NATURAL FOOD AND FISH FEEDS

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THE IMPORTANT OF NATURAL FOOD FOR FISH FRY

Rearing fry and fingerlings is to nurture 3 or 4-day-old postlarvae, which start to eat food, into fingerlings for stocking in grow-out ponds. It is generally divided into two stages: at the first stage, fry are cultured for 18–25 days to a body length of 3 cm. At the second stage, fry are reared for another 3-5 months to fingerlings with a body length of 8-20 cm. Most of the grow-out ponds are stocked with fingerlings, but sometimes with some two-year-old fingerlings.

At fry and fingerling stage, especially at fry stage, fish are not only delicate and small, but their power of movement and their ability to feed are weak. Their diet is restricted to a number of items and they have very low adaptive power to changes in environmental conditions and have little power to escape from enemies. They, on the other hand, have a high metabolism. Careful management should therefore be performed to raise the survival rate of fry and fingerlings and to produce healthy and desirable-sized fingerlings.

BIOLOGY OF FRY AND FINGERLINGS

Fish have a fast growth during fry and fingerling stage and their biological characteristics are different from that of the adults, especially in feeding habits, growth and habitus.

1. Food intake

Because of fry and fingerling are changes their feeding organs, feeding patterns and food composition All in all, animal feedstuff is considered to be of great importance for fry and fingerlings. They have a higher metabolic intensity, faster growth and greater food intake, but all these are relatively declining with the increase of their body weight. The amount of their food intake varies with kinds of food and water temperature, etc. at different developmental stages. Under the optimum temperature, the maximum daily food intake of Grass carp fingerlings comes to 49.9% of its body weight, but only 16.8% and 16.4% for Silver carp and Bighead respectively. It is reported that the daily food intake of juvenile Grass carp is 32-71% and the diurnal variation of food intake is as follows: juvenile Grass carp have a maximum food intake at 8:00 and 16:00 and it increases in the evening while the maximum food intake of Silver carp and Bighead fingerlings is between 12:00-20:00 and it declines after 20:00. Silver carp and Bighead stop eating between 24:00 and 06:00 and the intensity of food intake is rising obviously after 08:00. The retention time of food in the gut of fry and fingerlings is related to the water temperature. It is shown by the experiment that rotifera and Daphnia Bosmina longirostris fed to Grass carp fry and fingerlings remain in the gut for an hour and a half to three hours and twenty minutes at water temperature of 20–22°C. When the water temperature reaches to 30–32°C, foods are digested in less than one hour. The food in Silver carp's gut is digested in one hour and twenty minutes at water temperature of 22–26°C and even within one hour when the water temperature is 30°C.

2. Growth rate

Fry and fingerlings of various species have different growth rates. Even the same species also have different growth rates at different developmental stages. At fry and fingerling stage, Black carp, Grass carp, Silver carp and Bighead all have a high growth rate, but from fry to summerlings, their relative growth rate is at its maximum, which is the peak in their life span. Particularly, the relative growth rate is much higher between 3 and 10 days after stocking and the daily growth rate is 15-

25% in length and 30–57% in weight. Based on the measurement, within 10 days after being stocked in ponds, the body weight of fry would be double 6 times for Silver carp and 5 times for Bighead. On an average, it is double the previous weight every two days. But fish during this period are small in size and therefore, the absolute increase of their body weight is rather low. The average daily increase in body weight is only between 10 and 20 mg and the average daily increase in body length is 0.71 mm for Bighead and 1.2 mm for Silver carp. (Table 1)

Table 1. Growth Rate of Silver carp and Bighead Fry

Species	Bighead		Silver carp	
Age	Body length	Body weight	Body Length	Body weight
2	8.1	4	7.2	3
4	8.5	12	8.1	10
6	11.6	27	10.7	21
8	11.8	54	13.3	40
10	13.0	90	18.8	94
12	15.2	134	19.2	188

At the fingerling stage, the relative growth rate conspicuously decreases, compared with the fry stage. Within the rearing period of 100 days, the body weight of fish is double 9-10 times. On an average, it doubles every 10 days, which is 5-6 times less than that at the fry stage. However, the absolute increase in weight is remarkable. (Table 2)

Table 2. Growth Rate of Silver carp, Bighead and Grass carp Fingerlings Unit: mm &g

Species	Silver carp				Bighead				Grass carp			
Age (day)	Total body length	Body weight	Average daily increment		Total body length	Body weight	Average daily increment		Total body length	Body weight	Average daily increment	
			Body length	Body weight			Body length	Body weight			Body length	Body weight
20	47	1.08	3.1	1.4	435	0.9	5.0	5.16				
27									57	1.48	3.4	3.8
60	173	55.3	2.4	6.78	242	207.5	2.3	7.1				
74									216	157	2.6	8.4
120	318	420			376	633						
134									372	661		

In accordance with the observation during the cultivation, the fry of four species collected from rivers and polycultured in a manured pond have different growth rates. After being stocked for 1-- 4 days, the growth of Grass carp is the fastest; Silver carp and Bighead the second. However, after the 8th day of rearing, Silver carp always come in first; Bighead the second; Grass carp the third and Black carp always the last. This remains until the fry reach to summer fingerlings. Apart from heredity, the growth rate of cultivated fish is closely related to the ecological conditions such as nutrition, stocking density, water quality and temperature, etc.

3. Distribution and environmental requirements

Fry are more or less evenly distributed in the pond shortly after stocking. When fry reach a body length of about 1.5 cm, their distribution follows the change of their feeding habits. Grass carp and Black carp start to move to the middle and bottom layers of water body and most of them live in the shallow places around pond dikes where there are more macro-zooplankton and benthos; whereas Silver carp and Bighead gradually leave pond banks and move to the central area and stay in the upper and middle layers of water body. Fry and fingerlings have a much higher metabolic rate, particularly at the fry stage. For example, the oxygen consumption rate and energy demand of Silver carp fry is 5-10 times as much as that of summer fingerlings and it is even much higher than that of two-year-old fingerlings. The status of other species is similar to the above; therefore, high dissolved oxygen and abundant food supply should be ensured for rearing fry and fingerlings. The optimum pH value in nurturing ponds is around 7.5-9. Fry can tolerate salinity of 4-5%. Its growth however, is retarded when the salinity reaches 3%.

