Force-feeding effects on growth, carcass and blood composition in the young chick

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1. Excessive amounts of food (70% greater than *ad lib.* intake) introduced into the gastrointestinal tract of young chicks were efficiently digested and caused increased growth resulting mainly from lean body substance and partially from fat deposition, more efficient energy utilization than the *ad lib.*-fed controls, increased relative weights of the crop, proventriculus, intestine, liver and abdominal adipose tissue. Pancreas relative weight was not changed and that of the gizzard was reduced.

2. The treatment also caused changes in blood plasma composition. Free fatty acid, triglyceride, α_2-, β- and γ-globulin and pre-β-lipoprotein concentrations increased.

3. Fasting for 30 h caused higher body fat losses and lower body protein losses in the force-fed chicks than in the *ad lib.*-fed chicks.

4. The effects of over-feeding on body and blood plasma composition and differences found in these measurements during starvation are discussed.

It has been shown that when excess food is introduced into the gastrointestinal tract of adult Leghorn cockerels (Lepkovsky & Furuta, 1971) or of geese (Nir, Perek & Katz, 1972), energy is efficiently utilized, as shown by gains in weight and body fat and by balance studies (Nir, Nitsan & Vax, 1973). These studies were carried out with adult birds or with birds past the age of maximal growth rate. Therefore their increase in body-weight was caused essentially by fat deposition. During the stage of maximal growth rate in young animals, deposition of fat is negligible, and most of the body-weight gain is due to protein. The close relationship between food intake and body-weight gain existing in young animals raises a hypothetical question. Which factor is the mandatory one: appetite or food utilization and growth potential? Or, in other words, which is the limiting factor: appetite, which limits the amount of metabolites available to the tissues for growth, or the capacity of the digestive tract to digest and absorb efficiently large amounts of nutrients and the anabolic potential of the tissues?

The objective of the present study was to determine the ability of young chicks to

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Table 1. *Composition of the diet given to chicks*

Constituents (g/kg)		Energy (MJ/kg (kcal/kg)) and chemical composition (g/kg)	
Maize	200	Gross energy	16·65 (3980)
Milo	311	Metabolizable energy†	12·76 (3050)
Soya-bean meal (440 g protein/kg)	350	Water	120
		Total protein (N × 6·25)	240
Fish meal	20	Diethyl ether extract	75
Meat and bone meal	15	Crude fibre†	31
Feather meal	15	Calcium†	10·5
Lucerne meal	8	Phosphorus†	7·3
NaCl	3	Ash	64·9
$CaCO_3$	7		
$CaHPO_4$	17		
Vitamins and trace elements concentrate*	4		
Soya-bean oil	50		

* To supply (/kg): retinol, 2·5 mg; cholecalciferol, 50 μg; α-tocopheryl acetate, 5 mg; menaphthone, 2 mg; riboflavin, 6 mg; pantothenic acid, 11 mg; nicotinic acid, 25 mg; pteroylmonoglutamic acid, 0·5 mg; pyridoxamine, 1·5 mg; cyanocobalamin, 10 μg; choline chloride, 500 mg; ethoxyquin, 125 mg; manganese, 80 mg; zinc, 50 mg; iodine, 1·2 mg; cobalt, 0·2 mg; copper, 2 mg; iron, 25 mg.

† Calculated as described by (US) National Research Council (1971).

utilize food given in amounts exceeding their *ad lib.* consumption. The effect of force-feeding on growth rate, the composition of the carcass, liver and blood, and the weight of the gastrointestinal tract was determined.

EXPERIMENTAL

Animals and diet

Cross-bred male New Hampshire × White Leghorn chicks were wing-banded with numbers and kept in thermostatically-controlled, electrically-heated batteries with raised wire floors. The room was illuminated by natural daylight, with fluorescent lights until 20.00 hours. The composition of the diet given before and during the experimental period is shown in Table 1. At the age of 41 d, two groups of fifteen birds were force-fed and two similar groups served as *ad lib.*-fed controls. Force-feeding was carried out daily at 08.00 and 17.00 hours. The diet was blended with water (5·0 parts mash + 6·5 parts water, w/v) and introduced into the crop through a 4 mm diameter plastic tube until the crop was fully distended. The amount of food introduced was recorded by weighing the chicks before and after force-feeding and by multiplying the weight difference by the factor 0·435.

