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# Effect of feed particle size on growth and egg-laying parameters of Japanese quail (*Coturnix japonica*) in Côte d'Ivoire

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## Abstract

In Côte d'Ivoire, the quail breeding is confronted with the lack of food specific to the species. Thus, in the south-east of this country, an experimental study was conducted at the ISMOREL farm in the sub-prefecture of Adiaké. This study, which aims to improve the productivity of day-to-day farms, focused on the grain size of the feed. From grower (GD) and layer (LD) diets, 5 experimental diets have been manufactured. There are: LD 5 with a particle size of 5 mm, LD 3 and GD 3 with a particle size of 3 mm as well as LD 2 and GD 2 with a particle size of 2 mm. The growth parameters related to 750 two-week-old unsexed subjects weighing 49.67 ± 0.17 g on average. For egg-laying, 300 female quails were used at 6-week-old. The results showed an influence of the 2 mm grain size (LD 2 and GD 2) on parameters such as feed intake (186.96 ± 4.73 g and 153.46 ± 5.33 g), average live weight (142.37 ± 1.76 g and 155.85 ± 1.85 g), the average daily gain (4.29 ± 1.22 g/d and 4.74 ± 1.25 g/d), the age of first egg laid (49.33 ± 0.58 d and 46.33 ± 1.26 d) and egg-laying rate (67.24 ± 30.97% and 74.12 ± 34.03%). At the end of this study, it appears that the 2 mm particle size induces better growth and egg-laying performance in Japanese quail.

**Keywords:** Quail; Granulometry; Nutrition; Zootechnics

## 1. Introduction

In Côte d'Ivoire, quails breeding is confronted with a major constraint related to quails feeding. To feed their animals, breeders use feeds intended for other poultry species, such as chicken in general, layers in particular. This practice induces a weak expression of raised quail performances. So, faced with this problem, several scientific studies including those of [1] then [2] were carried out. These aimed to provide Ivorian quail growers with new feed formulations based on local products that can ensuring better expression of zootechnical parameters by quails. However, these investigations were only based on the bromatological composition of the feed without worrying about the probable effects of its particle size on quail performances. In view of the morphological characteristics of the beak of the Japanese quail, the grain size of the feeds currently used in Ivorian coturniculture would be unsuitable. This could cause a deficit in certain nutrients assimilation by these animals. It would therefore be appropriate to determine the grain size of the feed best suited to quail from a zootechnical point of view. This present study therefore proposes to test the feeds mainly used by Ivorian quail growers, by varying the grain size of each type of food. Thus, while waiting for the development of a specific quail feed in Côte d'Ivoire, quail growers could obtain more satisfactory results. The general objective is to improve the productivity of Ivorian quail farms by developing feed with an adapted grain size to quail according to age. Specifically, it is a question of determining the effect of the grain size of the feed on growth and egg-laying parameters and indicating for each period the best suited feed.

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## 2. Material and methods

### 2.1. Study site

This study took place at the ISMOREL farm located in Côte d'Ivoire at 2 km from Adiaké's town (5° 17' 06'' N latitude and 3° 18'07 W longitude). The relative humidity and temperature during the experiment period varied from 75% to 95% and 23.7° to 32.2°C respectively. The annual precipitation was 1689.54 mm.

### 2.2. Experimental animals

Seven hundred and fifty (750) unsexed 14-day-old Japanese chicks were used for the growth parameters study. These locally produced animals weighed between 50 g and 60 g. Depending on the types of feed to be tested, five subgroups of animals comprising 150 quails each were formed. Then these quails were placed in metal cages batteries measuring 0.6 m long, 0.4 m wide and 0.35 m high due to 25 animals per cage. For the egg-laying study, a total of 300 female quails at 6 weeks old and weighing an average of 167.75 ± 1.1 g, were used. These were placed in metal cages batteries with same dimensions as those used in the study of growth parameters. Thirty (30) female quails among the 300 were selected for determining the age of first egg laid in individual cages batteries. The temperature inside the building was varied between 28°C – 30°C with relative humidity between 65 - 70%. These data were recorded at the experimental site.

### 2.3. Experimental diets

For this study, 2 types of diet were used. These were chosen on the basis of the results of a survey aimed at determining the most used types of feed in quail breeding in the district of Abidjan (Côte d'Ivoire). Using a grinder-mixer and half-moon discs, experimental diets differing from the standard diet only by the grain size were made. Thus three types of experimental diets were made from the 2 main starting diets. These are:

For type 1 diet or Laying diet (LD) which was made up of LD 5 (5 mm) = standard diet; LD 3 (3 mm) = Experimental diet of 3 mm particle size; LD 2 (2 mm) = Experimental feed with a granulometry of 2 mm.

For type 2 feed or grower diet (GD) which was composed of GD 3 (3 mm) = standard feed; GD 2 (2 mm) = Experimental feed with a granulometry of 2 mm.

Feed with 2 mm size (LD 2 and GD 2) were made by using 2 mm half-moon disc in the grinder-mixer. For the 3 mm size (LD 3 and GD 3), 3 mm half-moon disc was used in the grinder-mixer.

**Table 1** Composition of the different types of feed used for this study

| Constituent | Laying diet (LD) | Growth diet (GD) |
|---|---|---|
| Metabolizable energy | 2782 kcal/kg | 2567 kcal/kg |
| Crude protein (%) | 17 | 18 |
| Crude fat (%) | 5.2 | 4.4 |
| Crude ash (%) | 13.6 | 6.57 |
| Crude fibre (%) | 4.9 | 4.41 |
| Calcium (g/kg) | 36.5 (3.65 %) | 10.73 (1.07 %) |
| Total phosphorus (g/kg) | 5.8 | 6.31 |
| Sodium (%) | 0.17 | 0.18 |
| Vitamin A (UI/kg) | 9000 | 10000 |
| Vitamin D3 (UI/kg) | 2250 | 2000 |
| Vitamin E (UI/kg) | 16 | 20 |

At two-day-old, 1100 quails were separated into two groups according to the experimental feeds (650 chicks for the laying feed and 450 chicks for the pullet feed). From the second to the tenth day of age, the quails belonging to the LD

group were fed with the laying feed and those of the GD group were fed with the growth feed. For this period, the different feeds were presented in mealy form. All the quails of each group were reared together under the same conditions. The feed was distributed to them *ad libitum* twice a day. From the eleventh day of age, the chicks were divided into subgroups of 200 animals each according to the test feeds (LD 5, LD 3, LD 2, GD 3 and GD 2). A three-day feed transition was made from the eleventh to the thirteenth day of age for each type of test feed to facilitate their acceptance by the quails. On the fourteenth day, 150 chicks were selected from each subgroup for the rest of the experiment. This selection was based on weight and apparent health status. From the fourteenth day of age to the forty-ninth day of age for the growth parameters study as well as to egg-laying study (from six weeks of age to threeteenth week of age), selected quails in each subgroup received 100% of the corresponding feed at the rate of 35 g per quail. Water was distributed *ad libitum*.