DIGESTION IN TELEOST FISHES

Definition of the Gut and its Subdivisions

The gut is a tubular structure beginning at the mouth and ending at the anus. It is commonly divided into four parts. The most anterior part, the head gut, is most often considered in terms of its two components, the oral (buccal) and gill (branchial, pharyngeal) cavities. The foregut begins at the posterior edge of the gills and includes the oesophagus, the stomach, and the pylorus. In fish, such as the cyprinus, which lack both a stomach and pylorus, the foregut consists of the oesophagus and an intestine anterior to the opening of the bile duct. This posterior demarcation is arbitrary and primarily for convenience during gross dissection and may have little relation to the functional aspects. The midgut includes the intestine posterior to the pylorus, often with no distinct demarcation posteriorly between it and the hindgut. The midgut often includes a variable number of pyloric caecae (pyloric appendages) near the pylorus, although pyloric caecae are always absent in fishes which lack stomachs. The midgut is always the longest portion of the gut and ma be coiled into complicated loops (often characteristic for each species) when longer than the visceral cavity. In some fish, the beginning of the hindgut is marked by an increase in diameter of the gut. The posterior end of the hindgut is the anus. Only rarely is there a hindgut caecum in fish comparable to that found in mammals. A cloaca (a chamber common to anal and urogenital openings and formed from infolded body wall) never occurs in teleost fish, except the Dipnoi, although it is universal in sharks and rays.

Evolution and Ontogeny of the Digestive Tract

The gut of protochordates consists of a simple, straight tube through which food is propelled by ciliary action. An early elaboration of the gut is seen in lampreys where an infolding (typhlosole) of the gut wall presumably increases the absorptive area of the gut. A similar, but spiral, infolding of the hindgut occurs in sharks, rays, and the coelocanth (Latimeria) in the form of the spiral valve (spiral intestine). The gut wall in lampreys also contains diagonal muscle fibres, although true peristalsis (travelling wave of contraction) is thought not to occur. Teleost fish have a gut which is typical of the higher vertebrates in many respects, although the midgut villi (absorptive papilli) of mammals are absent in fish.

The gut forms very early during embryological development (ontogeny) and shows some of the same stages of development as in the evolution of the vertebrate gut, some larval fish having portions of their gut which are ciliated, for example. The general character and even the length of the gut may change during development. The gut appears to shorten, for example, in fish in which the larval stage is herbivorous and the adult stage is carnivorous. In other fish the gut length remains relatively constant in proportion to body size throughout life.

Generalizations

A number of generalizations about the gut of fishes have been attempted, many of them extrapolated from terrestrial vertebrates. The commonest of these, the observation that herbivores have longer guts than carnivores, appears only partially true in fish. While this may be true in limited groups of fish, it is not universal in teleosts as a whole. Gut lengths have been listed as 0.2-2.5, 0.6-8.0 and 0.8-15.0 times body length in carnivores, omnivores, and herbivores, respectively. Thus, the longest guts are found in herbivores, but not all herbivores have long guts; i.e., the gut lengths of some herbivores are shorter than those of some carnivores. Part of the explanation lies in the fact that many fish eat a variety of food, sometimes ingested with considerable indigestible material (e.g. mud) which often influences gut length. The size of the food particles - from submicroscopic plankton to whole fish - may also influence gut configuration.

One generalization so far appears to have no exception. In fishes having no stomachs, no acid phase of digestion occurs, even when the midgut develops stomach-like pouches anteriorly. Although gut tissues exhibit great versatility, the midgut appears unable (or does not need) to duplicate the stomach functions.

In general, most studies relating food habits to gut morphology show considerable relationship between the two. However, the gut also retains considerable reserve ability to respond to new foods, new environments, and new opportunities. This versatility has been demonstrated in a number of cases in which a single genus has adapted to new niches and evolved whole new modes of feeding and digestion to utilize otherwise unexploited food resources and done so over rather short evolutionary periods of time.

At the same time, there are usually severe constraints on adaptations to new food. As long as swimming continues to be important to a fish's lifestyle, any major change in body shape, such as a bulging visceral mass resulting from enlarging the stomach or lengthening the midgut, must extract a penalty in terms of increased effort needed for swimming. Feeding mechanisms must not interfere with the respiratory functions of the gills and vice versa. All in all, "packaged" so that any major change in the digestive system would call for major compromises in many other systems. Perhaps the best generalization is that teleost fish maintain an intimate relationship between the form and function of their gut and their food resource. In the final analysis, all of the other life processes continue to function only when sufficient materials and energy are obtained and assimilated via the gut.

Anatomy and General Physiology of the Gut

Functional Anatomy of the Gut

The mouth exhibits a variety of fascinating adaptations for capturing, holding and sorting food, ratcheting it into the oesophagus and otherwise manipulating it prior to entry into the stomach. Only two which have possible relevance to digestion Will be discussed.

In milkfish (Chanos), the gill cavity contains epibranchial (suprabranchia) organs dorsally on each side, consisting either of simple blind sacs or elaborate, spirally-coiled ducts. The organs occur in several relatively unrelated families of lower teleosts and apparently relate to the kind of food eaten. Those fish with simple ducts all eat macro-plankton and those with the larger ducts microplankton. Although their function is unknown, concentrating the plankton has been suggested as a possibility.

The common carp provides an excellent example of non-mandibular teeth being used as the primary chewing apparatus. Pharyngeal teeth occur in the most fully developed forms of the Cyprinidae and Cobitidae, although many other groups also show some degree of abrading or triturating ability with some part of the gill bars. In carp, the lower ends of the gill bars have a well developed musculature which operates two sets of interdigitating teeth so as to grind plants into small pieces before swallowing them. The grinding presumably increases the rather small proportion of plant cells which can otherwise be successfully attached by digestive enzymes.

Many fish which chew their food have some ability to secrete mucus at the same time and place. This would have some apparent benefit when ingesting abrasive food. Although one might be tempted to equate such secretions with saliva, enzyme activity in the mucus does not appear to have been demonstrated, so the mucus is only partly comparable to saliva.

