The potency of *Lactobacillus acidophilus* and *L. lactis* probiotics and *Guazuma ulmifolia* Lam. extract as feed additives with different application times to improve nutrient intake and feed efficiency in *Coturnix coturnix japonica* females

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**KEY WORDS:** Coturnix coturnix japonica, *Guazuma ulmifolia* Lam., health, probiotic

**ABSTRACT.** Research on the combination of *Lactobacillus acidophilus* and *L. lactis* probiotics and *Guazuma ulmifolia* Lam. to find an alternative to antibiotic growth promoters has never been conducted, thus the present study aimed to evaluate their effect on nutrient intake and feed efficiency in females of *Coturnix coturnix japonica*. The experiment was conducted for 35 days, including the adaptation period. Supplementation was administered for 7 and 14 days, and the parameters were analysed accordingly. The experiment was set up as a completely randomized factorial design (2 × 3), where the first factor was the period of administration (a0 – one week and a1 – two weeks), and the second factor was feed additive (b0 – without feed additive, b1 – probiotics, b2 – *G. ulmifolia* Lam. extract). The results showed that there was a significant difference (*P* < 0.05) between the treatments in terms of nutrient intake (dry matter, organic matter, ash, crude protein, ether extract, crude fibre, nitrogen free extract, metabolisable energy) and feed efficiency (*P* < 0.05). Based on the results of the study, it can be concluded that the application of *L. acidophilus* and *L. lactis* probiotics and *G. ulmifolia* Lam. extract has the potential to improve nutrient intake and feed efficiency in females of *C. coturnix japonica*, thereby improving safety and health-promoting properties of livestock products for humans and reducing animal production costs.

**Introduction**

Since 2006, the European Union and several other countries have banned the use of antibiotic growth promoters (AGP) in livestock (Wu et al., 2021). This is the initial step in addressing the problem of antibiotic resistance due to their long-term use. To balance and maintain a healthy digestive tract condition and increase animal growth without the use of antibiotics, an effective, safe and more economical alternatives to antibiotics are needed (Cogliani et al., 2011; Wu et al., 2021). Probiotics are viable and non-pathogenic organisms that improve the host’s health by balancing the diversity
of intestinal microbes, improving the intestinal barrier function, quality of external and internal eggs, and these microbials particularly include Lactobacillus and Bifidobacterium (van Belkum et al., 2007; Figueroa et al., 2011; Lokapirnasari et al., 2019; Jayani et al., 2020). Probiotics as feed additives have been reported to improve nutrient digestibility, growth performance, caecal microflora balance, plasma immunoglobulins, and chicken immunity (Tang et al., 2017; Alaqil et al., 2020). Probiotic species include Lactobacillus bulgaricus, L. plantarum, Pediococcus pentosaceus, Bifidobacterium bifidum, L. acidophilus, L. casei or L. lactis (Khaksfedi and Rahimi, 2005; Yulianto et al., 2021; Lokapirnasari et al., 2022; Agustono et al., 2022). L. acidophilus is a non-spore species of lactic acid bacteria and is used as a probiotic to improve the qualitative performance of broilers (Salarmoini and Fooladi, 2011).