The force-fed chicks also had access to food and the amount consumed voluntarily by each group was recorded daily. Force-feeding lasted for 15 d. Following this period, eight chicks were selected from each of the two groups of force-fed and *ad lib.*-fed birds, taking care that the mean body-weights of the resulting sub-groups were close to the mean values for all thirty birds raised by each method. All remaining chicks were subsequently fed *ad lib.* to determine if force-feeding caused permanent changes at maturity. Eight selected chicks from each treatment were starved during

the following 28–33 h and eight were force-fed or *ad lib.*-fed according to their initial treatment. The last force-feeding was carried out at 08.00 hours, 4 h before the start of autopsy, which took place from 12.00 to 17.30 hours.

Autopsy and preparation of blood and organs for analysis

The chicks were guillotined in blocks of four (eight blocks, thirty-two chicks) after blood withdrawal by cardiac puncture. In each block, one fed and one starved chick from each treatment was killed serially. The autopsy and dissection of each group lasted about 40 min. Blood was taken using EDTA as anticoagulant. It was then transferred to centrifuge tubes kept in crushed ice and packed cell volume was determined (Adams Autocrit Centrifuge, Clay Adams Inc., New York). After centrifugation, samples of plasma were transferred to Dole mixture (Dole, 1956) for free fatty acid (FFA) determination; other samples were transferred to tubes for lipoprotein determination and kept at 4°; the remainder was kept at −22° for other chemical analyses. At autopsy the crop, proventriculus, gizzard, small intestine and caecum were emptied of their contents, washed with saline (9 g NaCl/l), blotted on filter paper and weighed. Abdominal adipose tissue was carefully removed, weighed, and put into the carcass with the empty digestive tract. The carcasses were then frozen for chemical analyses. After weighing the livers, a sample was immediately placed in ethanolic KOH (300 g/l) for glycogen determination. The rest of the liver and kidneys were frozen for further analysis.

Chemical analyses

Carcasses. These were weighed and autoclaved for 3 h at 120°. They were weighed again when cooled and homogenized with a Waring Blendor. The homogenates were analysed for dry matter by drying at 105° for 24 h; samples for determination of ash were incinerated at 600° for 2 h; total nitrogen and phosphorus contents were determined with a Technicon AutoAnalyzer as described by Nir, Nitsan & Vax (1973). Fat was determined by continuous diethyl ether extraction of samples triturated with anhydrous Na_2SO_4. Energy content was determined using dried samples (80°, overnight) with a Gallenkamp Ballistic Bomb Calorimeter (A. Gallenkamp and Co. Ltd, London EC 2). Protein and energy retention were calculated assuming that the initial carcass composition was similar to the final carcass composition of the *ad lib.*-fed, non-starved group.

Liver and kidneys. Total N in liver and kidneys, and fat in livers were determined as in carcasses. Glycogen was extracted from liver by the method of Passonneau, Gatfield, Schulz & Lowry (1967), and its level was determined with the anthrone reagent as described by Hassid & Abraham (1957).

Blood plasma. Glucose was determined by the glucose oxidase method with the Biochemica Test Combination (C. F. Boehringer & Sohne GmbH, Mannheim, W. Germany). FFA, triglycerides, cholesterol, total protein and protein fractions were measured as described by Nir & Perek (1971). The absolute amount of the protein fractions was obtained by multiplying the relative amount by the total protein concentration. FFA were determined by the method of Dole (1956); lipoproteins