### 2.4. Data collect

During the growth phase of the quails, distributed and remaining feed quantities were weighed each day before each feeding service in order to determine the average quantity of feed ingested (FI). The mean live weight (LW) of the quails was determined at the start of the experiment and all 7 days. These two parameters made it possible to determine the average daily gain (ADG) and the consumption index (CI) of the subjects. Upon observation of the first egg laid by each quail, the animals concerned were weighed and then the date of laying was noted. These two data were used to calculate the average age at first egg laid (AFEL) and the average live weight at first egg laid (LWFEL). For the determination of the average laying rate (LR) for a given subgroup, the total number of eggs laid daily in each batch belonging to this subgroup was determined.

During the growth and laying phases, the average mortality rate (MR) was calculated by determining the number of dead animals over a period of seven days and the number of animals alive at the start of this period. Table II presents the different formulas used to calculate these zootechnical parameters.

### 2.5. Statistical analyzes

The various statistical tests were carried out under XLSTAT 2014.5.03. Data were presented as means followed by the standard deviation of the mean in tables.

**Table 2** Formulas used for the calculation of the various parameters studied

| **Parameters** | **Formulas** |
|---|---|
| Average feed intake (FI) = | $\frac{\text{served feed quantity (g)} - \text{refusal feed quantity (g)}}{\text{number of served quails}}$ |
| Average live weight (LW) = | $\frac{\text{sum of live weights}}{\text{number of weighed quails}}$ |
| Average daily gain (ADG) = | $\frac{\text{final live weight (g)} - \text{initial live weight(g)}}{\text{Nomber of days}}$ |
| Consumption index (CI) = | $\frac{\text{quantity of ingested feed (g)}}{\text{average daily gain (g)}}$ |
| Average age at first egg laid (AFEL) = | $\frac{\text{sum of first egg laid age (d)}}{\text{number of quails}}$ |
| Average live weight at first egg laid (LWFE) = | $\frac{\text{sum of live weights at first egg laid (g)}}{\text{number of weighed quails}}$ |
| Average laying rate (LR) = | $\frac{\text{total number of weighed eggs}}{\text{number of living quails}}$ |
| Average Mortality Rate (MR) = | $\frac{\text{number of dead quails}}{\text{number of living quails at the period start}} \text{ X } 100$ |

One-factor analysis of variance (ANOVA 1) was used in the processing of data collected to highlight the existence of significant differences between the subgroups for each of the parameters studied. To rank the significantly different means, Tukey's test was used. The confidence interval was set at 95%. The null hypothesis was rejected when the value

of P was greater than 0.05. The chi 2 ($\chi^2$) test was used for comparisons of the different proportions (mortality rate and egg-laying rate).

## 3. Results

### 3.1. Effect of feed particle size on Japanese quail growth parameters according to age

*3.1.1. Food intake*

Table III presents the average weekly feed intakes (FI) obtained in each feed subgroup during their growth. Statistical analyzes revealed several significant differences between the values obtained in each subgroup. Thus, in the group of quail fed with laying diet (LD), a lower feed intake was observed in the LD 5 subgroup compared to the LD 3 and LD 2 subgroups. These differences were observed at weeks 3 ($P < 0.05$ and $P < 0.01$), 4 ($P < 0.01$ and $P < 0.001$) and 5 ($P < 0.01$ and $P < 0.001$). In this group, the LD 2 feed was the best ingested by the quails ($P < 0.01$ and $P < 0.001$) throughout their growth. The average intakes recorded in each of these subgroups from week 3 to week 4 were 118.01 ± 4.27 g, 146.68 ± 3.95 g and 186.96 ± 4.73 g for LD 5, LD 3 and LD 2 respectively. In quails fed the growth diet (GD), a higher intake of the diet ($P < 0.05$ and $P < 0.01$) was observed in the GD 2 subgroup at weeks 3 and 4. The values obtained were 76.03 ± 0.19 g and 157.06 ± 0.22 g. Apart from these two weeks, no other significant difference was observed until the end of growth ($P > 0.05$). Intergroup comparisons also revealed several other significant differences between recorded intakes. These indicated in particular that the feed intake values obtained in LD 5 were also lower ($P < 0.01$ and $P < 0.001$) than those of the GD 3 and GD 2 subgroups from week 3 to the end of the week 5. On the other hand, the intakes recorded in LD 2 were higher ($P < 0.01$ and $P < 0.001$) than those of these subgroups (GD 3 and GD 2).

*3.1.2. Average live weight*

The average live weights (LW) obtained in each sub-group of food during the growth of the quails, have been recorded in Table IV. After statistical analyses, several differences were observed from week 3 to week 7. These observations were made both within the same group and from one group to another. In the quails fed with the laying diet (LD), those of the LD 2 subgroup obtained a higher LW ($P < 0.05$) than that of the quails belonging to the LD 5 subgroup. The values obtained for these two subgroups were 76.3 ± 1.31 g for LD 2 and 63.56 ± 1.63 g for LD 5. From the fourth week of age until the seventh, the LW obtained in the quails of the subgroups LD 5 and LD 3 were lower ($P < 0.01$) than those of the quails belonging to the subgroup LD 2. Also, the LW of quails fed with the LD 3 feed were high compared to those of the quails of the LD 5 subgroup ($P < 0.05$) over this same period (weeks 4, 5, 6 and 7). On average, during their growth, the quail fed with the LD 2 diet recorded the highest LW. This was 142.37 ± 1.76 g.

