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Ammonium production during decomposition of fish food pellets in sea water

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Decomposition of organic nitrogen and production of ammonia from fish food pellets was observed over 26 days and described with kinetic first order model. The decomposition rate constant of organic nitrogen was 0.098 day^{-1} and was not dependent on the quantity of food pellets. Initial concentration of organic nitrogen and the final concentration of total ammonia-N were proportional to pellet concentration.

Key words: Ammonium, decomposition, food pellets

INTRODUCTION

Feeding of fish in cage culture with food pellets may cause the eutrophication of the farm environment. Excess nitrogen and phosphorus in fish farm surroundings originate from two sources, either by fish excretes (feces, urine) or by decomposition of food. Food pellets have very high levels of organic nitrogen, and the decomposition of waste products may produce nitrogen compounds very suitable for uptake by phytoplankton and benthic algae. Fish food pellets also contain vitamins and thus provide an excellent medium for growth of different microorganisms.

The knowledge of the rate of decomposition of pellet food in sea water and the consequent production of ammonium, a toxic agent for fish on the one side (WAJSBROT *et al.*, 1991; TUDOR *et al.*, 1994) and a link in the eutrophication process on the other, is therefore necessary to evaluate the of nutrient loading of an area in vicinity of fish farms and hatcheries as well as for their proper management.

MATERIAL AND METHODS

Twenty litres of non-filtered sea water salinity of 37 psu and ground commercial pellet (TROUVIT 2B: moist 9.8%, total protein 46%, cellulose 3.3%, fats 8.5%, carbohydrates 12.0%) were put in plastic containers in concentrations of 10, 20, 40, 80 and 160 mg dm^{-3}. The experiment began in October when the sea water temperature was about 17°C. Containers were kept in a dark thermostatic chamber at 17±0.5°C and aerated to provide sufficient oxygen and mixing. Sampling of sea water for total ammonium analysis (TAN) and oxygen was performed initially and every second day for total experimental time of 26 days.

Analysis of of total ammonium (TAN = NH_4^+-N + NH_3-N) was made after the method by SOLORZANO (1969), and oxygen was determined by WINKLER method (STRICKLAND and PARSONS, 1972).

The rate of organic nitrogen decomposition was modeled with a first order kinetic reaction

$$dN/dt=-kN$$

where N is the total concentration of nitrogen and k the decomposition rate constant. At any moment $N = N^o - N_a$ where N^o is the initial concentration of organic nitrogen and N_a the concentration of produced ammonium. Replacing N in a differential equation, and after integration, the analytical form of the dependence of TAN on time is

$$N_a = N^o (1 - exp(-kt))$$

and N^o and k on time were obtained by non-linear regression after the method of MARQUARDT (1963).

RESULTS

The production of ammonium during decomposition of fish food pellets was rapid. At initial concentrations of pellet of 10 to 160 mg dm^{-3} the concentration of TAN ranges from 0.2 to 1.73 mg dm^{-3} after four days of incubation (Fig.1). At the end of experiment the TAN concentrations reach maximum values of about 0.6 to 6.5 mgTAN dm^{-3} for pellet concentrations of 10-160 mg dm^{-3}.

The differences between the coefficients of the decomposition rates of organic nitrogen (k) from pellet fish food are not statistically significant ($P>0.05$) and the mean value of all experiments was 0.098±0.019 day^{-1} (± 95% confidence limit) (Table 1).

The initial organic nitrogen concentrations estimated by the model were lineary related to the initial pellet concentration in the sea water (C_P in mg dm^{-3}) (Fig. 2).

The regression was

$$N^o = 0.050C_P + 0.212 \qquad r^2 = 0.99$$

Since the intercept of the line is not statistically significantly different from zero ($P>0.05$) the initial concentration of organic nitrogen in pellet food was directly proportional to the initial pellet concentration.