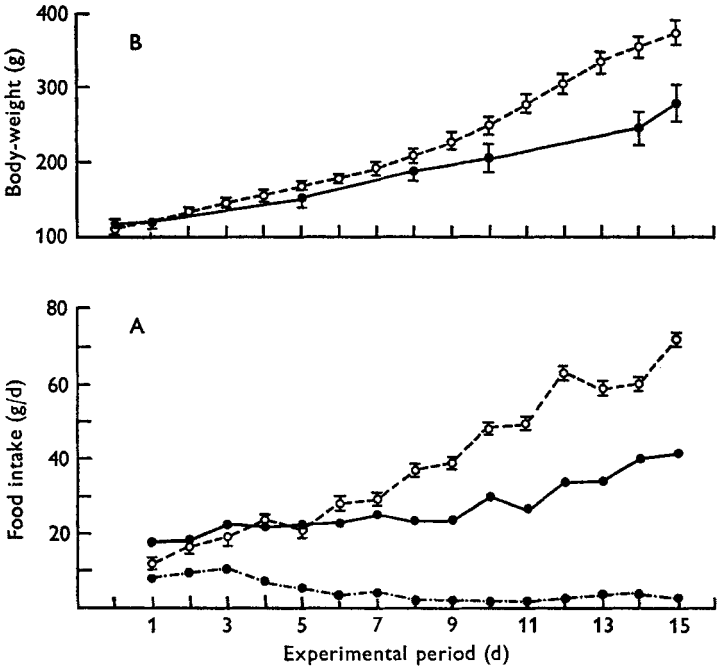

Fig. 1. Food intake (A) and body-weights (B) of force-fed (○—○) and *ad lib.*-fed (●—●) chicks; (●-·-●) voluntary food intake of the force-fed group. Vertical bars represent the SE of the mean. Values are those for the whole group of *ad lib.*-fed chicks and those for the whole group of force-fed chicks.

were estimated using agarose gel as described by Noble (1968), using Bio-Gram A lipoprotein profile (Bio-rad Laboratories Richmond, California). The relative amounts were determined by densitometry using a Beckman Model 100 Densitometer.

Statistical analyses were performed as described by Snedecor & Cochran (1967). The differences between all groups were analysed by Newman's Q test and the significance of main effects and interactions were assessed by the F test, taking each group of four as a block in a randomized block analysis.

RESULTS

Carcass composition and food utilization

The force-fed chicks adapted gradually to force-feeding. The amount of food that could be force-fed increased substantially only after 1 week from the start of force-feeding (Fig. 1). Following this period their food consumption was increased gradually, up to 70% more than that of the control group. The voluntary food consumption of the force-fed chicks decreased gradually as the amount given by force-feeding increased. During the 2nd week of the experiment practically no voluntary consumption of food was observed. The final body-weight was correlated with food consumption (r = 0·83; sixteen chicks).

Force-feeding resulted in an increase in the body-weight gain (about 50%) and in

Table 2. *Body-weight gain and food utilization by chicks following 15 d of force-feeding or* ad lib. *feeding*

(Mean values for eight chicks/group)

	Treatment					Statistical significance of effects of:		
	Ad lib.-fed		Force-fed					
	Fed	Starved	Fed	Starved	SE of mean	Force-feeding	Starving ($P <$)	Interaction
Food intake (g)	395	354	648	598				
Initial body-wt (g)	116	112	115	115	4	NS	NS	NS
Final body-wt (g)	319^{c}	265^{d}	415^{a}	355^{b}	12	0·01	0·01	NS
Body-wt gain (g)	203^{c}	153^{d}	300^{a}	240^{b}	10	0·01	0·01	NS
Lean body-wt gain (g)*	190^{c}	148^{d}	243^{a}	201^{b}	5	0·01	0·01	NS
Carcass energy (MJ)	$2{\cdot}48^{c}$	$1{\cdot}63^{d}$	$3{\cdot}84^{a}$	$2{\cdot}96^{b}$	0·13	0·01	0·01	NS
Carcass protein (g)	$64{\cdot}1^{c}$	$53{\cdot}8^{d}$	$75{\cdot}5^{a}$	$68{\cdot}5^{b}$	1·6	0·01	0·01	NS
Carcass fat (g)	$19{\cdot}7^{c}$	$11{\cdot}6^{d}$	$57{\cdot}8^{a}$	$40{\cdot}0^{b}$	1·5	0·01	0·01	NS
Utilization								
Food (body-wt gain:intake)	0·510	0·414	0·459	0·396				
Protein (retained:intake)†	0·47	0·40	0·39	0·35				
Energy (retained:intake)†	0·204	0·153	0·291	0·220				