The oesophagus, in most cases, is a short, broad, muscular passageway between the mouth and the stomach. Taste buds are usually present along with additional mucus cells. Freshwater fishes are reputed to have longer (stronger?) oesophageal muscles than marine fish, presumably because of the osmoregulatory advantage to be gained by squeezing out the greatest possible amount of water from their food (i.e., marine fish would be drinking seawater in addition to that ingested with their food and freshwater fish would have to excrete any excess water).

The oesophagus of eels (Anguilla) is an exception to this general pattern. It is relatively long, narrow, and serves during seawater residence to dilute ingested seawater before it reaches the stomach. A possible conflict between the osmoregulatory and digestive roles of the gut in marine fish in general will be discussed later (Section 3.5).

Fish stomachs may be classified into four general configurations. These include (a) a straight stomach with an enlarged lumen, as in Esox, (b) a U-shaped stomach with enlarged lumen as in Salmo, Coregonus, Clupea, (c) a stomach shaped like a Y on its side, i.e., the stem of the Y forms a caudally-directed caecum, as in Alosa, Anguilla, the true cods, and ocean perch, and (d) the absence of a stomach as in cyprinids, gobidids, cyprinodonts gobies, blennies, scarids and many others, some families of which only one genus lacks a stomach.

The particular advantage of any configuration seems to rest primarily with the stomach having a shape convenient for containing food in the shape in which it is ingested. Fish which eat mud or other small particles more or less continuously have need for only a small stomach, if any at all. The Y-shaped stomach, at the other extreme, seems particularly suited for holding large prey and can readily stretch posteriorly as needed with little disturbance to the attachments of mesenteries or other organs. Regardless of configuration, all stomachs probably function similarly by producing hydrochloric acid and the enzyme, pepsin.

The transport of food from the stomach into the midgut is controlled by a muscular sphincter, the pylorus. The control of the pylorus has not bean demonstrated in fish, but the best guess at this time is that it resembles that in higher vertebrates. The pylorus is developed to various degrees in different species for unknown reasons, in some species even being absent. In the latter case, the nearby muscles of the stomach wall take over this function, which may also include a grinding function by the roughened internal lining. In fish which lack a stomach, the pylorus is absent and the oesophageal sphincter serves to prevent regress of food from the intestine, i.e., in fish lacking a stomach and pylorus, the midgut attaches directly to the oesophagus.

The digestive processes of the midgut have not been studied extensively, except histo-chemically (see Section 4 for details on enzymes), but so far as known resemble the higher vertebrates. The midgut is mildly alkaline and contains enzymes from the pancreas and the intestinal wall, as well as bile from the liver. These enzymes attack all three classes of foods - proteins, lipids, and carbohydrates - although predators such as salmonids may be largely deficient in carbohydrases. The pyloric caecae attached to the anterior part of the midgut have attracted considerable attention because of their elaborate anatomy and their taxonomic significance. Histological examination has proved them to have the same structure and enzyme content as the upper midgut. Another suggestion was that pyloric caecae might contain bacteria which produce B-vitamins as in the rodent caecum. When tested, this hypothesis had no factual basis either. Pyloric caecae apparently represent a way to increase the surface area of the midgut and nothing more. This still leaves an interesting question of how food is moved into and out of the blind sacs which are often rather lone and slim: e.g., in salmonids.

The demarcation between midgut and hindgut is often minimal in terms of gross anatomy, but more readily differentiated histologically - most secretory cells are lacking in the hindgut except for mucus cells. The blood supply to the hindgut is usually comparable to that in the posterior midgut, so presumably absorption is continuing similarly as in the midgut. Formation of faeces and other hindgut functions appear to have been studied minimally, except histologically.

Peristalsis and its Control

Peristalsis consists of a travelling wave of contraction of the circular and longitudinal layers of muscle in the gut wall such that material inside the gut is moved along. The pharmacology of this system has been investigated in isolated trout intestine demonstrating that an intrinsic nerve network exists to control peristalsis; i.e., cholinergic drugs stimulated and adrenergic drugs inhibited peristaltic movements. The oesophagus arid stomach are also innervated extrinsically by branches of the vagal (cranial X) nerve. No studies appear to have been made so far concerning details of food transport through the teleost gut except for measurements of gastric evacuation time and total food passage time, although gut stasis has been hypothesized to occur in the Pacific salmon, as in domestic animals.

Gastric Evacuation Time and Related Studies

Many studies have been performed relating to developing an optimum feeding schedule, mostly for salmonids, but also including a number of other cultured fish. Variables considered with feeding rate and gastric evacuation time included temperature, season, activity, body size, gut capacity, satiety, and metabolic rate. A relatively consistent finding has been that gastric emptying rate declines more or less exponentially (sometimes linearly) with time. Larger meals first are often, but not always, digested at a faster rate than small meals and the amount of pepsin and acid produced was somewhat proportional to the degree of distension of the stomach. Stomach mobility often increases with the degree of stomach distension also. The appetite, digestion rate, and amount of secretions produced all decreased with decreased temperature, but the secretions also decreased if tested at temperatures in excess of the acclimation temperature. Appetite, i.e., the amount of food eaten voluntarily at one time, appears to be the inverse of stomach fullness, although this does not explain the entire appetite phenomenon. Appetite continues to increase for a number of days after the stomach is empty, indicating that additional metabolic or neural mechanisms are operating. Data on gastric emptying time, digestion rate, and temperature for sockeye salmon have been shown to reflect the underlying phenomenon. Direct comparison of data on digestion among different workers is difficult, because of differences in species, food and methods used.

The total time for passage of food through the gut until the non-digestible portions of a meal are voided as faeces has not commonly been measured. Gastric emptying time and total passage time in skipjack tuna at 23-26 C was about 12 hours with the intestine being maximally filled about five hours after eating and empty after about 14 hours. Defaecation often occurred 2-3 hours after a meal, presumably being material from a previous meal. After a single meal, faeces were found 24, 48 and even 96 hours after the meal. Thus, there is considerable variation in food passage time, presumably relating to the digestibility of the food. Magnuson (1969) commented that the passage rates in skipjack tuna were at least twice as fast as known for any other fish.

