{n}$ content of barley. As has been shown by Jensen et al. (1958), Grobas et al. (1999a, c), and Ravindran et al. (2016), an increase in these 2 dietary components might increase egg size. Published data on the minimum requirement of LNL to optimize egg size in laying hens are not consistent. Scragg et al. (1987) reported that brown egg-laying hens required more than 2.0% LNL to maximize egg size. Moreover, Lohmann (2016) recommend a minimum of 1.8% in diets for commercial laying hens. In contrast, Pérez-Bonilla et al. (2014)
observed that egg size was maximized with as little as 1.1% of LNL in the diet. In fact, Grobas et al. (1999c) and Safaa et al. (2008b) demonstrated that an increase in the LNL content of the diet from 1.15% to 1.65% and from 1.12% to 1.60%, respectively, did not affect egg weight in brown egg-laying hens from 22 to 65 wk and from 59 to 70 wk of age, respectively. In these two experiments, however, egg size increased significantly when extra amounts of supplemental fat were included in the diet, irrespective of their LNL content. In the current experiment, feeding barley resulted in heavier eggs compared with feeding corn or wheat. Probably, the higher level of supplemental fat of the barley diets, compared with that of the corn and wheat diets (4.9% vs. 1.8% and 1.6%, respectively) rather than the LNL content that was high and above 1.8% in all cases, was responsible for the increase in egg weight observed in hens fed barley. The results reported herein are consistent with data of Herrera et al. (2017) who reported heavier eggs in hens fed diets based on barley containing 5.3% supplemental fat and 3.4% LNL than in hens fed diets based in corn containing 4.7% supplemental fat and 3.7% LNL. These results confirm the suggestion of Grobas et al. (1999c) which indicated that once the LNL requirement of the hens was reached (around 1.0 to 1.2% of the diet), an increase in the level of supplemental fat, rather than a further increase in LNL, was responsible for the increase in egg weight often observed.

For the entire experimental period, FCR tended to be better with the barley- than with the wheat- and corn diets. In the research we accepted that the exogenous enzymes increase the energy content of barley by 2%. Probably, the enzyme complex used improved the AMEn content of barley more than expected (Gracia et al., 2003). In this respect, Lázaro et al. (2003) reported that the supplementation of the diet with an enzyme complex based on β-glucanase and
Figure 2. Effect of screen size used to grind the cereal of the diet on egg production (A), ADFI (B), egg weight (C), egg mass (D), and feed conversion ratio per kg of eggs (E), of the hens from 33 to 65 wk of age

|xylanase, similar to that used in the current research, improved energy utilization of the barley diet by up to 5.5%.

Mortality tended to be higher in hens fed corn than in hens fed wheat or barley, probably because of differences in CF among the diets (Mateos et al., 2012; 2017). Similarly, Hartini et al. (2002) reported higher mortality in laying hens fed corn diets than in laying hens fed barley diets (2.9% vs. 5.3% CF, respectively) from 17 to 24 wk of age. Diets with a low fiber content increase aggressiveness and feather pecking in poultry resulting in higher mortality. In this respect, Francesch et al. (2005) reported also greater mortality in laying hens fed corn based diets than in hens fed barley based diets (4.3% vs. 5.1%, respectively) from 22 to 46 wk of age.
Screen Size

It is widely accepted that, when allowed to choose, hens show a preference for consuming the larger feed particles. Consequently, finely ground diets might reduce voluntary FI (Safaa et al., 2009; Lohmann, 2016; Herrera et al., 2017, 2018) and therefore, egg size and egg production (Isa Brown, 2009). In the current research, however, the size of the screen used to grind the cereals had little effect on hen production or egg quality traits. Similarly, Herrera et al. (2017) did not detect any difference on these traits using screens varying in size from 6 to 12 mm. In contrast, Safaa et al. (2009) reported a significant 2.5% increase in FI in hens fed corn or wheat ground with a 10-mm screen (GMD ± GSD: 1208 ± 2.19) than in hens fed these same diets ground with a 6-mm screen (GMD ± GSD: 886 ± 2.21), although no differences in egg production or egg weight were detected. In general, the data reported herein show a trend for increases in FI, egg production, and egg weight in hens fed the 10-mm ground diets compared with hens fed the 6-mm ground diets, although the differences were significant only for some of the traits during the first part of the experiment. In this respect, egg mass was greater and FCR was better when the cereal was ground with a 10-mm screen from 33 to 49 wk of age with no differences observed from 49 to 65 wk of age. The data suggest that laying hens respond better to increases in particle size of the diet at younger ages, with effects disappearing with age. In the current research, the differences in GMD between the coarse and the fine diets were 265 and 151 μm for corn, 260 and 155 μm for wheat, and 250 and 141 μm for barley, for the first (33 to 44 wk) and second (45 to 64 wk) batches of the diets, respectively, differences that were lower the second than for the first period. In the experiment of Safaa et al. (2009), in which the authors reported greater FI in hens fed diets based on corn or wheat ground with a 10-mm screen than in hens fed the same cereals ground with a 6-mm screen, the difference...
in GMD reported was of 491 and 252 \( \mu m \), respectively, greater than the differences reported in the current research. Consequently, the possibility that the greater effect of increased grinding size on production in the first part compared to the second part of the experiment could be due to differences in GMD of the diets cannot be ruled out.

In conclusion, the main cereal of the diet did not affect FI, egg production, BW gain of the hens, or eggs quality traits of the hens for the entire experiment. However, hens fed barley had less mortality and produced heavier eggs than hens fed wheat or corn, probably because of the higher level of fiber that reduces feather pecking, and of supplemental fat that increased egg size of the barley diets. Feed conversion ratio tended to be better in hens fed barley than in hens fed wheat or corn, suggesting that the enzyme complex used improved energy and nutrient utilization of the barley diets more than expected. For the entire experiment, the screen size (6 vs. 10 mm) used to grind the cereals had little effect on egg production or egg quality. Barley and wheat, supplemented with adequate enzymes, can substitute up to 55% of the corn in diets for laying hens, without any adverse effect on production or egg quality traits.

RESOURCES


Boletín Oficial del Estado. 1995. Real Decreto 2257/1994 por el que se aprueba los métodos oficiales de análisis de piensos o alimentos para animales y sus primeras materias. BOE 52:7161–7237.381