NS, not significant.
Values with common superscript letters do not differ significantly ($P < 0{\cdot}05$).
* Calculated after deduction of diethyl ether-extract fraction.
† Calculated as:

$$\frac{(\text{Final body-wt} \times \%\text{component}) - (\text{initial body-wt} \times \%\text{component in } \textit{ad lib.}\text{-fed group})}{\text{component intake}}.$$

the lean body-weight gain (about 30 %) as compared with the *ad lib.*-fed controls (Table 2). Starving for 30 h reduced body-weights by about 16 % in both groups. The fat content of the force-fed group (non-starved) was about 14 % and that of the control group was about 6 % (Table 3). Fat concentration was negatively correlated to water concentration, $r = -0{\cdot}91$, between all thirty-two chicks; and $r = -0{\cdot}74$ as calculated for variation between chicks on the same treatment. Starving caused a reduction of about 2 % in the fat content of both groups. The marked difference in water concentration and slight differences in protein, ash and P concentrations caused by force-feeding and by starving were the result of the different fat content of the birds. No differences were found between the groups in the lean carcass composition (Table 3).

Force-feeding had only a small effect on food utilization (Table 2). Assuming that the body composition at the start of the experiment was similar to that of the control group at the end of the experiment, it was found that with force-feeding, protein utilization decreased by about 14 %, while efficiency of energy retention was increased from 0·204 to 0·291 (i.e. by 40 %) (Table 2).

Organ weights

Force-feeding caused a threefold increase in the relative weight of the empty crop, a 15 % increase in the proventriculus weight, and about a 30 % increase in the weight of the small intestine (Table 4). No significant change was observed in the weight of

Table 3. *Carcass and lean carcass composition (g/kg) of chicks following 15 d of force-feeding or* ad lib. *feeding*

(Mean values for eight chicks/group)

	Treatment					Statistical significance of effects of:		
	Ad lib.-fed		Force-fed					
	Fed	Starved	Fed	Starved	SE of mean	Force-feeding	Starving	Interaction
						($P <$)		
Carcass composition*								
Water	722^{b}	745^{a}	654^{d}	696^{c}	7	0·01	0·05	NS
Protein	201^{a}	203^{a}	182^{b}	193^{ab}	5	0·05	NS	NS
Fat (diethyl ether extract)	$61·8^{c}$	$43·7^{d}$	$139·3^{a}$	$112·8^{b}$	6·0	0·05	0·05	NS
Ash	$32·7^{b}$	$34·9^{a}$	$31·1^{b}$	$30·6^{b}$	0·6	0·01	NS	0·05
Phosphorus	5·79	6·46	5·69	5·75	0·15	0·05	NS	NS
Protein (g/carcass)	$64·1^{c}$	$53·8^{d}$	$75·5^{a}$	$68·5^{b}$	1·4	0·01	0·01	NS
Fat (g/carcass)	$19·7^{c}$	$11·6^{d}$	$57·8^{a}$	$40·0^{b}$		0·01	0·01	NS
SE of mean	(1·4)		(2·9)					
Energy (MJ/kg)	$6·86^{c}$	$6·53^{c}$	$9·58^{a}$	$8·70^{b}$	0·25	0·01	0·01	NS
Lean carcass composition†								
Water	770	779	760	734	8	NS	NS	NS
Protein	214	212	211	217	6	NS	NS	NS
Ash	34·9	36·5	36·1	34·5	0·6	NS	NS	NS
Phosphorus	6·17	6·76	6·61	6·48	0·17	NS	NS	NS

NS, not significant.
Values with common superscript letters do not differ significantly ($P < 0·05$).
* After bleeding, without liver, kidneys or pancreas.
† Calculated after deduction of diethyl ether-extract fraction.

the caecum. The relative weight of the gizzard was decreased by about 20 %, that of the liver was increased by about 25 % and that of the abdominal adipose tissue was increased about sixfold. No change was observed in the relative weight of the pancreas. The weight of the kidneys was slightly increased by over-feeding. Starving caused a reduction only in weights of liver and abdominal adipose tissue.