**Table 3** Average weekly feed intake of growing Japanese quail according to feed particle size

| Average feed intake (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age (Week) | Laying diet (LD) | | | P1 | Growth diet (GD) | | P2 | P3 |
| | LD 5 | LD 3 | LD 2 | | GD 3 | GD 2 | | |
| Week 3 | 52.87 ± 0.32 $^{d}$ | 72.8 ± 0.19 $^{bc}$ | 96.74 ± 0.17 $^{a}$ | 0.006 | 55.8 ± 0.22 $^{cd}$ | 76.03 ± 0.19 $^{b}$ | 0.041 | 0.003 |
| Week 4 | 76.86 ± 0.15 $^{c}$ | 100.8 ± 0.23 $^{b}$ | 166.63 ± 0.21 $^{a}$ | < 0.001 | 112.52 ± 0.25 $^{b}$ | 157.06 ± 0.22 $^{a}$ | 0.007 | < 0.001 |
| Week 5 | 110.52 ± 0.24 $^{c}$ | 166.05 ± 0.34 $^{b}$ | 218.44 ± 0.27 $^{a}$ | < 0.001 | 156.95 ± 0.25 $^{b}$ | 168.12 ± 0.32 $^{b}$ | 0.041 | < 0.001 |
| Week 6 | 167.99 ± 0.34 $^{b}$ | 181.15 ± 0.36 $^{b}$ | 223.57 ± 0.42 $^{a}$ | < 0.001 | 168.93 ± 0.35 $^{b}$ | 179.21 ± 0.31 $^{b}$ | 0.518 | < 0.001 |
| Week 7 | 192.05 ± 0.39 $^{bc}$ | 212.6 ± 0,64 $^{ab}$ | 229.44 ± 0.37 $^{a}$ | 0.007 | 187.83 ± 0.54 $^{c}$ | 204.87 ± 0.36 $^{bc}$ | 0.077 | 0.005 |
| Average | 118.01 ± 4.27 $^{c}$ | 146.68 ± 3,95 $^{b}$ | 186.96 ± 4.73 $^{a}$ | < 0.001 | 136.21 ± 3.94 $^{bc}$ | 153.46 ± 5.33 $^{b}$ | 0.095 | < 0.001 |

On the same line, the means assigned at least one identical letter are not significantly different from each other; P1, P2 and P3 represent respectively the p-value of the comparisons in the LD group, in the GD and between the LD and GD groups.

**Table 4** Average live weight of growing Japanese quail according to feed grain size

| **Average live weight (g)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age (Week)** | **Laying diet (LD)** | | | **P1** | **Growth diet (GD)** | | **P2** | **P3** |
| | **LD 5** | **LD 3** | **LD 2** | | **GD 3** | **GD 2** | | |
| Week 2 | 49.84 ± 0.42 [a] | 49.47 ± 0.53 [a] | 49.77 ± 0.51 [a] | 0.999 | 49.76 ± 0.47 [a] | 49.52 ± 0.34 [a] | 0.999 | 0.999 |
| Week 3 | 63.56 ± 1.63 [b] | 71.24 ± 2.26 [ab] | 76.3 ± 1.31 [a] | 0.043 | 72.44 ± 1.81 [ab] | 78.57 ± 1.6 [a] | 0.338 | 0.039 |
| Week 4 | 80.15 ± 2.23 [d] | 92.38 ± 1.21 [c] | 108.22 ± 2.10 [b] | 0.007 | 99.46 ± 2.52 [bc] | 121.06 ± 1.91 [a] | 0.006 | < 0.001 |
| Week 5 | 102.06 ± 2.13 [e] | 124.09 ± 2.20 [d] | 149.66 ± 2.19 [b] | < 0.001 | 136.63 ± 1.97 [c] | 167.75 ± 2.42 [a] | < 0.001 | < 0.001 |
| Week 6 | 129.64 ± 1.92 [e] | 152.58 ± 2.18 [d] | 177.87 ± 2.30 [b] | < 0.001 | 167.78 ± 2.57 [c] | 196.45 ± 2.45 [a] | 0.004 | < 0.001 |
| Week 7 | 150.57 ± 2.56 [e] | 173.44 ± 2.27 [d] | 199.78 ± 2.24 [b] | < 0.001 | 185.84 ± 2.19 [c] | 215.42 ± 2.37 [a] | 0.004 | < 0.001 |
| Average | 105.2 ± 1.82 [d] | 122.75 ± 1.76 [c] | 142.37 ± 1.76 [b] | < 0.001 | 132.43 ± 1.92 [bc] | 155.85 ± 1.85 [a] | 0.007 | < 0.001 |

On the same line, the means assigned at least one identical letter are not significantly different from each other; P1, P2 and P3 represent respectively the p-value of the comparisons in the LD group, in the GD and between the LD and GD groups.

The quails that received the LD 5 feed recorded the lowest LW of this group with an average of 105.2 ± 1.82 g. With regard to the group of quails fed with growth diet (PF), no significant difference ($P > 0.05$) was observed at the third week of age of the quails. The differences in LW ($P < 0.01$ and $P < 0.001$) were observed from the fourth week of age until the end of the growth phase (week 7). Intergroup comparisons revealed significant differences ($P < 0.05$ and $P < 0.001$) between subgroups. These differences were observed from the third week of age. At this age, a higher LW was observed in the GD 2 subgroup (78.57 ± 1.6 g) compared to the LD 5 subgroup (63.56 ± 1.63 g). No significant difference ($P > 0.05$) was observed between the other subgroups. From the fourth to the seventh week of age, the quails fed with GD 2 feed recorded the LW. Similarly, the LD 5 subgroup recorded the lowest LW ($P < 0.001$). When the quails were between five and seven weeks old, the LW recorded in LD 2 were higher ($P < 0.05$).

