# Compensatory growth in broiler chicks fed on *Lemna gibba*

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**The growth of broiler chickens on diets containing various levels of *Lemna gibba* was evaluated. Groups of broiler chicks were fed on diets containing 0–400 g *Lemna gibba*/kg for 3 weeks. These chickens were then changed to standard diets for a further 2 weeks. As the level of *Lemna gibba* increased, feed consumption and weight gain decreased. However, when diets were changed to the standard diet, compensatory growth was observed. In a second experiment, diets were formulated with a metabolizable energy of 5·02 MJ (1200 kcal)/kg *Lemna gibba* and included a finer-milled *Lemna gibba*. Chickens were fed on diets containing 0–300 g *Lemna gibba*/kg for 4 weeks. Each group was then divided into two sub-groups. For the next 2 weeks one of these sub-groups was maintained on the experimental (*Lemna gibba*) diets (LL), while the other sub-group was changed to a standard diet (LS). Bird fed at levels above 150 g *Lemna gibba*/kg had decreased consumption and weight gain. These birds when changed to a standard diet tended to have increased weight gain compared with chickens continuously fed standard rations. LS birds had significantly higher weight gains and feed consumption and lower feed conversion than LL birds. In contrast to older birds, chicks fed on *Lemna gibba* at high concentrations showed growth retardation. When changed back to a standard diet they demonstrated normal or compensatory growth.**

*Lemna gibba*: **Duckweed: Compensatory growth: Broiler chicks**

*Lemna gibba* (duckweed) is an indigenous small aquatic macrophyte that grows world-wide. It grows rapidly and is easy to harvest. When dried, *Lemna gibba* contains up to 380 g protein/kg, and 1200 mg xanthophyll/kg (Abdulayef, 1969; Muztar *et al.* 1976).

We have previously demonstrated the nutritional value of *Lemna gibba* when included in the diets of layer hens (Haustein *et al.* 1990*b*). Also, older broilers had excellent growth when fed on high levels of *Lemna gibba* (Haustein *et al.* 1990*a*). However, no comparable reports are available for broiler chicks.

The present study evaluates the performance of chicks given various levels of sewage-grown *Lemna gibba*. It also describes the pattern of accelerated growth achieved when chicks were changed to a normal diet.

## MATERIALS AND METHODS

Titan broiler chicks (1-d-old) were obtained from a local breeder in Lima (Avicola Hannan). The baby chicks were randomly distributed by weight in batteries provided with individual thermostats set at 37°. *Lemna gibba* was harvested from the San Juan sewage

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Table 1. *Expt 1. Composition and nutritional value (g/kg) of the experimental diets*

| | *Lemna gibba* (g/kg) | | | | |
|---|---|---|---|---|---|
| Ingredients Diet... | Control | 100 | 200 | 300 | 400 |
| *Lemna gibba* | 0 | 100 | 200 | 300 | 400 |
| Yellow maize | 560 | 600 | 570 | 570 | 530 |
| Wheat middlings | 150 | 160 | 100 | 50 | — |
| Fish meal | 130 | 130 | 90 | 50 | 20 |
| Soyabean meal | 130 | — | — | — | — |
| Sugar | — | — | 30 | — | 5·0 |
| Hydrogenated fish oil | — | — | — | 30 | 30 |
| Calcium carbonate | 8·3 | 4·5 | — | — | — |
| Dicalcium phosphate | — | — | 5·0 | 9·8 | 13·6 |
| DL-methionine | 0·75 | 1·5 | 1·0 | 1·4 | 1·6 |
| Premix* | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 |
| Salt | 2·2 | — | — | — | — |
| Total | 1000·0 | 1000·0 | 1000·0 | 1010·0 | 1000·0 |
| Composition | | | | | |
| ME (MJ/kg) | 12·142 | 12·142 | 12·142 | 12·142 | 12·142 |
| Crude protein† | 220·4 | 196·2 | 194·0 | 190·6 | 190 |
| Lysine | 12·8 | 11·5 | 11·7 | 11·5 | 12·0 |
| Methionine | 5·3 | 5·8 | 5·2 | 5·2 | 5·2 |
| Methionine + cystine | 8·6 | 8·6 | 8·6 | 8·6 | 8·6 |
| Available phosphorus | 4·5 | 4·5 | 4·6 | 4·5 | 4·5 |
| Calcium | 9·0 | 9·1 | 8·4 | 10 | 11·4 |
| Sodium | 2·5 | 2·9 | 4·5 | 6·0 | 7·6 |

ME, metabolizable energy.