The obvious importance of food passage time becomes apparent when one wishes to analyze faeces resulting from ingestion of a specific meal. If one waits to feed a test meal until the gut is completely empty, then the digestion processes observed will be typical only of starved fish. If one feeds the test meal as part of a regular feeding programme, then the problem is to mark the food for appropriate faecal analysis. Thus the problem is not as simple as it might appear at first.

THE FERTILIZERS FOR FISH POND

Fertilization

In general it is believed that both phosphorus (P) and nitrogen (N) are required in minimum quantities for optimum primary production in fish ponds. The favorable action of potassium (K) has not been clearly demonstrated. Since the required quantities of these minerals are not always available in ponds, it has become a necessity to add them in order to establish an optimum standing crop of zooplankton. This can be achieved by adding minerals either directly (chemical fertilizers) or indirectly (organic fertilizers).

Fertilization means to supply phytoplankton with nutrients for photosynthesis and to promote the growth of phytoplankton, by which zooplankton and other aquatic animals are fed on for their growth and propagation. Fish feed on plankton and other hydro bios. Pond fertilization lies in cultivation of various food organisms and their propagation in large quantities in fish ponds to provide fish with abundant natural feeds, by which they can grow faster. The yield of fish pond may be raised thereby.

Among the fish food organisms in ponds, there are a series of interrelations between the predator and the prey. The biological term is “food chain”. Fish is the last link of the food chain of hydro bios in ponds.

e.g. phytoplankton→Silver carp
phytoplankton→zooplankton→Bighead
aquatic plant→Grass carp
plankton→benthos→Black carp

Usually, animals could use only 5–20% energy of both animal and plant feeds. Utilization of energy is related to the length of food chain. The shorter the food chain is, the higher the rate of energy transfer will be, in other words, the higher the utilization rate of energy transfer is, the higher the fish production will be.

The hydro bios in ponds are in a constant progress of growth and death. The dead bodies of organisms will turn from complex organic materials into simple inorganic materials through decomposition by bacteria, and then dissolve in water, which can again be utilized by phytoplankton to produce new individuals. Hence, the materials in ponds are in a constant state of circulation mainly through the food relationship between living organisms. This kind of circulation is called pond material circulation.

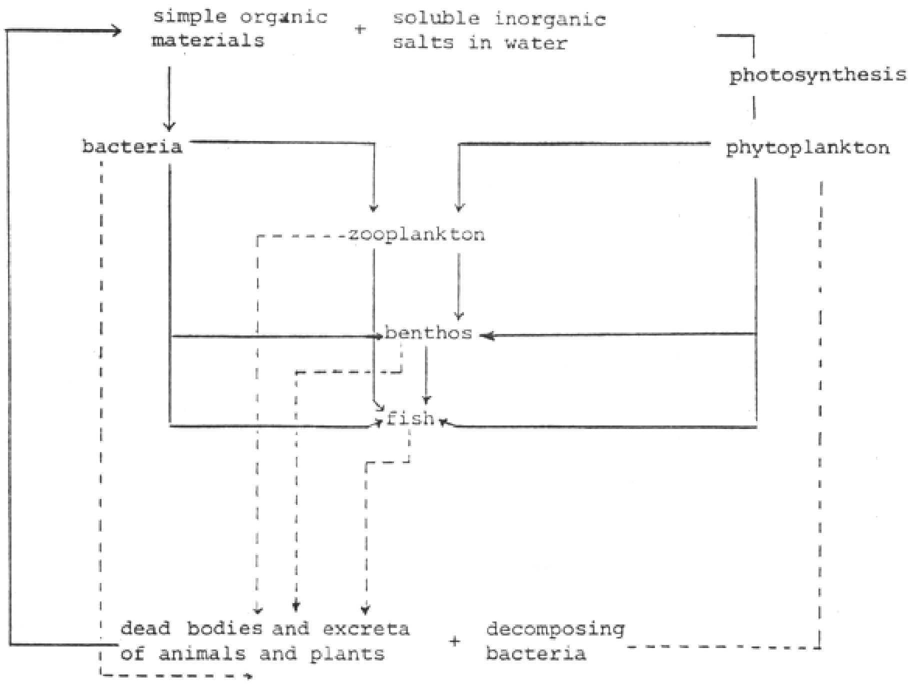

Fig 1 A diagram of material circulation in ponds

The process of pond material circulation is just that of the production of fish and their food organisms in ponds. The circulation originates from the soluble minerals in water. Under certain conditions of light and heat, the propagation of phytoplankton depends upon the amount of nutrients in water. In turn, the production of all food organisms depends upon the proliferation of phytoplankton. Fertilization is just to enhance the quantity of nutrients and to nurture food organisms in ponds so as to create favorable conditions for raising fish yield.

Chemical fertilizers

In general the mineral composition of chemical fertilizers is expressed either as a percentage of equivalent N, P_2O_5 or K_2O. In practice, the main fertilizers used are: super phosphate (containing about 20% P_2O_5), triple super phosphate (containing about 45% P_2O_5), urea (containing about 45% N) and NPK 15:15:15 (15% N, 15% P_2O_5, 15% K_2O).

(1) Kinds of inorganic manures and methods of application

Inorganic manures mean chemical fertilizers. According to the composition, the chemical fertilizers can be divided into three groups, that is, nitrogenous, phosphoric and potash fertilizers. The advantages of inorganic fertilizers are exact constituents, fast effect, and slight pollution, no consumption of dissolved oxygen in water, small application amount and convenient operation. However, when chemical fertilizers are applied in ponds, the first link of the food chain in ponds is principally phytoplankton which, if taken as food for zooplankton, is nutritionally not as nice as bacteria. Therefore, the zooplankton amount in ponds applied with inorganic manure often lags far behind that in ponds applied with organic manure. Moreover, in most ponds applied with chemical fertilizers, the predominant species of phytoplankton are Chlorophyta, which is nutritionally worse than the predominant species in ponds applied with organic manure, such as Chrysophyceae, Bacillatiophyceae and Cryptophyceae. In addition, the manure effect is rather short and it is difficult to control the water quality, therefore, the result of the application of chemical fertilizers there is not better than that of the application of organic fertilizers.