*3.1.3. Average daily gains*

The average daily gains (ADG) recorded in the quails of the different subgroups during their growth have been recorded in Table V. The statistical analyzes. In LD, the ADG was higher ($P < 0.05$) in quails fed with LD 2 feed at the third week of age than that of the LD 5 subgroup. The values obtained were 3.79 ± 0.06 g and 1.96 ± 0.07 g respectively for LD 2 and LD 5. However, no significant difference ($P > 0.05$) was revealed between the ADG recorded in LD 2 and that of the LD 3 subgroup. Observations made at week 3 were similar to those made at week 5. At the fourth week of age on the other hand, the ADG obtained in LD 2 (4.56 ± 0.07 g) was higher than those of the subgroups LD 5 and LD 3 (respectively 2.37 ± 0.03 g and 3.02 ± 0.02 g). Overall the ADG was highest in quails of subgroup LD 2 while the lowest value was obtained in LD 5. With regard to quails fed pullet feed, no significant difference ($P > 0.05$) was observed between the ADGs of the subgroups regardless of the week considered. However, intergroup comparisons revealed that the ADGs recorded in GD 2 were higher ($P < 0.05$) than those in the LD 5 subgroup.

*3.1.4. Consumption index*

The consumption indices (CI) calculated during the growth of the quails have been recorded in Table VI according to the grain size of the feed. Statistical analyzes indicated that quail fed the LD 2 diet had a higher CI ($P < 0.05$) than those in the LD 5 and LD 3 subgroups. This observation was made at the sixth week of age. The values obtained in each subgroup were 7.93 ± 0.16 for LD 2, 6.36 ± 0.19 for LD 3 and 6.09 ± 0.11 for LD 5.

**Table 5** Average daily gain of growing Japanese quail according to feed particle size

| **Average daily gain (g/d)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age (Week)** | **Laying diet (LD)** | | | **P1** | **Growth diet (GD)** | | **P2** | **P3** |
| | **LD 5** | **LD 3** | **LD 2** | | **GD 3** | **GD 2** | | |
| Week 3 | 1.96 ± 0.07 [b] | 3.11 ± 0.13 [ab] | 3.79 ± 0.06 [a] | 0.032 | 3.24 ± 0.11 [ab] | 4.15 ± 0.17 [a] | 0.512 | 0.264 |
| Week 4 | 2.37 ± 0.03 [d] | 3.02 ± 0.02 [cd] | 4.56 ± 0.07 [b] | 0.013 | 3.86 ± 0.10 [bc] | 6.07 ± 0.14 [a] | 0.012 | 0.007 |
| Week 5 | 3.13 ± 0.09 [c] | 4.53 ± 0.03 [bc] | 5.92 ± 0.06 [ab] | 0.034 | 5.31 ± 0.04 [ab] | 6.67 ± 0.18 [a] | 0.051 | 0.007 |
| Week 6 | 3.94 ± 0.10 [a] | 4.07 ± 0.04 [a] | 4.03 ± 0.01 [a] | 0.906 | 4.45 ± 0.14 [a] | 4.1 ± 0.09 [a] | 0.972 | 0.347 |
| Week 7 | 2.99 ± 0.07 [a] | 2.98 ± 0.04 [a] | 3.13 ± 0.12 [a] | 0.615 | 2.58 ± 0.07 [a] | 2.71 ± 0.07 [a] | 0.881 | 0.287 |
| Average | 2.88 ± 0.52 [b] | 3.54 ± 0.74 [ab] | 4.29 ± 1.22 [a] | 0.046 | 3.89 ± 0.89 [ab] | 4.74 ± 1.25 [a] | 0.211 | 0.026 |

On the same line, the means assigned at least one identical letter are not significantly different from each other; P1, P2 and P3 represent respectively the p-value of the comparisons in the LD group, in the GD and between the LD and GD groups.

**Table 6** Consumption index of growing Japanese quail according to the feed particle size of the feed

| **Consumption index** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age (Week)** | **Laying diet (LD)** | | | **P1** | **Growth diet (GD)** | | **P2** | **P3** |
| | **LD 5** | **LD 3** | **LD 2** | | **GD 3** | **GD 2** | | |
| Week 3 | 3.85 ± 0.09 [a] | 3.34 ± 0.13 [a] | 3.65 ± 0.11 [a] | 0.705 | 2.42 ± 0.17 [a] | 2.00 ± 0.06 [a] | 0.901 | 0.698 |
| Week 4 | 4.63 ± 0.13 [ab] | 4.77 ± 0.02 [ab] | 5.22 ± 0.16 [a] | 0.438 | 4.16 ± 0.08 [ab] | 3.7 ± 0.07 [b] | 0.475 | 0.046 |
| Week 5 | 5.03 ± 0.07 [ab] | 5.24 ± 0.21 [a] | 5.27 ± 0.24 [a] | > 0.999 | 4.22 ± 0.11 [ab] | 3.6 ± 0.05 [b] | 0.671 | 0.043 |
| Week 6 | 6.09 ± 0.11 [b] | 6.36 ± 0.19 [b] | 7.93 ± 0.16 [a] | 0.041 | 5.42 ± 0.06 [b] | 6.24 ± 0.18 [b] | 0.065 | 0.02 |
| Week 7 | 8.7 ± 0.08 [a] | 10.19 ± 0.16 [a] | 10.47 ± 0.09 [a] | 0.691 | 10.4 ± 0.18 [a] | 10.8 ± 0.12 [a] | > 0.999 | 0.689 |
| Average | 5.66 ± 1.68 [a] | 5.98 ± 1.55 [a] | 6.51 ± 1.59 [a] | 0.496 | 5.33 ± 1.53 [a] | 5.27 ± 1.6 [a] | > 0.999 | 0.071 |

On the same line, the means assigned at least one identical letter are not significantly different from each other; P1, P2 and P3 represent respectively the p-value of the comparisons in the LD group, in the GD and between the LD and GD groups.

Apart from this difference, no other was revealed in this group. In quails fed growth diet (GD), statistical analyzes showed no significant difference ($P > 0.05$) between the CIs of the main subgroups. In contrast, intergroup comparisons revealed significant differences at weeks 4, 5, and 6 ($P < 0.05$) between CIs. Thus, it was revealed that the IC recorded in LD 2 was higher ($P < 0.05$) than that of the GD 2 subgroup over this period. At the fourth week of age, the IC recorded in GD 3 was also higher than that of the GD 2 subgroup. The GD 3 subgroup recorded a lower CI ($P < 0.05$) than that of the LD 2 subgroup at 6 weeks of age.