* Premix composition (mg/kg feed): retinyl palmitate 5·99, cholecalciferol 25 μg, D-tocopheryl acetate 10, sodium bisulphite 3, riboflavin 4·5, nicotinic acid 30, D-panthothenic acid 9, vitamin $B_{12}$ 12, choline chloride (100%) 450, chlorotetracyline 20, butylated hydroxytoluene 120, zoalene 120, manganese 60, zinc 30, iron 30, copper 1·5, iodine 1·5, cobalt 150.

† Nitrogen × 6·25.

lagoons and dried as previously described (Haustein *et al.* 1990*b*). All diets were formulated according to the recommendations of the National Research Council (1984).

### *Expt 1*

Two hundred and twenty 1-d-old chicks were randomly distributed by weight in groups of eleven birds per experimental pen. Experimental diets containing different levels of *Lemna gibba*: 0, 10, 20, 30 and 40 g/kg were then provided to the birds (see Table 1). The group given a standard diet (SD) (0 g *Lemna gibba*/kg) was the control group. Each treatment was performed in four replicate pens. The diets were formulated using a metabolizable energy (ME) value for *Lemna gibba* of 8·37 MJ (2000 kcal)/kg, obtained from studies in roosters. On day 21 all birds were weighed individually, feed consumption per pen was recorded and all diets were changed to a standard isonitrogenous, isoenergetic (control) diet for the next 2 weeks. At the end of this period, birds were individually weighed and the feed consumption of each pen was noted.

### *Expt 2*

One hundred and ninety eight 1-d-old chicks were randomly distributed by weight in groups of eleven birds per experimental pen. Experimental diets containing different levels of *Lemna gibba*: 0 (control), 10, 15, 20, 25 and 300 g/kg, were then provided to the birds (see

Table 2. *Expt 2. Composition and nutritional value of the experimental diets*

| | | *Lemna gibba* (g/kg) | | | | |
|---|---|---|---|---|---|---|
| Ingredients | Control | 100 | 150 | 200 | 250 | 300 |
| *Lemna gibba* | — | 100 | 150 | 200 | 250 | 300 |
| Yellow maize | 600 | 600 | 600 | 600 | 590 | 530 |
| Wheat middlings | 150 | 90 | 50 | 30 | — | — |
| Fish meal | 130 | 130 | 130 | 130 | 110 | 90 |
| Soyabean meal | 100 | 50 | 30 | — | — | — |
| Hydrogenated fish oil | 9·0 | 20 | 30 | 30 | 50 | 70 |
| Calcium carbonate | 11·2 | 7·0 | 4·8 | 7·2 | 2·4 | 1·5 |
| DL-methionine | 1·6 | 1·4 | 1·2 | 1·2 | 0·8 | 0·5 |
| Premix* | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 |
| Total | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Composition | | | | | | |
| ME (MJ/kg) | 12·561 | 12·561 | 12·561 | 12·561 | 12·561 | 12·561 |
| Crude protein | 206·5 | 207·6 | 207·6 | 205·8 | 206·5 | 206·7 |
| Lysine | 11·9 | 12·6 | 12·6 | 12·7 | 12·8 | 13·1 |
| Methionine | 5·6 | 5·6 | 5·6 | 5·6 | 5·5 | 5·8 |
| Methionine + cystine | 8·9 | 8·9 | 8·9 | 8·9 | 8·9 | 8·9 |
| Arginine | 12·2 | 12·6 | 12·6 | 12·6 | 12·8 | 13·3 |
| Tryptophan | 12·3 | 12·5 | 12·5 | 12·6 | 12·6 | 12·7 |
| Available phosphorus | 4·5 | 4·5 | 4·5 | 4·5 | 4·6 | 4·6 |
| Sodium | 1·8 | 4·2 | 4·2 | 4·8 | 5·4 | 6·4 |

ME, metabolizable energy.