In addition to probiotics, phytobiotics are other feed additives that can be used to improve growth performance of livestock. Guazuma ulmifolia Lam. is among the phytobiotics that show high potential. Scientific classification of G. ulmifolia Lam. derived from the National Inventory of the Natural Heritage Database is as follows: Kingdom: Plantae, Class: Equisetopsida, Order: Malvales, Family: Malvaceae, Genus: Guazuma Mill., Species: Guazuma ulmifolia Lamarck. (INPN-FR, 2019). The leaves and fruits of G. ulmifolia can be used as a source of proteins in animal feeds (Pereira et al., 2019). The main secondary metabolites of G. ulmifolia Lam. include bioactive compounds, especially proanthocyanidins, flavonoids and phenolic acids, and among the identified antioxidant compounds are chlorogenic acid, caffeic acid, rutin, quercitrin, quercetin and luteolin. Previous phytochemical studies on secondary metabolites such as proanthocyanidins showed their antimicrobial and antioxidant effects; other activities include antidiarrheal, antiprotozoal and cardioprotective properties (Morais et al., 2017; dos Santos et al., 2018; Assis et al., 2019; Pereira et al., 2019). Phytochemical analyses of G. ulmifolia Lam. leaf tissue identified phenolic acids (cafeic acid and chlorogenic acid) and flavonoids (quercetin 3-O-rhamnosyl-glucoside, luteolin and quercetin 3-O-rhamnosyl) as the main compounds. Moreover, chlorogenic acid (25.3 mg/g extract), quercetin (24.6 mg/g extract) (Junior et al., 2016; Morais et al., 2017), octacosanol, taraxerol, friedelin-3-â-oac, â-sitosterol, Friedelinol-3-acetate (Kumar and Gurunani, 2019), procyanidin dimer B and glycosylated derivatives of catechins, kaempferol and luteolin were also detected (de Souza et al., 2018; dos Santos et al., 2018). Tannin content in G. ulmifolia Lam. was reported at the level of 1.2 g/kg (Manriquez-Mendoza et al., 2011), and ent-catechin, epicatechin, ent-gallocatechin, epigallocatechin, epiafzelechin-(4β→8)-epicatechin, epicatechin-(4β→8)-catechin (procyanidin B1), epicatechin-(4β→8)-epicatechin (procyanidin B2), epicatechin-(4β→8)-epigallocatechin, and 4′-O-methyl-epiafzelechin have also been identified (Lopes et al., 2009).

Feed efficiency is influenced by its intake and production rate. Low feed intake but high production equals to high feed efficiency, and thus reduced livestock production costs. Nutrients in the feed are used for maintenance and animal production. Feed efficiency can be calculated by comparing the egg production with the amount of feed consumed at a certain time. Research to find an alternative to AGP using a combination of probiotics and G. ulmifolia Lam. has never been carried out, thus this study aimed to evaluate their effect as feed additives on nutrient intake (dry matter, organic matter, ash, crude protein, ether extract, crude fibre, metabolisable energy) and feed efficiency in Coturnix coturnix japonica.

Material and methods

Ethanol extract of G. ulmifolia Lam. leaves

Fresh leaves of G. ulmifolia Lam. were collected in Surabaya city. The leaves were dried in an oven at 65 °C and ground using a hammer mill. Extracts were obtained by adding G. ulmifolia Lam. leaf powder (1000 g) to 70% alcohol (7000 ml), and 24-h reaction was performed twice to completely remove the compounds. The obtained extracts were filtered and evaporated at 40 °C (modified from Adedapo et al., 2009; Assis et al., 2019).

Study period and location

The study was conducted for 35 days, including the adaptation period. Days 1–14 days were the adaptation period in the cage, days 15–21 were the adaptation period of feeding the additives, and days 22–35 were the feed additive treatment. The treatment was administered for 7 and 14 days. The data collection was performed after 7 and 14 days of the trial. C. coturnix japonica were reared in colony cages on the farm in Kediri Regency. Proximate analysis of the feed and variables was conducted at the Laboratory of Animal Nutrition, Division of Animal Husbandry, Department of Veterinary Medicine Science, Faculty of Veterinary Medicine, Universitas Airlangga.
Experimental design

The study material consisted of *L. acidophilus* and *L. lactis* probiotics from the W.P. Lokapirnasari collection (from the Division of Animal Husbandry, Universitas Airlangga, Surabaya, Indonesia) and *Guazuma ulmifolia* Lam. extract in drinking water. The commercial feed contained ash (11.4923%), dry matter (90.8835%), and crude fibre (4.8105%), crude lipid (6.7717%) and crude protein (23.2626%). This study used a factorial complete randomized design, and 72 females of *Coturnix coturnix japonica* (52 days old) divided into 2 × 3 treatments in six replications, with each replication consisting of two *Coturnix japonica* females. The treatments in this study were as follows: a0b0 – week-1, without feed additive; a0b1 – week-1, 4 ml probiotic/l drinking water; a0b2 – week-1, 4 ml *G. ulmifolia* Lam. extract /l drinking water; a1b0 – week-2, without feed additive; a1b1 – week-2, 4 ml probiotic /l drinking water; a1b2 – week-2, 4 ml *G. ulmifolia* Lam. extract /l drinking water. The method of treatment administration was as follows: probiotics and *G. ulmifolia* Lam. extract was mixed with drinking water, according to the dose and treatment period (7 and 14 days). Drinking water and feed were provided ad libitum. Probiotics and *G. ulmifolia* Lam. extract were added to drinking water and stirred evenly. Preparation of probiotics and *G. ulmifolia* Lam. extract was carried out every morning. The tested variables included dry matter intake, organic matter intake, ash intake, crude protein intake, crude fat intake, crude fibre intake, nitrogen-free extract (NFE) intake, metabolisable energy (ME) intake, and feed efficiency. All variables were calculated using the following formula (Yulianto et al., 2020; Suwignyo et al., 2021; Hadi et al., 2021):