*3.1.5. Mortality rate*

Mortality rates (MR) calculated during the growth phase are reported in Table VII. Within the GD group, no significant difference ($P > 0.05$) was observed between the GD 3 and GD 2 subgroups. On the other hand, a difference ($P < 0.05$) was observed in the LD group between the LD 5 and LD 2 subgroups at weeks 3 (8.67 ± 1.05 % and 2.67 ± 0.55 %) and 4 (5.84 ± 1.26 % and 0.68 ± 0.41 %). Over these same periods, a significant difference ($P < 0.05$) was also observed between the MR of the LD 5 and GD 2 (2 ± 0.52 % and 0.68 ± 0.41 %) subgroups.

### 3.2. Effect of feed particle size on Japanese quail egg-laying parameters as a function of age

*3.2.1. Age at first egg laid*

The average age at first egg laid (AFEL) of the quails showed differences depending on the grain size of the feed (Table VIII). In the LD subgroup, quails fed LD 2 feed (49.33 ± 0.58 d) started laying earlier than those fed LD 3 and LD 5 feed

(P < 0.01 and P < 0.001 respectively). Also, in the PF subgroup, the quails having received the GD 2 feed (46.33 ± 1.26 d) had an earlier start to lay (P < 0.01) than those who received GD 3 feed (55.33 ± 0.96 d). Intergroup comparisons showed the existence of a difference (P < 0.05) between the APOPs recorded in the LD 2 and GD 3 subgroups. The AFEL of the GD 3 subgroup was higher. On the other side, the GD 2 subgroup recorded a lower AFEL than those of the LD 3 subgroups (59.67 ± 0.76 d) and LD 5 (64.33 ± 1.15 d). No significant difference (P > 0.05) was however, observed between the AFELs of the LD 2 and GD 2 subgroups.

*3.2.2. Average live weight at first egg laid*

The mean live weights at start of lay (LWFE) determined during this study showed significant differences in LD (P < 0.001) as well as in GD (P < 0.01). In the LD group, the quails fed with LD 2 feed (202.16 ± 0.18 g) recorded a higher LWFE than those of quails fed with LD 5 (174.26 ± 0.33 g) and LD 3 (189.99 ± 0.53 g). Similarly, the LWFE obtained in LD 3 was higher than that of the LD 5 subgroup. In the group of quails fed growth diet (GD), a lower LWFE was recorded in GD 3 (194.24 ± 0.57 g). Intergroup analyzes revealed that the LWFE of quails of the GD 2 subgroup (216.17 ± 0.45 g) was higher quails of subgroups LD 5, LD 3 and LD 2. Also, quails of subgroup GD 3 had a high LWFE compared to that of the LD 5 subgroup. Table IX presents the results obtained for this parameter.

**Table 7** Mortality rate during the growth phase of Japanese quail according to feed particle size

| **Mortality rate (%)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age (Week)** | **Laying diet (LD)** | | | **P1** | **Growth diet (GD)** | | **P2** | **P3** |
| | **LD 5** | **LD 3** | **LD 2** | | **GD 3** | **GD 2** | | |
| Week 3 | 8.67 ± 1.05 [a] (13/150) | 5.33 ± 1.17 [ab] (8/150) | 2.67 ± 0.55 [b] (4/150) | 0.043 | 4.67 ± 0.84 [ab] (7/150) | 2 ± 0.52 [b] (3/150) | 0.052 | 0.067 |
| Week 4 | 5.84 ± 1.26 [a] (8/137) | 3.52 ± 0.82 [ab] (5/142) | 0.68 ± 0.41 [b] (1/146) | 0.042 | 2.09 ± 0.55 [ab] (3/143) | 0.68 ± 0.41 [b] (1/147) | 0.716 | 0.043 |
| Week 5 | 1.55 ± 0.52 [a] (2/129) | 1.46 ± 0.82 [a] (2/137) | 0.69 ± 0.41 [a] (1/145) | 0.905 | 1.43 ± 0.52 [a] (2/140) | 1.37 ± 0.52 [a] (2/146) | 0.911 | 0.899 |
| Week 6 | 0.00 [a] (0/129) | 0.00 [a] (0/137) | 0.00 [a] (0/145) | > 0.999 | 0.00 [a] (0/140) | 0.00 [a] (0/146) | > 0.999 | > 0.999 |
| Week 7 | 0.00 [a] (0/129) | 0.00 [a] (0/137) | 0.00 [a] (0/145) | > 0.999 | 0.00 [a] (0/140) | 0.00 [a] (0/146) | > 0.999 | > 0.999 |
| Average | 15.33 ± 3.36 [a] (23/150) | 10 ± 2.49 [a] (15/150) | 4 ± 1.02 [a] (6/150) | 0.468 | 8 ± 2.08 [a] (12/150) | 0.84 ± 0.84 [a] (5/146) | 0.671 | 0.461 |

**Table 8** Average age at first egg laid of Japanese quail according to feed particle size

| **Parameter** | **Laying diet (LD)** | | | **P1** | **Growth diet (GD)** | | **P2** | **P3** |
|---|---|---|---|---|---|---|---|---|
| | **GD 5** | **GD 3** | **GD 2** | | **GD 3** | **GD 2** | | |
| Age at First Egg Laid (j) | 64.33 ± 1.15 [d] | 59.67 ± 0.76 [c] | 49.33 ± 0.58 [a] | < 0.001 | 55.33 ± 0.96 [b] | 46.33 ± 1.26 [a] | < 0.01 | < 0.001 |

**Table 9** Average live weight at onset of Japanese quail according to the grain size of the feed

| | **Laying diet (LD)** | | | **P1** | **Growth diet (GD)** | | **P2** | **P3** |
|---|---|---|---|---|---|---|---|---|
| | **LD 5** | **LD 3** | **LD 2** | | **GD 3** | **GD 2** | | |
| LWFE (g) | 174.26 ± 0.33 [d] | 189.99 ± 0.53 [c] | 202.16 ± 0.18 [b] | < 0.001 | 194.24 ± 0.57 [bc] | 216.17 ± 0.45 [a] | 0.006 | < 0.001 |

On the same line, the means assigned at least one identical letter are not significantly different from each other, P1, P2 and P3 represent respectively the p-value of the comparisons in the LD group, in the GD and between the LD and GD groups.