(i) Nitrogenous fertilizers

A. Liquid ammonia: Molecular formula, NH_4OH or NH_3 x H_2O, with a nitrogen content of 12-16%. It is a water solution of ammonia, which is an important product of small-scaled nitrogenous fertilizer factory with simple synthesizing procedure and low cost. Ammonia is in an unsteady state when in water, easy to volatilize, so it could almost lose its effect through the volatilization if it is exposed to the air for a long period of time.
B. Ammonium sulphate: Molecular formula, $(NH_4)_2SO_4$, with a nitrogen content of 20-21%. It is produced from the liquid ammonia directly neutralized with diluted sulphuric acid. It is white crystals when pure, apt to dissolve in water. 100 kg of water can dissolve 75 kg of ammonium sulphate. With a little absorption of moisture, it is convenient to preserve and apply.
C. Urea: Molecular formula, $Co(NH_2)_2$, with a nitrogen content of 44-46%. Ammonia and carbon dioxide are interacted and synthesized into urea under high heat & pressure. It is white crystals with a strong absorption of moisture. After dissolution in water, urea does not turn out ions and is unable to be absorbed directly by plants. It can be utilized by plants only after it is decomposed by urease excreted by urea-decomposing bacteria and transformed into ammonium carbonate. The conversion rate of urea is related with the temperature. It can be totally transformed into ammonium carbonate in 4-5 days at 20°C and in 2 days at 30°C.

(ii) Phosphoric fertilizers

Calcium superphosphate: Main contents, $Ca(H_2PO_4)_2$ H_2O with 12-18% of P_2O_5; subsidiary-contents, $CaSO_4$. $2H_2O$, about 50%. Usually, it is white powder. It is corrosive, and is apt to absorb moisture, smelling acidic since there is some free acid in the products.

(2) Methods of the application of inorganic manure

Nitrogen is one of the essential nutritional elements in a plant. It is also the principal content in protein, and can accelerate the formation of plant chlorophyll and strengthen photosynthesis. For this reason, the nitrogen content is one of the decisive factors of phytoplankton production.

Nitrogen is always short in pond water, so the application of nitrogenous fertilizer may achieve better results.

Nitrogenous fertilizer is generally better to be used as an additive because of its quick-effectiveness, and the nitrogenous fertilizer with ammonium content must not be mixed with strong-alkaline materials lest it should convert into gas and lose effect through volatilization. In the utilization of nitrogenous fertilizer in ammonium form, due attention must be paid to toxicity of ammonia. Either ammonium or liquid ammonia will become ionic $(NH_4)^+$ and nonionic (NH_3) once they are placed in water. This phenomenon may be expressed in the following formula:

$$NH_3 + H_2O \rightleftharpoons NH^+{}_4 + OH^-$$

In an acidic state, the balance inclines to the right side with the concentration of ammonium ions enhancing; and in an alkaline state, NH_3 concentration will raise high. As water temperature comes up to 25°C with pH6, the concentration of NH_3 holds 0.05% in total nitrogen; pH7, 0.49%; pH8, 4.7%; pH9, 32.9%.

NH_3 is toxic to fish. It poisons juvenile rainbow trout at 0.3-0.4 mg/L. The Chinese carp have a higher toleration to ammonia anyhow; ammonia inhibits the growth of fish. The mortal concentration is beyond 13 mg/L. The highest concentration permitted in the water body for fish farming is 0.1 mg/L. For this reason, the amount must be strictly controlled in one application. What is more, caution must be given to pH value to avoid being applied in strong alkaline water (e.g. just after pond clearing with lime) since liquid ammonia is alkaline itself. Besides, the amount of nonionic ammonia is rising with the increasing of water temperature, so special care is needed when nitrogenous fertilizer in ammonia form is used in hot summer and autumn.

The application amount of nitrogenous fertilizer depends upon the nitrogen content of the fertilizer applied. In a pond with the area of 1000 m^2 and the water depth of about 1.5 m, 2.5-3 kg may be given as base manure. From then on, the additive of the fertilizer is applied 3-4 times monthly with 0.75 kg/1000 m^2 each time. For example, if nitrogen content in ammonium sulphate is about 20% and 2 kg are given to 1000 m^2 as base manure, the amount of ammonium sulphate needed is 10 kg.

$$2 \text{ kg} \times 100/20 = 10 \text{ kg}$$

Applying method: make a solution of it and spread it near the dikes. In case of liquid ammonia, put the container with ammonia under water and then open the lid so as to let liquid ammonia diffuse out slowly. By this way, the volatilization can be avoided during the operation on the bank.

Most waters are lacking phosphorus, so it is important to apply phosphoric fertilizer, which can accelerate the reproduction of a zotobacteria, and enrich nitrogenous fertilizer in water.

The application amount of phosphoric fertilizer is calculated in accordance with the content of phosphoric acid applied. If 0.75-1.5 kg/1000 m^2 is used as base manure the annual amount might be about 5 kg. The method of calculation and application is the same as above.

Potassuum is also one of the principal nutritive elements for plants, but usually it is plentiful in water. There is no particular need to apply potash fertilizer in aquaculture.

Organic fertilizers

The most commonly used organic fertilizers are poultry manure, duck manure, pig dung, sheep dung and cow dung. In general, the fertilizing value of manure depends upon the C:N ratio in increasing order from cow and sheep manure followed by a grouping of pig, chicken and duck manure. The quantity of organic and inorganic fertilizers required varies from place to place and from pond to pond. In the catfish nursing ponds were fertilized with dry chicken manure at a rate of 50 kg/100 m^2 one week prior to stocking. This resulted in a good phytoplankton bloom, the pond water containing about 1.5-2 ml of plankton per 100 litre of water and having a secchi disk reading of 20-25 cm

(1) Kinds of organic manures and methods of application

Organic manures mainly refer to excrements of farm animals. It is a general term of manures containing organic matter. Nowadays, manures applied in fish ponds are mainly organic manures. In production, the following are often used, faeces and urine of livestock and poultry, night soil, green manure, compost and silkworm faeces etc. Only through decomposition by microorganisms, organic manures may be converted to nutrients, which plants can absorb, and then, organic manures are full of nutritional elements with long effects.