\[
\text{Dry matter intake (g) = feed intake (g) × feed dry matter (%)},
\]

\[
\text{Organic matter intake (g) = feed intake (g) × feed organic matter (%) × feed dry matter (%)}.
\]

\[
\text{Ash intake (g) = feed intake (g) × feed ash (% × feed dry matter (%))},
\]

\[
\text{Crude protein intake (g) = feed intake (g) × feed crude protein (% × feed dry matter (%))},
\]

\[
\text{Crude fat intake (g) = feed intake (g) × feed crude fat (% × feed dry matter (%))},
\]

\[
\text{Crude fibre intake (g) = feed intake (g) × feed crude fibre (% × feed dry matter (%))},
\]

\[
\text{NFE intake (g) = feed intake (g) × feed NFE (% × feed dry matter (%))},
\]

\[
\text{ME intake (g) = feed intake (g) × feed ME (kcal/kg) × feed dry matter (%)}.
\]

\[
\text{Feed efficiency (%) = (egg production / feed intake) × 100.}
\]

Statistical analysis

The data collected during this study were statistically analysed in a fully randomized 2 × 3 factorial design. All data were tested for normality of distribution and homogeneity of variance. A 2 × 3 factorial design was used to analyse data of nutrient intake and feed efficiency in a response to 2 levels of administration time periods (a0 – one week and a1 – two weeks) and 3 levels of feed additives (b0 – without feed additives, b1 – probiotics, b2 – *G. ulmifolia* Lam. extract). Differences between means were detected using a 2-way analysis of variance. The differences between means were determined using Duncan’s test (*P* < 0.05).

Results

Dry matter intake

The result showed that there was a significant difference (*P* < 0.05) in the 1st and 2nd week of the administration period, as well as a significant difference (*P* < 0.05) regarding the type of feed additive; however, no interaction was observed between the time of administration and the type of feed additive. The average dry matter intake is listed in Table 1.

Table 1. Dry matter intake (g/quail/day) of *Coturnix coturnix japonica* during administration of probiotics and *Guazuma ulmifolia* Lam. extract in individual periods

<table>
<thead>
<tr>
<th>Feed additive</th>
<th>Periods</th>
<th>a0</th>
<th>a1</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>b0</td>
<td>21.5950± 0.29</td>
<td>21.5350± 0.39</td>
<td>21.5650± 0.51</td>
<td></td>
</tr>
<tr>
<td>b1</td>
<td>19.2867± 0.30</td>
<td>19.4604± 0.58</td>
<td>19.3733± 0.52</td>
<td></td>
</tr>
<tr>
<td>b2</td>
<td>19.9083± 0.38</td>
<td>19.3567± 0.37</td>
<td>19.6325± 0.52</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>20.263 ± 1.0494</td>
<td>20.117 ± 1.1170</td>
<td>20.177 ± 1.1170</td>
<td></td>
</tr>
</tbody>
</table>

data are presented as mean value ± SEM (standard error of the mean); a,b,c – means with different letters in the same column and row are significantly different (*P* < 0.05) between treatments (a0 – week-1, a1 – week-2, b0 – without feed additive, b1 – 4 ml probiotic /l drinking water, b2 – 4 ml *G. ulmifolia* Lam. extract /l drinking water).