*3.2.3. Egg laying rate*

The egg laying rates (LR) calculated at the start and end of the spawning phase have been recorded in Table X. Following statistical analyses, differences ($P < 0.05$ and $P < 0.001$) were revealed between the subgroups. At the start of lay, quail fed LD 5 and GD 3 had a higher production ($P < 0.05$) than quail fed LD 2. These subgroups recorded rates of 8.47 ± 1.43%, 8.33 ± 2.06 and 3.33 ± 1.45% respectively. At the end of the laying phase, the statistical analyzes showed that the quail fed with LD 5 feed (56.67 ± 1.31%) recorded a laying rate very low ($P < 0.001$) compared to those fed with other feeds (LD 3, LD 2, GD 3 and GD 2). Also, quails fed GD 3 (81.67 ± 0.95%) and GD 2 (78.33 ± 0.95%) had respectively a lower production ($P < 0.05$) than those fed with LD 2 (86.67 ± 2.95%) and LD 3 (88.33 ± 1.05%) feeds.

*3.2.4. Mortality rate*

The mortality rate did not vary significantly between subgroups ($P > 0.05$). The averages obtained in each subgroup have respectively been recorded in Table XI.

## 4. Discussion

The results showed an increase in feed intake with the reduction in particle size. In each group, the LD 2 and GD 2 feeds with the smallest grain size were the best ingested by the quails throughout this study. This would prove that the grain size of these feeds was best suited to the size of the beak of the quails. According to [3], poultry consume particles large enough to be effectively grasped by the beak. For [4] this eating behavior corresponds to energy optimization. The relative size of the particles in relation to the birds' beaks would therefore be a selection criterion in their feed intake. These statements would clearly justify the impact of grain size on the feed intake of domestic quail. The ingestion recorded in the GD 2 and LD 2 subgroups corroborate those obtained by [5] during the finishing phase of his quails. However, these values were higher than those of other authors ([1]; [6]; [7]; [8]). These authors obtained values of 14.4 g/d respectively; 12.17 g/d; 18.1 g/d and 22.44 g/d. These differences in intake could be explained by the bromatological composition (protein content, energy content, calcium content, etc.) of these rations.

**Table 10** Egg laying rate of Japanese quail according to the grain size of the feed

| **Egg laying rate (%)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Laying phase** | **Laying diet (LD)** | | | **P1** | **Growth diet (GD)** | | **P2** | **P3** |
| | **LD 5** | **LD 3** | **LD 2** | | **GD 3** | **GD 2** | | |
| Start | 8.47 ± 1.43 $^{a}$ | 3.33 ± 1.45 $^{b}$ | 5 ± 1.27 $^{ab}$ | 0.022 | 8.33 ± 2.06 $^{a}$ | 6.67 ± 2.07 $^{ab}$ | 0.067 | 0.023 |
| End | 56.67 ± 1.31 $^{c}$ | 88.33 ± 1.05 $^{a}$ | 86.67 ± 2.95 $^{a}$ | < 0.001 | 81.67 ± 0.95 $^{b}$ | 78.33 ± 0.95 $^{b}$ | 0.063 | < 0.001 |
| Average | 32.57 ± 1.37 $^{b}$ | 45.83 ± 1.25 $^{a}$ | 45.84 ± 2.11 $^{a}$ | 0.004 | 45 ± 1.51 $^{a}$ | 42.5 ± 1.51 $^{a}$ | 0.06 | 0.004 |

**Table 11** Mortality rate during the laying phase of Japanese quail according to the grain size of the feed

| **Taux de Mortalité (%)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Laying phase** | **Laying diet (LD)** | | | **P1** | **Growth diet (GD)** | | **P2** | **P3** |
| | **LD 5** | **LD 3** | **LD 2** | | **GD 3** | **GD 2** | | |
| Beginning | 0.00 $^{a}$ (0/60) | 0.00 $^{a}$ (0/60) | 0.00 $^{a}$ (0/60) | > 0.999 | 0.00 $^{a}$ (0/60) | 0.00 $^{a}$ (0/60) | > 0.999 | > 0.999 |
| End | 1.67 ± 0.58 $^{a}$ (1/60) | 1.67 ± 0.58 $^{a}$ (1/60) | 5.00 ± 1.73 $^{a}$ (3/60) | 0.083 | 1.67 ± 0.58 $^{a}$ (1/60) | 3.33 ± 1.15 $^{a}$ (2/60) | 0.106 | 0.083 |
| Average | 0.84 ± 0.29 $^{a}$ | 0.84 ± 0.29 $^{a}$ | 2.50 ± 0.82 $^{a}$ | 0.129 | 0.84 ± 0.29 $^{a}$ | 1.67 ± 0.14 $^{a}$ | 0.251 | 0.129 |

On the same line, the means assigned at least one identical letter are not significantly different from each other.

P1, P2 and P3 represent respectively the p-value of the comparisons in the LD group, in the GD and between the LD and GD groups.

The quantities of metabolizable energy of the feeds used in the present study were 2782 kcal/kg DM and 2567 kcal/kg DM respectively for the layer feed and the pullet feed. These should have been between 2800 Kcal/kg DM and 3000 Kcal/kg DM in the starting phase and 2600 Kcal/kg DM in the finishing phase according to [9]. This energy deficit could therefore explain the high feed ingestion observed in the quails in this study. Since the metabolizable energy content was stable during this work, an influence of the protein content on the FI could be envisaged ([10]). According to [11] to ensure better quail growth, starter feed should contain between 25% and 28% protein, 22% for fattening and 24% for laying. However, the feeds used during this work contained 17% and 18% crude protein respectively for laying diet (LD) and growth diet (GD). This deficiency could be the basis of the hyperphagia observed in this study. In their work, [12]; [13] as well as [14] observed an increase in feed consumption with the reduction in protein content in rats and chicks, below the recommended requirements.