(i) Faeces and urine of livestock and poultry

A. Pig manure Composition and characteristics: pig manure includes much organic matter and other nutritional elements like nitrogen, phosphorus and potassium and is a kind of fine, complete manure. Pig faeces are delicate, containing more nitrogen with a c/n proportion of 14/1, smaller than that of other livestock faeces, so they are easy to rot. The major portion in pig urine is nitrogen in urea form. It is easy to decompose. See Table 3 about pig faeces elements.

Table 3. Nutritional elements in pig manure

Elements Kind	Moisture	organic matter	N	P_2O_5	K_2O
Faeces	85	15	0.6	0.5	0.4
Urine	97	2.5	0.4	0.1	0.7

Excretory amount: The excretory amount of pig is greatly associated with its body weight and food intake. From the measurements, a pig of 50 kg in body weight discharges about 10 kg per day, about 20% of body weight. A pig offers 1000 kg of faeces, 1200 kg of urine in the culturing period of 8 months from pigging to the adult Pig's daily excretory amount is less than cow's or horse's. But, pigs have the merits of faster growth, shorter fattening period, and suitableness for pen culture, whereas the scale of pig rising is much larger; so it is more beneficial to collect their manure.

B. Cattle manure Composition and characteristics: The elements are similar to those in pig manure, but cattle are ruminants and the food-stuffs are repeatedly masticated, so that the excrement is delicate. There is less nitrogen in the composition of cattle manure. The C/N proportion is 25:1. The cattle urine contains more nitrogenous element in hip uric acid form, ($C_6H_5CONHCH_2COOH$), so that cattle excreta are slow to decompose.

Table 4. Nutritional elements in cattle excrement (%)

element Item	Moisture	organic matter	nitrogen	P_2O_5	K_2O
Faeces	85	14	0.3	0.2	0.1
Urine	93	2.3	1.0	0.1	1.4

Excretory amount: The average daily excreta is 25 kg each, in which the ratio of faeces and urine is about 3:2. The yearly total amount of excrement for each is 9000 kg.

C. Poultry manures Composition and characteristics: Poultry manures include faeces of chicken, duck and geese, which contain much more nutrients. For the nutritional elements in poultry manures.

Table 5. Average amount of nutrients in poultry manures

element Kind	Moisture	organic matter	nitrogen	P_2O_5	K_2O
chicken faeces	50.5	25.5	1.63	1.54	0.85
duck faeces	56.6	26.2	1.10	1.40	0.62
goose faeces	75	23.4	0.55	0.50	0.95

Poultry manures are easy to rot and the nitrogen in poultry manures is chiefly in uric acid form, which could not be absorbed directly by plants, accordingly, poultry manures are better to be used after fermentation.

Excretory amount: As for each fowl, the yearly amount of excrement is not large, chicken 5-5.7 kg; duck 7.5-10 kg and goose 12.5-15 kg. Though the excretory amount of each is small, the quantity of poultry culture is often great; therefore, every fowl faece is one of manure sources. The total amount is quite a lot.

(ii) Night soil

Composition and characteristics: The composition of night soil is greatly dependent on the food, with a larger quantity of nitrogen, of which 70-80% is in urea form. It is apt to be absorbed with good effect. C/N proportion of human excreta is three to one. They are easy to ferment. The nutritional elements in human excreta are listed in Table 6

Table 6. Nutritional elements in human excreta (% in wet weight)

Element Kind	organic material	N	P_2O_5	K_2O
Human excreta	5-10	0.5-0.8	0.2-0.4	0.2-0.3
Human faeces	20	1.0	0.5	0.37
Human urine	3	0.5	0.13	0.19

Excretory amount: Night soil is a popularly-applied manure. From the measurements, a yearly amount from an adult is shown in Table 7

Table 7. Yearly amount of an adult's excreta (kg)

Item Kind	Excretory amount	Equivalent		
		$(NH_4)_2SO_4$	calcium superphosphate	potassium sulphate
Human faeces	90	4.5	2.25	0.7
Human urine	700	17.5	4.55	2.8
total	790	22	6.8	3.5

Night soil, used as manure has to be fermented before application. It can be rotten under anaerobic conditions in storage for 2-4 weeks. The decomposition of human waste produces ammonia. Under airtight conditions, after reaching to a certain concentration, ammonia can sterilize human waste. 1-2% quicklime or 0.1-0.2% formalin can also kill harmful insects and bacteria in night soil.

(iii) Silkworm dregs
Composition and characteristics : Silkworm dregs are composed of the faeces and sloughs of silkworm as well as mulberry residues. Silkworm dregs are full of organic matter. Dried ones contain 87% organic materials and 3% nitrogen. They are also good feeds for fish. 8 kg of silkworm dregs can produce 1 kg of fish.

(iv) Green manures
All wild grasses and cultivated plants, if used as manure, are called green manures, which are apt to rot and decompose, providing ideal environments for bacteria propagation, so they are good for application in ponds. A few common green manures are listed in Table 8

Table 8. Nutritional elements in green manures (% wet weight)

Plant	N	P_2O_5	K_2O
stems and leaves of broad bean Vicia faba	0.55	0.12	0.45
Rape Brassica napus	0.43	0.26	0.44
Alfalfa Medicago falcate	0.54	0.14	0.40
wild grass	0.54	0.15	0.46
barnyard grass Echinochioa crusgalli	0.35	0.05	0.28
water peanut Alternanthera philoxeroides	0.20	0.09	0.57
water hyacinth Eichhornia crassipes	0.24	0.07	0.11
water lettuce Pistia stratiotes	0.22	0.06	0.10

(v) Compost
Mixed compost is made of green manures and animal wastes. The mixture of several manures may make the ingredients of manure all the more suitable to the reproduction of plankton. The ratio of the constituents of manures depends upon the local sources of manures. From experiments, the following proportion of the ingredients of compost is suitable for plankton reproduction.

A. Green grass 8:cattle faeces 8: human excreta 1:lime 0.17.
B. green grass 1:cattle faeces 1:lime 0.02

There are two methods to make compost, that is, heaping and soaking. Heaping method: The manure heap is to be made under aerobic conditions. Spread one layer of green grass, then sprinkle some lime on it. Then add another layer of faece manure and do it again, layer by layer up to 1.5-2 m. At last, cover the heap with 5-6 cm thick of mud. The ingredients of the compost will rot and decompose. After 3-4 weeks the compost can be used.