Ash intake

The results of statistical analysis showed that there was no significant difference (*P* > 0.05) between the treatments in ash intake of *Coturnix japonica* females when feed additives were administered for one and two weeks; however, a significant difference (*P* < 0.05) was recorded for the types of feed additives. There was no interaction between the duration of administration and the type of feed additive. The average ash intake is provided in Table 2.
Organic matter intake

The results of statistical analysis showed that there was no significant difference (P > 0.05) between the treatments with respect to organic matter intake of *C. coturnix japonica* females when feed additives were administered for one or two weeks; however, there was a significant difference found (P < 0.05) for the type of feed additives. There was no interaction between the time of administration and the type of feed additive. The average organic matter intake is listed in Table 3.

Crude protein intake

The results of statistical analysis showed that there was no significant difference (P > 0.05) between the treatments in crude protein intake of *C. coturnix japonica* females during the supply of feed additives in the 1st and 2nd week; however, a significant difference was observed (P < 0.05) in the types of feed additives. There was no interaction between administration time and the type of feed additive. The average crude protein intake is listed in Table 4.

Crude fat intake

The results of statistical analysis showed that there was no significant difference (P > 0.05) between the treatments in crude fat intake of *C. coturnix japonica* females during the supply of feed additives for one or two weeks; however, a significant difference was observed (P < 0.05) in the types of feed additives. There was no interaction between administration time and the type of feed additive. The average crude fat intake is listed in Table 5.

Crude fibre intake

The results of statistical analysis showed that there was no significant difference (P > 0.05) between the treatments with respect to crude fibre intake in *C. coturnix japonica* females during the supply of feed additives for one or two weeks; however, there was a significant difference (P < 0.05) in the types of feed additives. There was no interaction between the duration of administration and the type of feed additive. The average crude fibre intake is provided in Table 6.
Table 6. Crude fibre intake (g/quail/day) of Coturnix coturnix japonica during administration of probiotics and Guazuma ulmifolia Lam. extract in individual periods

<table>
<thead>
<tr>
<th>Feed additive</th>
<th>Periods</th>
<th>a0</th>
<th>a1</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>b0</td>
<td>1.0400 ± 0.01</td>
<td>1.0363 ± 0.01</td>
<td>1.0383 ± 0.0158</td>
<td></td>
</tr>
<tr>
<td>b1</td>
<td>0.9236 ± 0.02</td>
<td>0.9367 ± 0.03</td>
<td>0.9325 ± 0.0217</td>
<td></td>
</tr>
<tr>
<td>b2</td>
<td>0.9600 ± 0.02</td>
<td>0.9317 ± 0.02</td>
<td>0.9458 ± 0.0227</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.9761 ± 0.0507</td>
<td>0.9683 ± 0.0537</td>
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</table>

NFE intake

The results of statistical analysis showed that there was no significant difference (P > 0.05) between the treatments regarding NFE intake in C. coturnix japonica females in the supply of feed additives for one or two weeks. However, there was a significant difference (P < 0.05) in the types of feed additives. There was no interaction observed between the time of administration and the type of feed additive. The average NFE intake is given in Table 7.

Table 7. Nitrogen-free extract intake (g/quail/day) of Coturnix coturnix japonica during administration of probiotics and Guazuma ulmifolia Lam. extract in individual periods

<table>
<thead>
<tr>
<th>Feed additive</th>
<th>Periods</th>
<th>a0</th>
<th>a1</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>b0</td>
<td>9.6200 ± 0.1279</td>
<td>9.5967 ± 0.1702</td>
<td>9.6083 ± 0.1440</td>
<td></td>
</tr>
<tr>
<td>b1</td>
<td>8.5917 ± 0.1337</td>
<td>8.6683 ± 0.2570</td>
<td>8.6300 ± 0.1994</td>
<td></td>
</tr>
<tr>
<td>b2</td>
<td>8.8667 ± 0.1687</td>
<td>8.6233 ± 0.1630</td>
<td>8.7450 ± 0.2029</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>9.0261 ± 0.4674</td>
<td>8.9628 ± 0.4988</td>
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</tr>
</tbody>
</table>

ME intake

The results of statistical analysis showed that there was no significant difference (P > 0.05) between the treatments with respect to ME intake in C. coturnix japonica females in the supply of feed additives during week 1 and 2; however, a significant difference (P < 0.05) in the types of feed additives was recorded. There was no interaction between the time of administration and the type of feed additive. The average ME intake is listed in Table 8.