Blood plasma, liver and kidney composition

Force-feeding or starving did not affect the blood packed cell volume. The plasma glucose concentration was not changed by force-feeding, but the glucose concentration in the plasma of the force-fed chicks fell more quickly during starvation than did that in the *ad lib.*-fed group, with the result that after 30 h of starvation the plasma glucose was reduced by 7 % in the *ad lib.*-fed group and by 20 % in the force-fed chicks (Table 5).

Force-feeding caused increases in the plasma FFA and triglyceride levels. Although starving resulted in increased FFA level in both groups, and to a similar extent (about 55 %), it caused a more pronounced decrease in the plasma triglycerides in the force-fed chicks (a two- to threefold decrease). The plasma cholesterol level was slightly, but not significantly, increased by force-feeding but was not affected by starving in either group. Force-feeding caused an increase in the total plasma protein concentration; this increase was due to α_2-, β- and γ-globulins and not to albumin, the

Table 4. *Relative organ weight (% body-weight) and liver and kidney composition (mg/g) of chicks following 15 d of force-feeding or* ad lib. *feeding*

(Mean values for eight chicks/group)

	Treatment				SE of mean	Statistical significance of effects of:		
	Ad lib.-fed		Force-fed			Force-feeding	Starving	Interaction
	Fed	Starved	Fed	Starved		($P <$)		
Organ weight:								
Crop*	0·391^b	0·437^b	1·13^a	1·12^a		0·01	NS	NS
SE of mean	(0·018)		(0·03)					
Proventriculus*	0·660	0·617	0·769	0·785	0·056	0·05	NS	NS
Gizzard*	3·27^a	3·30^a	2·43^b	2·68^b	0·13	0·01	NS	NS
Small intestine*	3·38	3·18	4·24	4·07	0·34	0·05	NS	NS
Caecum*	0·462	0·491	0·413	0·442	0·033	NS	NS	NS
Pancreas	0·442	0·410	0·452	0·463	0·023	NS	NS	NS
Liver	3·18^b	2·79^c	4·08^a	3·34^b	0·11	0·01	0·01	NS
Kidney	1·05	1·05	1·12	1·28	0·07	NS	NS	NS
Abdominal adipose tissue	0·203^b	0·075^b	1·28^a	1·09^a	—	0·01	0·05	NS
SE of mean	(0·059)	(0·056)	(0·08)					
Liver composition:								
Protein	192^b	211^a	190^b	209^a	3	NS	0·01	NS
Fat	36·9^b	31·1^b	47·9^a	34·9^b	1·7	0·01	0·01	NS
Cholesterol	5·49	5·40	4·65	5·16	0·25	0·01	NS	NS
Glycogen	13·7^a	0·22^b	17·8^a	0·19^b	—	NS	0·01	NS
SE of mean: Fed					(1·6)			
Starved					(0·03)			
Kidney composition:								
Protein	187^b	184^b	213^a	174^b	7	NS	0·05	0·05

NS, not significant.

Values with common superscript letters do not differ significantly ($P < 0·05$), as judged by the Newman–Keuls test.

* Empty weight.

concentration of which decreased slightly but not significantly. Starving had no effect on the total protein content or on the above fractions. Among the lipoproteins, the relative concentration of pre-β-lipoprotein was markedly increased by force-feeding but fell to very low concentrations during starvation in both groups.

Force-feeding did not change the protein concentration (N ×6·25) in the liver (Table 4). Starving caused a slight but statistically significant increase in protein concentration which was most probably due to the decrease in fat. The fat content was increased by about 20 % in the force-fed group (4·8 %; 3·7 % in the *ad lib.*-fed chicks). Starving reduced the fat content in both groups. A slight decrease was observed in the liver cholesterol concentration of the force-fed chicks. Glycogen concentration was not affected by force-feeding; starving reduced this value almost to zero. The kidney total protein (N ×6·25) concentration was increased in the non-starved, force-fed group. Starving caused a substantial and significant reduction in the kidney protein content of the previously force-fed chicks but did not affect the controls in a similar way.