Soaking method: dig a pit near fish ponds, put in green grass, lime and faeces one layer after another and then add some water to soak all manures with no leakage at all. The use of lime is to neutralize the organic acids turned out in the process of rotting & decomposition of the compost so that they could not attenuate the activities of microorganisms, whereas they could promote the decomposition of organic materials. The compost can be taken out for use after 10-20 day's fermentation at a temperature of 20°-30°C.

(2) Methods of the application of organic manures

(i) Application of Dacao:
Dacao is habitually used to fertilize pond water. The so-called Dacao means several composite plants. In reality the grass is not limited to composite plants; some gramineous plants and leguminous plants are sometimes used as well. In application, Dacao is just heaped at a corner of pond and is turned once every other day or every two days. The rotten part will go spreading in water and at last, the roots and stems which are hard to rot, will be dredged up out of ponds. The decomposition of green manure in water consumes a great amount of oxygen. In light of

experiments, if 1500 kg of grasses are applied in a pond of 1000 m^2 with a water depth of one meter, all fish may die of lacking oxygen as the pond is in a state of no oxygen from the second day to the sixth day. The peak of oxygen consumption is on the second and third day. And it will be reducing later on. It is appropriate to apply green manures frequently in a small amount, or to pour fresh water into ponds or adopt aerators, in order to guarantee plenty of oxygen in pond water.

(ii) Application of night soil.

Night soil is applied in fish ponds and the application amount varies with fish sizes. Before application, one portion of night soil is diluted with double portions of water. The dilution is then sprayed along the pond dikes. It is added once a day and the added amount is dependent on the fertility of water.

(iii) Application of livestock manures

The application of livestock manure as base manure is similar to that of green manures: heap the manures at a corner of pond or put them in small heaps in shallow water with a sunny exposure so as to make them decompose and spread gradually in water. If the manure is used as an additive, it is added in small heaps every 7-10 days.

(iv) Application of mixed compost

After fermentation, the compost is taken out, and given a flush. The liquid is collected and the residues are removed away. Spray the liquid evenly into ponds. In case the area of the pond is rather big, you may load the needed amount of manure on a boat, flush it with pond water in batches and then spray the liquid evenly in ponds. The manure dregs can be used to fertilize crops. For small ponds, there is no need to use a boat. The liquid is spread round the dikes. Another method is to put one side of the compost to the other in the pit and expose the liquid and then the manure liquid can be ladled out and spread into ponds according to the required amount.

The nutrients of the compost can be quickly absorbed by phytoplankton once the compost is applied in ponds. It consumes less dissolved oxygen in ponds since the organic materials are already decomposed after full fermentation.

(3) Effects of manure application on food organisms

First of all, the application of organic manure causes the propagation of bacteria in large quantities. On one hand, the bacteria decompose organic materials, mineralizing them into nutritional inorganic materials, which can be utilized by phytoplankton; on the other hand, they themselves take part of the nutrients as their own structural materials, reproducing a large population of bacteria.

After organic manure being applied, the organic detritus in water is increasing in quantity. The organic detritus carries dense bacteria on its surface; which are the important food for lower aquatic animals and filtering fish.

After manuring, the predominant species of plankton at their initial appearance in water depend closely on the properties of the manure. If organic manure is applied, those that are fond of organic materials will show the first population bloom phytoplankton: Ochromonas spp. Cryptomonas; zooplankton: Urotrichia spp. etc. For inorganic manure, the predominant species which will be seen at first are centric diatoms Centrales and Scenedesmus acuminatus. There is a close relationship between the amount of manure applied and the plankton community. Huge amount of manure will lead to the presence of some species of green algae Chlorophyta and blue algae Cyanophyta while small amount of manure will lead to the presence of Navicula rostellata and Cyclotella stelligera etc.

After each application, the nutrient content in the water increases, resulting in a plank tonic peak. Phytoplankton which is easily digested by silver carp reach a peak after 4 days, whereas those that are not so easily digested will attain a climax in 5-10 days. Zooplanktons reach a peak in 4-7 days.

Protozoan will be the first zooplankton to reach a peak, followed by rotifers, cladocerans, and finally copepods. Since protozoan multiply by binary fission, by which the population increases very rapidly, it will, therefore, be the first to reach a peak. Rotifers undergo parthenogenesis under normal condition. The eggs produced are not very many, with an average of 10-20 eggs during their life span. Thus, the rotifer population reaches a peak slightly later than the protozoan. Cladocerans also reproduce parthenogenically, but the span between hatching and sexual maturity is longer. So the cladoceran peak appears later than that of the rotifer. The timing of manure application is most important. Ideally, the peak should appear at a time

FUNDAMENTAL OF FISH NUTRITION

Significance of food application

In addition to the fertilization in ponds for proliferation of natural food organisms for fish, artificial feeds must be supplemented to meet the demands of various species of fish. Fish feeds are the prime material base of high-density fish culture. Applying artificial feeds in fish pond can raise the per-unit yield by a big margin. Take common carp as an example. The output does not exceed 25--30 kg/mu in extensive culture, whereas in intensive culture the output will be as high as 200–250 kg/mu. The rapid increase of yield comes from the direct effect of artificial feeding, the so-called fish yield of artificial feeding; however, the plankton-eater output is also enhanced. Especially in the system of polyculture in China, the consequence of feeding is more conspicuous. Because the food applied can be directly taken in by the so-called feed-eaters, in turn, the excreta of which can fertilize the pond water, multiplying the natural food for the plankton-eaters. In such a culture system, the yield of these species often occupies ⅓ of the total fish output.

Fish requirements for different nutrients

The nutrients that fish require are the same as the other animals. They can be sorted into five kinds: protein, carbohydrates, fats, vitamin and minerals. The demands of fish for these nourishing elements are the fundamental basis for selection and preparation of fish feeds.

Basis for selection and preparation of fish feeds.

(1) Protein
Protein is the basis of all living things. Just as other animals, from food, fish take in protein which's decomposed into amino acid through enzyme in the digestive organs. The amino acid is absorbed internally and synthesized into fish protein for growing mending tissues and maintaining life activities. It is used as energy for fish activities when fats and carbohydrates are not sufficient. One gram of protein can supply 4 kilo calories.