Table 8. Metabolisable energy intake (cal/g) of Coturnix coturnix japonica during administration of probiotics and Guazuma ulmifolia Lam. extract in individual periods

<table>
<thead>
<tr>
<th>Feed additive</th>
<th>Periods</th>
<th>a0</th>
<th>a1</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>b0</td>
<td>69.2133 ± 0.9271</td>
<td>69.0250 ± 1.2379</td>
<td>69.1192 ± 1.0473</td>
<td></td>
</tr>
<tr>
<td>b1</td>
<td>61.8117 ± 0.9621</td>
<td>62.3687 ± 1.8560</td>
<td>62.0892 ± 1.4389</td>
<td></td>
</tr>
<tr>
<td>b2</td>
<td>63.8067 ± 1.2251</td>
<td>62.0367 ± 1.1721</td>
<td>62.9217 ± 1.4700</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>64.9439 ± 3.3643</td>
<td>64.4761 ± 3.5835</td>
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</table>

Discussion

Dry matter intake. The average dry matter intake of C. coturnix japonica during probiotics and G. ulmifolia Lam. extract supplementation was 19.6325–21.5650 (g/quail/day) and in individual time periods it ranged from 20.117 to 20.263 (g/quail/day) (listed in Table 1). Low dry matter consumption was observed for G. ulmifolia Lam. extract administration for two weeks and probiotics for one week, which did not differ significantly from probiotic administration for two weeks. High dry matter intake was found in controls without probiotics or without G. ulmifolia Lam. extract supplementation. The results of this study are consistent with other studies in terms that feed intake in chicks fed a diet supplemented with L. acidophilus probiotic was significantly lower than in control; moreover, the number of L. acidophilus bacteria in the ileum and colon of treated birds was higher than one or two weeks; however, there was a significant difference (P < 0.05) in the types of feed additives. No interaction was found between the duration of administration and the type of feed additive. The average feed efficiency is summarised in Table 9.

Table 9. Feed efficiency (%) of Coturnix coturnix japonica during administration of probiotics and Guazuma ulmifolia Lam. extract in individual periods

<table>
<thead>
<tr>
<th>Feed additive</th>
<th>Periods</th>
<th>a0</th>
<th>a1</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>b0</td>
<td>32.9283 ± 1.7290</td>
<td>34.0367 ± 0.4643</td>
<td>33.4825 ± 1.3386</td>
<td></td>
</tr>
<tr>
<td>b1</td>
<td>40.2717 ± 1.8825</td>
<td>41.3167 ± 2.5345</td>
<td>40.7942 ± 2.1974</td>
<td></td>
</tr>
<tr>
<td>b2</td>
<td>37.6650 ± 0.9090</td>
<td>40.0300 ± 0.9046</td>
<td>38.8475 ± 1.5065</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>36.9550 ± 3.4562</td>
<td>38.4611 ± 3.5845</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
in control, while the abundance of coliform bacteria was lower, as previously described (Salaromoini and Fooladi, 2011). *L. acidophilus* is widely used as a probiotic for humans and animals (Li et al., 2018). These probiotic bacteria can inhibit the invasion of pathogens and is known to modulate the immune response *in vitro* and *in vivo*. *L. acidophilus* is known to produce bacteriocins and acids, thus it can lower intestinal pH. The addition of *L. acidophilus* to poultry feed helps prevent the proliferation of pathogenic bacteria and balance the gut flora through competitive exclusion and antagonism (Lin et al., 2007; Cogliani et al., 2011). In poultry, the addition of probiotics to feed is known to modulate the balance of the intestinal microbiota, increase feed digestibility and nutrient absorption, enhance the immune response, and reduce stress (Patterson and Burkholder, 2003; Revolledo et al., 2006; Prado-Rebolledo et al., 2017; Li et al., 2018).