At the same particle size, the best average live weights were obtained with growth diet (GD). This finding could be explained by the main property of this type of feed, which is to induce good growth in laying hens. This property would have allowed them to induce in quails having ingested them, a better weight gain. In the laying diet (LD) group the best live weight was obtained in the LD 2 subgroup. The LD 2 and GD 2 feeds therefore induced better weight gain in each of their respective groups. These feeds having the same grain size, it would be plausible to assert that the weight growth of domestic quail is influenced by the grain size of the food they consume. Indeed, these foods were the best ingested in the study. The best LW obtained in LD 2 and GD 2 would therefore be the result of the high feed ingestion observed in quails of these two subgroups. [15] also indicated during their work on chicks, that the growth of subjects was closely related to the particle size of the feed. Other authors such as [16] and [17] have also reported a positive relationship between chick weight growth and the feed particle size. At 6 weeks of age, the best LW obtained in the present work in GD 2 (196.45 g) was similar to that of several authors at the same age. Among these [18] then [19] who obtained respectively mean values of 200.5 g and 193.33 g of LW in their work. This LW was however higher than those of [5] (142.5 g), [20] (177.5 g), [21] (133.49 g) and [22] (86.55 g). At the same age, [23] obtained LWs ranging from 168.2 to 173.8 g in three different varieties of *Coturnix japonica*. Besides all these differences, other authors such as [24] and [25] obtained LW of 157.3 g and 162.4 g respectively. In younger quails (4–5 weeks old), [26] recorded higher LWs (242.1 and 284.9 g, respectively) than those obtained at the same age in the present study. [27] obtained even much better values in 4 different strains of quail (272.2 g to 302.8 g). The results obtained at 6 weeks of age, in quails of subgroups GD 2 (196.45 g) and LD 2 (177.87 g) are higher than the values defined by [6] in their range. The latter have in fact placed the live weight performance of the Japanese quail between 146 g and 175 g at this age, either to their composition. The grain size of the feeds used in each experiment could also have influenced this parameter. However, it is difficult to compare the results of these authors with those obtained in this study due to a more or less strong influence of certain factors such as genetics, breeding conditions and breeding management. The interactions between these factors can lead to opposing observations. Because according to [28], a difference between the quail strains used in each study could justify obtaining different results. The average live weight at the firs egg laid (LWFE) quails was different from one subgroup to another within the same group. LD 2 and GD 2 feeds with smaller particle sizes recorded the highest LWFE. These same subgroups were the ones with the best LW during growth. From this observation, it would be normal to affirm that the LWFE of quails depends on the weight gain recorded during the growth phase. In this study, it was found that reducing the feed particle size influenced the LW of quails during their growth. If therefore the LWFE is a function of the LW recorded during growth then the particle size of the feed would also have an influence on the LWFE. In the present study, the LWFEs were superior to those obtained by [5] and [29]. These authors indeed obtained live weight values around 158.6 g in their control group. [30] obtained in caged quails a live weight of 168.8 g. All these results however differ from the norms listed by [31]. According to the latter, domestic quail begin their laying at an average live weight of 120 g. These differences would be due to the composition of the different feeds, the environment, the strain of quail used, etc.

Quails fed GD 2 and LD 2 diets had the best average daily gains in this study. This could reflect not only a good consumption of these foods by the quails but also and above all a good assimilation of the nutrients contained in them. For the same group (LD or GD), the average gains were different. These increased from one subgroup to another. This parameter would have been influenced by the ingestion of the feeds used. Such a finding would provide crucial information as to the impact that the grain size of the feed could have on the gain. According to [32], the average daily gain (ADG) of poultry increases with their feed consumption. However, in this work, this ingestion would itself have been influenced by the grain size of the feed. The good ingestion of GD 2 and LD 2 feeds induced by their particle size would therefore be the basis. This would make it possible to affirm that the ADG of quails would be influenced by the particle size of the feed distributed to them. This statement could be confirmed by the growth retardation observed in LD 5. This growth retardation would be linked to the grain size because the ingested portion of this feed would provide a very small amount of metabolizable energy to the quails. A large part of the feed having a grain size unsuited to their age, the quails of this subgroup were forced to consume the floury part of the feed. However, in the LD group, the grain size was defined based on maize, which represented a large energy share of the feed. Its absence in the ingested portion

would have negatively impacted the amount of metabolizable energy contained in it compared to the normal intake of the whole feed. The best ADG values (AC 2: 6.67 g/d and AP 2: 5.92 g/d) obtained in the present study at week 5 were much higher than those obtained by other authors. This is the case of [2], [18], [21] as well as [25] who respectively obtained 3.91 g/d; 3.41 g/d to 3.65 g/d; 3.69 g/d and 3.64 g/d. ADGs close to those of this study were also obtained by [33], [35] as well as [42]. These authors obtained respectively between 6 g/d and 7 g/d; between 5.76 g/d and 6.44 g/d as well as and 5.8 g/d. At seven weeks of age, [36] obtained in their quails ADGs similar to those obtained in this work in quails of the same age. All the differences between these values and those of the present study could be due to the more or less strong influence of genetic factors, breeding and a possible interaction between these two factors. The bromatological composition of the feeds used in each study could be the basis of these differences. Indeed, some authors have highlighted the influence of the crude protein content in the feed on the ADG of quails [37].

Generally, the feed consumption index was not different from one subgroup to another within the same group. Although the LD 2 and GD 2 feeds were the best ingested of each group and those which induced better weight gain in the quails, this was not sufficient to improve the general CI. This observation would indicate that the Japanese quail uses the feed ingested in proportion to its weight gain. Therefore, the feed particle size would have no influence on this parameter. This conclusion agrees with those made by [17] then [38]. These authors did not in fact obtain any difference on the IC of the chicks according to the particle size of the feed consumed. In this study, the CI values were significantly higher than those obtained in several studies ([24]; [37]; [35] and [39]). These authors further obtained CI values ranging from 3.4 to 3.6; 3.52 to 3.69; 4.5 to 5.68 and 3.54 to 4.29 respectively. [25] recorded a feed consumption of 553 g for a production of 162.4 g live weight, i.e. an CI of 3.59. With a live weight of 177.5 g and a feed conversion of 3.38 [20] also obtained lower results than in this work. These high CIs obtained in the present study would be a clear indicator that the feed used does not meet the specific needs of domestic quail. The yield obtained is therefore low compared to what it should have been. However, CIs as high as those of this study have been obtained by certain authors such as [5], [21] and [40]. These authors obtained CI values ranging from 6.07 to 8.15, respectively; 5.2 to 6.49 and 5.77 to 6.01. Others have obtained even higher CI values. This is the case of [8] who reported a feed efficiency of 9.6 when reared. All of these changes could be due to the protein content of the feed as suggested by [37]. Other factors such as the rearing conditions, its duration, its period, the strain of the quails used, etc. could also be justified.