* Premix composition (mg/kg feed): retinyl palmitate 5·99, cholecalciferol 25 μg, D-tocopheryl acetate 10, sodium bisulphite 3, riboflavin 4·5, nicotinic acid 30, D-panthothenic acid 9, vitamin $B_{12}$ 12, choline chloride (100%) 450, chlorotetracyline 20, butylated hydroxytoluene 120, zoalene 120, manganese 60, zinc 30, iron 30, copper 1·5 iodine 1·5, cobalt 150.

Table 2). Each treatment was performed in three replicate pens. To improve digestibility, *Lemna gibba* was more finely milled in Expt 2. The diets were formulated using an ME value of 5·02 MJ (1200 kcal)/kg dried *Lemna gibba* after studies in chicks utilizing the chromium oxide method (Sibbald *et al.* 1963; Sibbald, 1976) demonstrated this to be the case. All diets and water were supplied *ad lib.* At the end of the experimental period (28 d) the birds were weighed individually and feed consumption for each pen was recorded. At this stage, birds from each treatment were randomly separated into two groups of ten birds, one group remained on the same diet and the other group was supplied with SD for 2 weeks. Thus, there were three study groups: (1) a standard groups (SS) which received SD during both the study periods (initial and recovery); (2) a changed-diet group (LS) which received varying levels of *Lemna gibba* in the initial period and then SD in the recovery period; (3) a group (LL) which received *Lemna gibba* during both study periods. Birds were then individually weighed and the feed consumption for each pen was recorded.

*Statistical analysis.* In order to determine the relationship between the dependent variables (weight gain, final weight, feed consumption, and feed conversion) and levels of *Lemna gibba*, linear and non-linear regression ($Y = a + b_1 X + b_2 X^2$) analyses were performed for each experiment (Hicks, 1983). Results from regression and correlation analyses, $r^2$ and significance ($P$) values are presented. The Mann–Whitney test was used to analyse differences between matched groups. Significance levels were set in advance at $P < 0·05$.

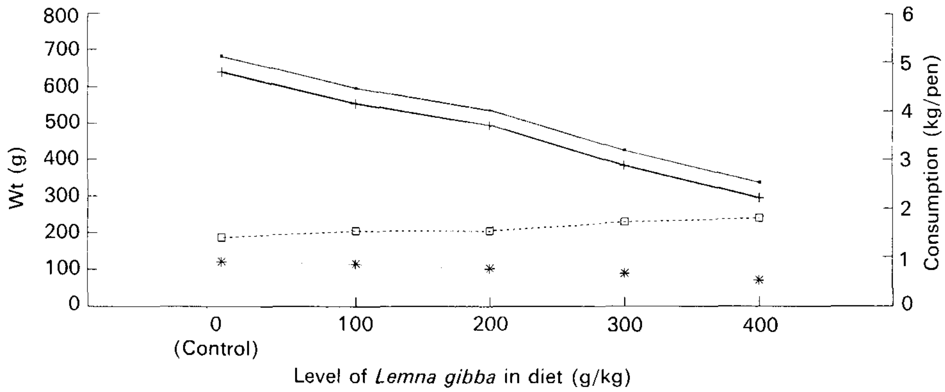


Fig. 1. Expt 1. Performance of broiler chicks fed on different levels of *Lemna gibba* during the initial period (days 0–21). (—■—), Final weight; (—|—), mean gain; (—*—), feed consumption; (---□---), feed conversion. For details of diets and procedures, see Table 1 and p. 329.