**Ash intake.** The average ash intake of *C. coturnix japonica* during the supplementation of probiotics and *G. ulmifolia* Lam. extract was 2.2567–2.4792 (g/quail/day) and in individual periods, it was in the range of 2.312–2.329 (g/quail/day) (listed in Table 2). Low ash consumption was recorded during the administration of *G. ulmifolia* Lam. extract for two weeks and probiotics for one week, and these results were not significantly different from probiotic supplementation for two weeks. High ash consumption was recorded during the control treatment without the supplementation of probiotics or *G. ulmifolia* Lam. extract. The results of other studies have shown that *L. acidophilus* is a Gram-positive bacterium widely used as a probiotic for animals and humans (Li et al., 2018). The average ash intake of *C. coturnix japonica* during the administration of probiotics and *G. ulmifolia* Lam. extract ranged from 4.5675 to 5.0167 (g/quail/day) and in individual periods varied from 4.6800 to 4.7139 (g/quail/day) (listed in Table 4). Low crude protein intake was recorded during the administration of *G. ulmifolia* Lam. extract for two weeks and probiotics for one week. These results were not significantly different from the variant with probiotic supplementation for two weeks. High crude protein intake was found in the control treatment without probiotics or *G. ulmifolia* Lam. extract. *L. acidophilus* is a Gram-positive bacterium widely used as a probiotic for animals and humans (Li et al., 2018).

**Crude protein intake.** The average crude protein intake of *C. coturnix japonica* during the administration of probiotics and *G. ulmifolia* Lam. extract was 1.3117–1.4608 (g/quail/day) and in individual periods it was 1.3628–1.3728 (g/quail/day) (listed in Table 2). Low ash consumption was recorded during the administration of *G. ulmifolia* Lam. extract for two weeks and probiotics for one week. These results were not significantly different from probiotic supplementation for two weeks. High crude protein intake was found in the control treatment without probiotics or *G. ulmifolia* Lam. extract. *L. acidophilus* is able to inhibit the invasion of pathogenic bacteria and modulate the immune response both *in vivo* and *in vitro* (Lin et al., 2007). The aforementioned studies have demonstrated that *L. acidophilus* has the potential to control pathogens in animals (Cogliani et al., 2011) and administration of probiotic microorganisms can increase protein availability. Symbiotics in turn can increase nutrient uptake as well as nitrogen stability (Falaki et al., 2011).

**Crude fat intake.** The average crude fat intake of *C. coturnix japonica* during probiotics and *G. ulmifolia* Lam. extract administration was 1.3117–1.4608 (g/quail/day) and in individual periods it was 1.3628–1.3728 (g/quail/day) (listed in Table 4). Low intake of crude fat was observed during the administration of *G. ulmifolia* Lam. extract for two weeks and probiotics for one week. These results were not significantly different from the outcomes of probiotic supplementation for two weeks. High crude fat consumption was found in the control treatment without the addition of probiotics or *G. ulmifolia* Lam. extract. Administration of probiotics was shown to have a modifying effect on the intestinal ecosystem by activating enzymes in the digestive tract and lowering pH (Kabir, 2009; Abd El-Hack et al., 2020). The colonization of probiotics in the intestine depends on several factors, including
the availability of fermented substrates (prebiotics), intestinal pH, dose and frequency of probiotic administration, age, genetics, health, nutritional status of the host, and stress factors (Bomba et al., 2002; Rehman et al., 2020). These results are thought to be related to the ability of probiotics to secrete enzymes such as proteases, amylase, and lipase, thereby increasing the level of digestion of feed nutrients, aiding fat, starch and protein digestion, and increasing nutrient availability (Bedford, 2000).

**Crude fibre intake.** The average crude fibre intake of *C. coturnix japonica* during probiotic and *G. ulmifolia* Lam. extract supplementation was 0.9325–1.0383 (g/quail/day) and in individual periods, it ranged from 0.9683 to 0.9761 (g/quail/day) (listed in Table 6). The intake of crude fibre was low during the administration of *G. ulmifolia* Lam. extract for two weeks and probiotics for one week and two weeks. High crude fibre consumption was recorded in the control treatment without probiotics or *G. ulmifolia* Lam. extract. Low crude fibre intake with *G. ulmifolia* Lam. extract could be related to the presence of phenolic compounds. Phenolic compounds occur in both insoluble and soluble-bound forms. The bound phenolics cannot be absorbed by the small intestine because they are attached to insoluble macromolecules such as hemicellulose, cellulose, pectin or structural proteins (Shahidi and Yeo, 2016). Thus, these compounds enter the large intestine (colon), where a fermentation process by the colon microbiota is carried out that releases immobilised phenols. The released phenolic compounds can lower the pH and modulate the development of fermentation microflora and prevent the growth of pathogenic bacteria, thereby playing a role in improving health (Shahidi and Yeo, 2016; de Rezende et al., 2018).