Table 5. *Blood packed cell volume, plasma composition and plasma lipoprotein composition of chicks after* 15 *d of force-feeding or* ad lib. *feeding*

(Mean values for eight chicks/group)

	Treatment				SE of mean	Statistical significance of effects of:		
	Ad lib.-fed		Force-fed			Force-feeding	Starving	Interaction
	Fed	Starved	Fed	Starved				
Packed cell volume	0·284	0·295	0·294	0·309	0·008	NS	NS	NS
Plasma composition:								
Glucose (mmol/l)	$14·0^{a}$	$13·0^{b}$	$13·9^{a}$	$11·1^{c}$	0·3	0·01	0·01	0·05
FFA (mmol/l)	424^{b}	663^{b}	604^{b}	920^{a}	82	NS	0·05	NS
Triglycerides (g/l)	$1·33^{b}$	$0·68^{c}$	$2·13^{a}$	$0·75^{c}$	0·09	0·01	0·01	0·01
Cholesterol (mmol/l)	3·08	3·34	3·86	3·68	0·23	NS	NS	NS
Protein (g/l)	38·9	37·7	44·3	42·4	2·0	0·05	NS	NS
Albumin (g/l)	15·2	13·1	14·5	13·9	0·8	NS	NS	NS
α_1-globulin (g/l)	2·1	2·2	2·3	2·3	0·5	NS	NS	NS
α_2-globulin (g/l)	3·8	4·7	5·2	4·8	0·4	0·01	NS	0·01
β-globulin (g/l)	$14·8^{ab}$	$13·5^{b}$	$17·2^{a}$	$16·1^{ab}$	0·8	0·05	NS	NS
γ-globulin (g/l)	$3·1^{b}$	$4·2^{ab}$	$5·0^{a}$	$5·2^{a}$	0·5	0·05	NS	NS
Lipoprotein fractions: (% of total)								
β-lipoprotein	$63·7^{a}$	$65·5^{a}$	$51·1^{b}$	$74·4^{a}$	3·7	NS	0·05	NS
Pre-β-lipoprotein	$12·2^{b}$	$0·0^{c}$	$30·5^{a}$	$1·5^{c}$	0·01	0·01	0·01	0·05
SE of mean	(3·1)		(5·4)	(1·3)				
α-lipoprotein	$24·1^{ab}$	$34·5^{a}$	$18·4^{b}$	$24·1^{ab}$	3·4	NS	NS	NS

NS, not significant; FFA, free fatty acids.

Values with common superscript letters do not differ significantly ($P < 0·05$), as judged by the Newman–Keuls test.

DISCUSSION

Growth, body composition and food utilization

Giving the young chick excessive amounts of food, by by-passing the appetite barrier using the technique of force-feeding, enhanced body-weight gain. The increase in body-weight resulted mainly from lean body substance (water, protein and ash) and partly from fat deposition (Table 3). It should be noted that the weights of the control chicks and composition of their carcasses were quite similar to the values reported by other workers (Scott, Nesheim & Young, 1969; Edwards, Abou-Ashour & Nugara, 1971).

The cessation of voluntary food consumption by the force-fed chicks was not the result of 'stress' caused by handling or by the introduction of a tube into the crop. At the start, when they were force-fed smaller amounts of food than the amounts consumed by the controls, the chicks ate additional food voluntarily. The cessation of voluntary food intake occurred later, when the amount force-fed exceeded the quantity consumed by the control chicks (Fig. 1).

The reduction in protein utilization of the force-fed chicks was probably caused by the excessive amount of protein consumed. Protein utilization decreases with increased consumption (Summers & Fisher, 1961).