The achievement of sexual maturity, defined by the average age of quails at the first egg laid, was different from one subgroup to another. It was early in the quails of the LD 2 and GD 2 subgroups. This result may be due to an influence of the grain size of the feed on egg laying in the Japanese quails. This hypothesis would be justified by the fact that these feeds have the same composition as the other feeds (LD on the one hand and GD on the other). These also induced the best live weights during the growth of the quails and therefore a better weight at the start of lay. This could explain the fact that these feeds induced this early egg-laying in the quails that consumed them. Indeed, genetic factors and body weight can influence the sexual maturity of Japanese quail [41]. Based on this statement, quail with better body weight during growth will reach sexual maturity faster than others. Those with a low body weight will have a later sexual maturity. This analysis is consistent with the results obtained in the present study. The assertion of these authors is also justified by the results obtained in the LD 5 subgroup. In this subgroup, the quails recorded a lower body weight during their growth and a later age of first egg laid compared to the others. Based on this fact, it would be fair to say that the grain size of the feed was the cause of the low weight observed in them. Indeed, this factor would have caused a decrease in feed intake by the quails of this subgroup (LD 5). Consequently, it would be the basis of the delay in the first egg laid observed in the latter. In this study, the grain size of the feed would have strongly influenced the feed intake of the quails. Thus, it would have influenced the weight gain of the quails. Based on this analysis and the results of [41], it would be normal to say that the grain size of the feed has an influence on the age at first egg laid in Japanese quail. The average ages of sexual maturity obtained in these studies were higher than those of [42]. These authors obtained an age of 42 days in their work. [29] obtained in their control batch a sexual maturity of 50 days. That is superior to the best results of the present study (those of the LD 2 and GD 2 subgroups). Even longer durations have been obtained by [30] then [43]. These have indeed obtained a duration reaching 62 and 70 days. All these differences could result from the environmental conditions that prevailed during their work. Among other things, the photoperiod which, according to [35], can act on the development of the reproductive organs of the Japanese quail.

The laying rate varied according to the type of feed. This observation corroborates that of [44]. According to these authors, the diet of poultry has the possibility of influencing their curve. This influence could extend not only to the body weight but also to the body composition of the poultry at the time of their entry into lay. Thus, it can modify the subsequent characteristics of the production of these. At identical grain size (GD 3 and LD 3 then GD 2 and LD 2), spawning rates recorded in GD were lower than those in the LD group. This could be explained by the fact that this type of feed (GD) is not suitable for the laying stage in poultry. It is indeed used to induce the growth of pullets in farms intended for egg production. Also, the richness of the egg-laying feed (LD) in calcium compared to pullet feed (GD) could justify this finding. The mobilization of calcium is of paramount importance in the process of eggshell

formation. The best egg-laying rates obtained in the present study were 81.67%; 86.67% and 88.33% respectively for GD 3, LD 2 and LD 3. These results corroborate those of [45]; [46]; [47]; [48] as well as [49]. These authors indeed obtained laying rates between 82% and 89.36% during a laying period of eight weeks (from the sixth to the fourteenth week). Lower yields compared to those obtained in this study were reported by [24]. These authors respectively obtained in quails a production of 44.6%Maximizing Medical Cannabis Growth and Quality: An Evaluation of the Effects of Ecological Water Regeneration in Greenhouse Cultivation

(over a period ranging from eight to ten weeks of age) and 32.3% (in the first month of lay).

In this study, the greatest mortality rates (MR) were recorded at 3 weeks of age. They were obtained in the LD 5, GD 3 and LD 3 subgroups. The lowest MR were obtained in the GD 2 and LD 2 subgroups. Several factors could explain such results. According to [50], the variation of the MR can be explained by the difference in incubator used, handling, environment, subject density, rearing system and diseases. In this study, the quail used came from the same incubator. They were installed in the same environmental conditions and underwent the same treatments in the same breeding system. In addition, the quails showed no signs of illness. This therefore means that these parameters could not have been the cause of these observed mortalities. At three weeks of age, feed intake was influenced by feed particle size. Thus, the stress induced by the diet could explain these mortalities. This would result in the inability of the quail to ingest these feeds at this age, given their grain size. In this work, it was noticed that when the FI increases, a reduction in quail mortality is observed. The higher MR in the LD 5, GD 3 and LD 3 subgroups would therefore be due to their low ingestion by the quails. Thus, the grain size of these foods would be the real reason for the mortalities in these subgroups. The best MR obtained in this study was 0.85%. This value is not significantly different from the 2.22% obtained by [24] as well as [51]. Other authors have recorded higher MRs. These include [1]; [25] and [52]. These authors obtained between 6% and 9% for the first, 7% and 4.36% respectively for the second and third.

## 5. Conclusion

The objective of this part was to determine the effect of the grain size of the feed on some zootechnical parameters (growth and egg-laying) of the Japanese quail in breeding. It appears at the end of this study, that the grain size of the feed influences the growth parameters of the Japanese quail. In each feed group, the best values for LW, ADG, FI and MR were obtained in the LD 2 and GD 2 subgroups. With regard to the final consumption index, it was better in LD 3 and GD 3 respectively for the LD and GD groups. Thus, the growth parameters taken as a whole were better externalized by the quails fed LD 2 and GD 2 feeds. These would therefore be the best suited for this rearing phase in domestic quail. With regard to the laying parameters, it should be remembered that the grain size of the feed impacts Japanese quail age of first egg laid. Therefore it influences the duration of the laying period of these. The overall egg-laying rate of the quails is therefore affected. The average live weight at first egg laid of Japanese quail was also affected by feed particle size. For these three parameters (age at start of lay, average live weight at start of lay and rate of lay), the best results were obtained in quails fed GD 2 and LD 2 feed. Based on all this information, feeding domestic quail with a feed having a grain size of 2 mm can be recommended to quail growers.

## Compliance with ethical standards

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*Disclosure of conflict of interest*

The authors state that there is no conflict of interest and that the rules of ethics and professional conduct were applied in this study.

*Statement of ethical approval*

This study used animals according to the standards established by the guide of good practices in animal husbandry of the OIE (2009).

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