**NFE intake.** The average NFE intake of *C. coturnix japonica* during the supplementation of probiotics and *G. ulmifolia* Lam. extract was 8.6300–9.6083 (g/quail/day) and in individual periods it was 8.9628–9.0261 (g/quail/day) (listed in Table 7). Low NFE levels were found in birds administered *G. ulmifolia* Lam. extract for two weeks and probiotics for one and two weeks. High NFE assimilation was found in the control treatment without probiotics or *G. ulmifolia* Lam. extract. Consistently with these findings, some researchers observed that feed intake was decreased after the addition of probiotics and prebiotics to broiler diets (Mokhtari et al., 2010; Falaki et al., 2011; Amerah et al., 2013; Olnood et al., 2015), which was attributed to good intestinal health, better nutrient digestion and absorption due to increased nutrient availability (Bedford, 2000).

**ME intake.** The average ME intake by *C. coturnix japonica* after probiotic and *G. ulmifolia* Lam. extract administration was 62.0892–69.1192 (cal/g) and in individual periods ranged from 64.4761 to 64.9439 (cal/g) (listed in Table 8). Low ME intake was observed during the administration of *G. ulmifolia* Lam. extract for two weeks and probiotics for one and two weeks. High ME consumption was found in the control treatment without probiotics or *G. ulmifolia* Lam. extract supplementation. ME intake obtained with the addition of probiotics and extracts was lower than in controls. This is believed to be related to efficiency and increased feed nutrient (protein and energy) utilisation and inhibition of gut colonisation by pathogens (Toghyani et al., 2011).

**Feed efficiency.** The average feed efficiency in *C. coturnix japonica* females administered probiotics and *G. ulmifolia* Lam. extract was 33.4825–40.7942% and in individual periods it ranged from 36.9550 to 38.4611% (listed in Table 9). High feed efficiency was recorded during the administration of *G. ulmifolia* Lam. extract for two weeks and probiotics for one and two weeks. Feed efficiency in the control treatment without probiotics or *G. ulmifolia* Lam. extract was low. Probiotic administrations resulted in a higher feed efficiency than in control; this was related to the viability requirements of probiotics, namely that probiotic isolates must be able to survive during processing and storage.

Administration of *G. ulmifolia* Lam. extract also resulted in higher feed efficiency compared to control. This was related to the presence of proanthocyanidins, which show antioxidant, antimicrobial, anti-inflammatory, vascular and pro-cardiac properties (Shahidi and Yeo, 2016; Tsao, 2010; Shahat and Marzouk, 2013). Proanthocyanidins, known as condensed tannins (catechins and epicatechins), occur in plants and show a protective effect against abiotic and biotic stresses. Supplementing *G. ulmifolia* Lam. extract can improve feed efficiency as these plants produce secondary metabolites that can provide astringency and flavour properties to food, as well as form complexes both with macromolecules (polysaccharides and proteins) and metal ions (Xie and Dixon, 2005; Shahat and Marzouk, 2013). In our study, the results regarding feed efficiency were consistent with the study of Nikpiran et al. (2013), who showed better feed conversion results after the addition of prebiotics to broiler rations compared to controls. This is believed to be related to a more balanced population of the gut biota as substrate availability can lead to improved efficiency of feed digestion and utilisation (Bedford, 2000; Salianeh et al., 2011).
Conclusions

Based on the presented data, it can be concluded that the use of *L. acidophilus* and *L. lactis* probiotics and *G. ulmifolia* Lam. extract has the potential to improve nutrient intake, including dry matter, organic matter, ash, crude protein, ether extract, crude fibre, NFE, ME and feed efficiency in *C. coturnix japonica* females.

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Conflict of interest

The Authors declare that there is no conflict of interest.

References