The demand of fish for protein contents in feeds is generally 25---40%. It is higher than the demand of terrestrial animals like chicken or pig or cattle, that is 12---17%. Since fish are cold-blooded animal without need of maintaining body temperature, they require lower energy comparatively. Different fish have different feeding habits, so do their requirements for protein contents in feeds. Carnivorous fish like rainbow trout and eel demand higher protein contents, while herbivorous fish lower.

The nutritional value of food depends not only on the quantity of protein but also on the quality of it, namely, the compositions of amino acids. Amid acid is the elementary unit, of which protein is constructed. The researches have proved that several amino acids are essential to fish growth. Therefore, they must be fully prepared into the feeds. These amino acids are termed essential amino acids while the other amino acids, which may not exist or may be just a little in feeds, are called dispensable amino acids because they are needed only in small amounts or can be synthesized internally.

The following ten amino acids are essential amino acids to fish: isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, arginine, and histidine. These ten must be included in fish feeds so that they can satisfy the nutritional requirements of fish and guarantee the normal development and growth. Besides, the proportion between different essential amino acids in protein must conform to the nutritional requirements of fish, which is dependent on the composition of amino acids in fish protein, so the proportion of all essential amino acids of fish may be referred to the composition of fish body protein. From the above-mentioned factors, We can arrive at a conclusion that the nutritional value of protein is determined mainly by the completeness of the sorts of essential amino acids and the equilibrium of specific value between all essential amino acids to the fish you feed. As for the incomplete and unbalanced protein, we can still raise its nutritional value greatly by way of supplementing those amino acids it lacks.

(2) Carbohydrates

carbohydrates are also called saccharide, in other words, the chief source of energy. Through digestion, they are decomposed into monosaccharide absorbed and utilized by fish body. In the organic body, part of them is decomposed through oxidization into carbon dioxide and water, releasing energy. Applicable heat is 4 kilocalories each gram of carbohydrate; part of them is conveyed into livers and muscles as glycogen to be preserved for the time being and the remaining part may be converted into fats, to be cumulated for life maintenance in case of shortage of food or stoppage of food-taking.

Cellulose is also a kind of carbohydrates, the major component of plant cell wall. Among the cultivated fish, only a few species like Tilapia and milk-fish can digest cellulose at a rather low utilization rate. It is believed that Cyprinids lack the cellulolytic enzyme. In consequence, they are unable to utilize cellulose, and neither are Grass carp, the typical herbivorous fish. An appropriate amount of crude fibers in fish feeds can stimulate the digestive movements of the intestinal tracts so as to promote the digestion and absorption of other nutrients.

(3) Fats

Fats are also a source of energy. Every gram of fats deliver 9 kilocalories of applicable heat. Fats are decomposed in digestive tracts into fatty acid and glycerol which can be absorbed. After absorption, the body fats are synthesized from the excessive fatty acid and glyceral, storing in subcutaneous tissues, muscles, spaces between connective tissues and the abdominal cavity.

Fats are apt to deteriorate through oxidization, bringing about toxic substances like aldehyde and ketone etc, which are detrimental to fish and destroy Vitamin E in fish feeds. If fish take in too much deteriorated fish meal and silkworm pupae, they will suffer from thin-back disease, muscular atrophy, losing weight and higher mortality.

(4) Vitamins

Vitamins are organic trace elements indispensable for fish. There are so many sorts of these substances with various physiological functions; however, all of them are indispensable to keep fish fit with a normal growth.

A number of Vitamins take part in the process of metabolism: e.g. Vitamin B1 of body carbohydrates; Vitamin B6, of proteins; Vitamin C, that of the synthesis of body protein of animal; And Vitamin D, of the normal metabolism of calcium and phosphorus, promoting the formation of skeleton.

As it is, it is not easy to determine the exact amount of various Vitamins required by fish. On the basis of the practical state and the characteristics of the cultivated species in China, fresh feeds are added to make up the deficiency of Vitamins. If pellet feeds are applied in farming Grass carp, green grass may be supplied at intervals so as to replenish the Vitamins the fish lack and the effect is desirable.

(5) Minerals
Minerals are essential elements of fish body composition. Without minerals, the organic bodies are unable to retain normal physiological functions. Phosphorus and calcium are the important components of skeleton. The deficiency of the two substances will affect the skeleton development with a result of deformity.

The minerals demanded by fish come basically from feeds and part of them directly from environmental water. Fish absorb the calciferous and phosphorous salts and the ions of clorine and sodium through their gill rakers and skin.

Minerals in diet may enhance the utilization of carbohydrates by fish, accelerate the growth of fish tissues like skeleton and muscles, improve their appetite and speed up the growth of fish body, and therefore, in the preparation of fish feeds, the minerals must be taken into consideration. As a whole, some additives like bone powder and table salt in fish feeds are enough for the pond fish.

4. Principle of Feed formulation

The process of determining the right kind and amounts of ingredients to be mixed together to produce a nutritionally adequate diet for a species is referred to as diet formulation. Data on nutrient requirements and various information on feed ingredients are needs.

The three mathematical methods commonly used in balancing diets are: the square method (or Pearson's square), algebraic method, and the computer method of least-cost formulation.

A. Square method
This is the simplest method in formulating diets, particularly supplemental, without resorting to trial and error. The method works only when the desired level of nutrient in the diet is between the levels found in the ingredients. It balances the diet with respect to one nutrient at a time.

B. Algebraic method
The use of algebraic equation solved simultaneously is convenient for more complicated problems such as those involving many ingredients, fixed components and certain dietary restrictions.

C. Computer method of Least-Cost Feed Formulation
The nutrient requirements, nutrient composition of feedstuffs, digestibility, cost of ingredients, and dietary restriction (maximum or minimum levels of incorporation) are among the information needed in feed formulation with the aid of a computer. Linear programming is a mathematical technique using a computer to check all possible combinations of ingredients that would meet the desired levels of nutrients in the diet being formulated. Theoretically, there can be several solutions to a given problem, but as soon as the cost factor is considered, there will only be one least-cost formulation. The computer output has to be examined in order to produce a more realistic ration. Computer formulations have to be reviewed and revised from time to time as more information on nutrient requirements and digestibility become available or when there are changes in the nutrient composition and price of feedstuffs.