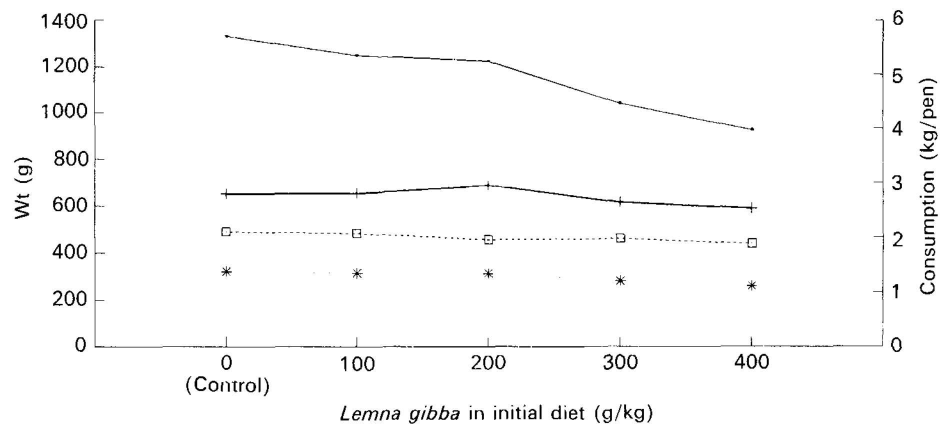


Fig. 2. Expt 1. Performance of broiler chicks initially fed on different levels of *Lemna gibba* followed by a standard diet recovery period (days 22–23). (—■—), Final weight; (—|—), mean weight gain; (—*—), consumption; (--□---), feed conversion. For details of diets and procedures, see Table 1 and p. 329.

## RESULTS

### *Expt 1*

*Initial period.* As shown in Fig. 1, as the level of *Lemna gibba* increased in the diets, mean weight gain decreased linearly ($r^2$ 0·985, $P < 0·01$).

*Recovery period.* When changed for a 2-week period to a standard diet that did not contain *Lemna gibba*, these chickens had two different patterns of weight gain: an initial increase followed by a decline. The curve best fitted a non-linear quadratic equation ($r^2$ 0·70, $P < 0·05$). The peak weight gain occurred in chickens previously fed a diet containing 200 g *Lemna gibba*/kg. These chickens tended to gain weight more rapidly than did the SD control group, even though feed consumption decreased at a linear rate ($r^2$ 0·82, $P < 0·01$; *Fig.* 2). However, the final weights of these chickens never achieved those of the SD controls. There was a linear decrease in final weight as the level of *Lemna gibba* in the diet was increased ($r^2$ 0·88, $P < 0·01$). Feed conversion tended to decrease but a significant correlation was not obtained although the best fit was linear. Lower *Lemna gibba* levels seemed to prime the birds to achieve compensatory growth and peak efficiencies when switched to a standard diet.

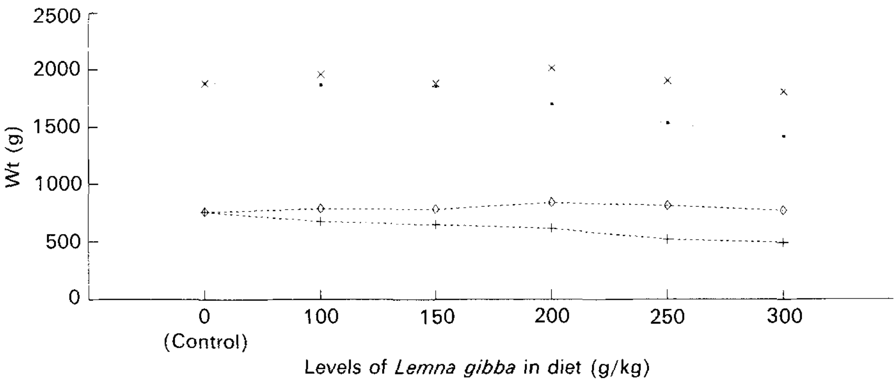


Fig. 3. Expt 2, Performance of broiler chicks fed on different levels of *Lemna gibba* during the initial period. (—■—), Final weight; (—|—), mean weight gain; (—*—), feed consumption; (---□---), feed conversion. For details of diets and procedures, see Table 2 and p. 329.