Energy retention was substantially increased in the force-fed chicks. This increase could be caused by any or all of the following: (*a*) a reduction in the relative amount of energy diverted for maintenance could occur, since the birds were growing more rapidly; (*b*) there may be an increased efficiency in conversion of carbohydrate to fat; in the present work the chicks force-fed twice daily could be considered as receiving discrete meals; it was demonstrated that meal-fed rats ingesting the same quantity of food as nibblers deposited excessive amounts of fat (Cohn, Joseph, Bell & Allweis, 1965); moreover, adipose tissue develops the enzymic mechanism for rapid and efficient conversion of glucose to lipid (Leveille, 1970); (*c*) the force-fed mash was finely ground and blended with water; these treatments could increase the digestible or metabolizable energy of the diet (Lepkovsky & Furuta, 1960; Calet, 1965); (*d*) following force-feeding the chicks became torpid for 3–5 h; this torpor could cause a reduction in the energy expended.

Changes in the digestive tract, liver and kidneys

The smaller weight increases found in the proventriculus and small intestine (20–25 %) as compared with that of the crop (300 %) (Table 4), were probably due to the fact that all the food was introduced into the crop in two meals, whereas its passage through the proventriculus and intestine extended throughout the day. In contrast to the increased weights of the proventriculus and small intestine, the relative weight of the gizzard was reduced. This reduction was probably due to the mechanical treatment of the food, i.e. grinding and blending with water, which reduced the activity of the gizzard which fulfils the same functions (Hill, 1971). No change was observed in the relative weight of the pancreas but its absolute weight was increased. This adaptation probably enabled it to secrete an increased supply of digestive enzymes in response to the large amounts of food passing through the digestive tract.

Plasma and liver composition

The trend in the changes observed in the blood plasma of the force-fed chicks was in agreement with the changes observed in the force-fed goose with fatty liver (Nir, 1972). Plasma lipids and β-globulin were increased and albumin was decreased. However, these changes were slight as compared with those observed in the force-fed goose and were not always statistically significant. It may be suggested that if, in the force-fed obese goose with fatty liver, the changes in blood plasma were the result of both excessive food intake and of malfunction of the fatty liver, in the force-fed chicks these changes were the result of excessive food intake only, which strained fat metabolism and transport. The livers of the force-fed chicks were larger than those of the controls but they were not fatty. Only a slight increase in their fat content was observed (from 37 to 48 g/kg), and the protein content was not changed. It is therefore suggested that force-feeding in the present work caused little or no metabolic strain.

The increase in plasma triglycerides was parallel to a marked increase in pre-β-lipoprotein, which is associated with a high-carbohydrate intake and the transport of the synthesized fat from the liver to the adipose and other body tissues (Frederickson, Levy & Lees, 1967).

Effect of starving

The effect of starving on the carcass composition differed between the groups. In the control chicks, starving caused a higher depletion in protein than in fat, the losses being 10·3 and 8·1 g/chick, respectively. In the over-fed chicks, the values were 7·0 and 17·8 g/chick. The loss of liver fat was also higher in the force-fed chicks than in the controls. These differences were in accordance with the differences in plasma glucose and FFA found between the groups following starvation: there was a larger increase in plasma FFA and decrease in plasma glucose ($P < 0.05$) and triglycerides ($P < 0.01$) in the force-fed chicks.

Similar effects of fasting on the fowl have already been described (Langslow, Butler, Hales & Pearson, 1970; Nir, Levy & Perek, 1973). Therefore, when the liver glycogen reserve was depleted, the over-fed chicks may have mobilized mainly fat as an energy source, whereas in the control chicks gluconeogenesis from tissue protein was emphasized (Hazelwood & Lorenz, 1959). Obese, non-diabetic humans secrete large amounts of insulin (Vague, Boeuf, Depieds & Vague, 1969). This possibility should also be considered in the over-fed obese chicks. Hyperinsulinism in the fowl causes an increase in plasma FFA, accompanied by a decrease in plasma glucose and voluntary food intake (Nir & Levy, 1973); similar findings were made with force-fed chicks.

The chicks were able to develop a remarkable capacity to deal with quantities of food exceeding the amounts consumed voluntarily. The excessive amounts of dietary protein and energy were efficiently converted into tissue protein and reserve fat. We therefore suggest that, up to a certain level of excessive feeding, the limiting factor for growth in chicks is that of appetite.

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