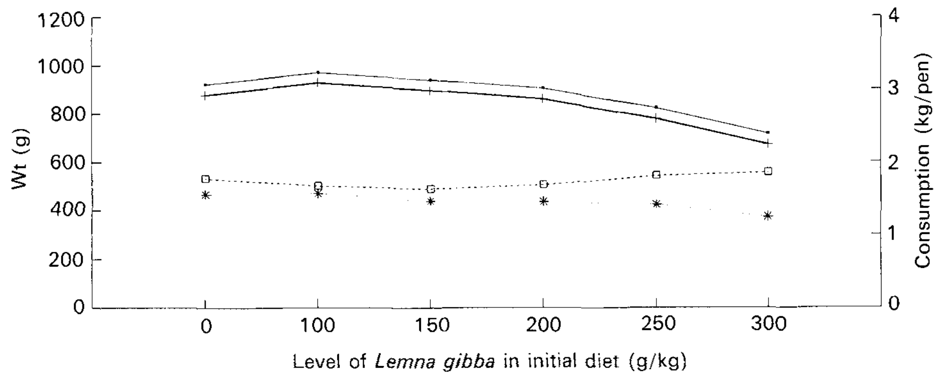


Fig. 4. Expt 2. Final weight and mean weight gain of broiler chicks fed on different levels of *Lemna gibba* (L) and fed on standard diet(s) or L during the recovery period (days 33–46). (· · · · ·), Final weight; (– – –), mean weight gain. Control, birds fed on S during the initial and recovery periods; (× · · · · ×, ◇– –◇), birds receiving L in the initial period and then S in the recovery period; (● · · · ●, +– –+), birds fed on L in the initial and recovery periods. For details of diets and procedures, see Table 2 and p. 329.

## *Expt 2*

In order to control for the effect of age, the phenomenon of compensatory growth was tested using a different experimental model. Chickens were fed on *Lemna gibba* (ME 5·02 MJ (1200 kcal)/kg) at varying concentrations for 4 weeks and then during the next 2 weeks each experimental group was divided into two new groups: LL, receiving *Lemna gibba* for both periods and LS receiving SD instead of *Lemna gibba*-containing diets.

*Initial period.* In contrast to the first experiment, birds fed on *Lemna gibba* at low levels had better weight gain and final weights than the controls. The regression curve for weight gain was non-linear and best fitted a quadratic model ($r^2$ 0·79, $P < 0·01$). The highest weight gain occurred when chickens were fed on a diet containing 100 g *Lemna gibba*/kg (Fig. 3). Similarly, feed conversion was not linear ($r^2$ 0·85, $P < 0·01$). The lowest feed conversion occurred when the diet contained 150 g *Lemna gibba*/kg (Fig. 3).

*Recovery period.* The weight gain for the LS group given more than 150 g *Lemna gibba*/kg tended to be higher than that of chickens in the SS group (Fig. 4). Feed consumption and feed conversion did not differ between the LS and SS groups (Fig. 5). Birds continuously fed *Lemna gibba* at levels of less than 200 g/kg, when compared with

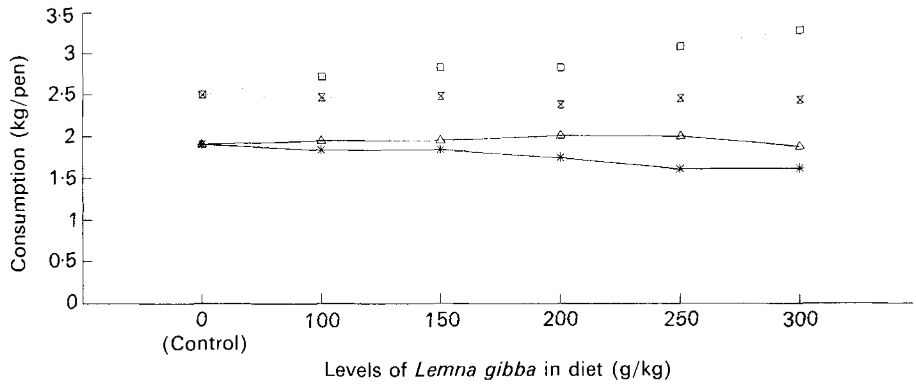


Fig. 5. Expt 2. Feed consumption and feed conversion of broiler chicks fed on different levels of *Lemna gibba* (L) and fed on standard diet (S) or L during the recovery period (days 33–46). (——), Feed consumption; (· · · ·), feed conversion. Control, birds fed on S diet during the initial and recovery periods; (⧖ · · · ⧖, △—△), birds receiving L in the initial period and then S in the recovery period; (□ · · · □, —*—), birds fed on L in the initial and recovery periods. For details of diets and procedures, see Table 2 and p. 329.

LS birds, revealed no difference in any of the four variables (weight gain, final weight, feed consumption and feed conversion) measured (Figs. 4 and 5). However, when all points were considered, a significant increase in weight gain, final weight and feed consumption and a significant decrease in feed conversion was found when the LS group was compared with the LL group ($P < 0·05$, Mann–Whitney test).

## DISCUSSION

*Lemna gibba* has great potential as a feed for poultry because of its high protein level (330–380 g/kg), its high xanthophyll content, and its ready availability as a natural waterplant (Abdulayef, 1968; Muztar *et al.* 1976). *Lemna gibba* is used to purify sewage (Oron *et al.* 1986). The large quantities of *Lemna gibba* produced and harvested through the purification process may provide a cheap source of nutrient for poultry and a substitute for costly ingredients such as soya bean and fishmeal which often need to be imported.

We have previously demonstrated that older birds have high growth rates when fed on high levels (200 g/kg) of *Lemna gibba* (Haustein *et al.* 1990*a*). In contrast to layers and broilers, the present study demonstrated that the growth of chicks is affected by inclusion of *Lemna gibba* in the diet at concentrations above 150 g/kg.

The use of older birds, finer milled *Lemna gibba* and an ME adjusted for age may account for the higher weight gain for chickens fed at the same level of *Lemna gibba* in Expt 2 compared with Expt 1. Probably the most important factor was the difference in the ME value for *Lemna gibba* used in the diets, 8·37 MJ (2000 kcal)/kg in Expt 1 *v.* 5·02 MJ (1200 kcal)/kg in Expt 2. The lower ME value was obtained in young birds and is probably a more relevant result. If the lower ME value is applied to the formulation of the Expt 1 diet (Table 1) then the diets containing high amounts of *Lemna gibba* have ME values considerably less than 12·55 MJ (3000 kcal)/kg. For example, in Expt 1, in a diet with 300 g *Lemna gibba* the ME value of the diet will be only 10·46 MJ (2500 kcal)/kg and with 400 g *Lemna gibba*/kg would be only 10·04 MJ (2400 kcal)/kg. These lower ME values are probably the major reason for the lower growth rates of birds in Expt 1.

*Lemna gibba* appears to behave in a manner similar to lucerne (*Medicago sativa*). Lucerne meal fed to starting turkeys at levels above 50 g/kg in the ratio depressed growth.

However, if given to turkeys after 8 weeks of age, levels of lucerne meal up to 350 or 400 g/kg did not depress growth (Holder *et al.* 1975).

Why chickens have depressed growth and older birds do not is not clear. Holder *et al.* (1975) has suggested it may be due to the saponin content of the feed but direct evidence for this hypothesis is lacking. Whether depression in growth is due to anti-metabolites or to decreased digestibility by an immature gut remains to be determined. The decline in growth rate produced by higher levels of *Lemna gibba* was reversible. Chickens initially fed on *Lemna gibba* and then changed to a standard diet demonstrated compensatory growth, i.e. they gained weight at rates that were usually higher than that of chickens continuously fed on standard rations.

The mechanism by which compensatory growth occurs is poorly understood (Forbes, 1974; Miller & Wise, 1976). Previous studies of this phenomenon have used rat models in which diets were first restricted and then replaced with control diets. In our studies all feeds were isoenergetic and isonitrogenous. In previous studies on rats, compensatory growth was associated primarily with increased food consumption. In the present study the relationships between weight gain, food conversion and feed consumption are not distinct enough to determine the mechanism by which compensatory growth occurred. Further studies are needed to elucidate the mechanism of compensatory growth noted in this chicken model and to determine whether it is the same as occurs after an illness in humans.

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