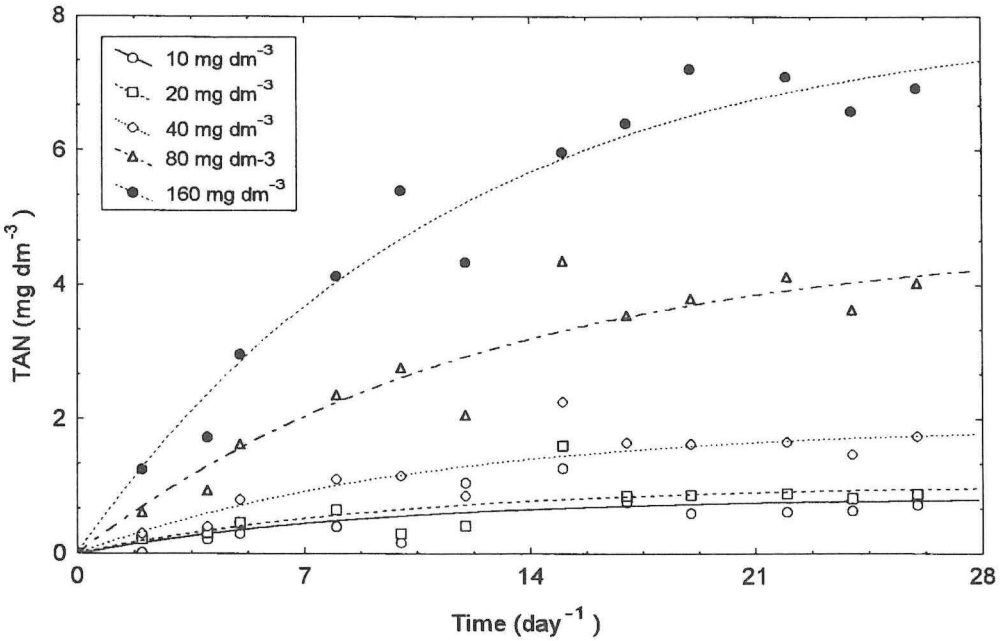

Fig 1. Concentrations of total ammonia (TAN) for different pellet concentration in sea water during the decomposition experiment. Lines represent the modelled ammonium production (see text)

Table 1. Values of model parameters for TAN production during pellet decomposition (N^o- is the initial concentration of organic nitrogen, k- is the decomposition rate constant, SE-standard error, r^2-coefficient of determination)

Pellet concentration (mg dm^{-3})	$N^o \pm SE$ (mg dm^{-3})	$k \pm SE$ (day^{-1})	r^2
10	0.839 ± 0.240	0.112 ± 0.084	0.556
20	1.030 ± 0.278	0.104 ± 0.074	0.576
40	1.916 ± 0.311	0.095 ± 0.039	0.816
80	4.718 ± 0.654	0.081 ± 0.024	0.912
160	8.025 ± 0.617	0.088 ± 0.015	0.964

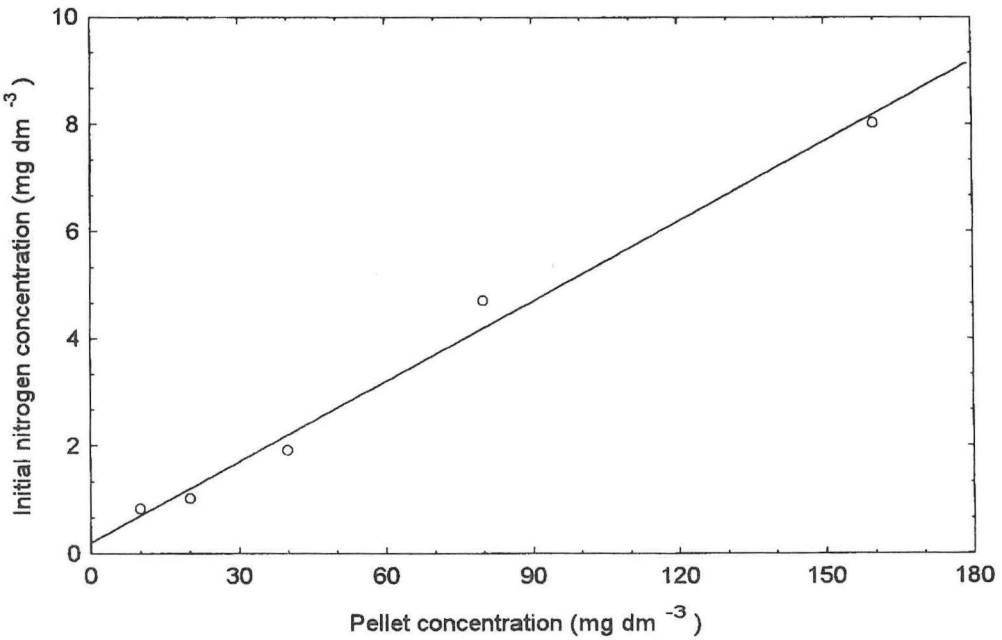

Fig. 2. Relationship between initial organic nitrogen concentration and pellet concentration in sea water

DISCUSSION

Ammonium is formed during decomposition of organic matter in sea water (VON BRAND *et al.*, 1937; GRILL and RICHARDS, 1964; GUNDERSEN and MOUNTAIN, 1973). Nitrogen mineralization is rather complex and there are several of intermediates between proteins and ammonium (GRILL and RICHARDS, 1964). The oxidation of one mole of ammonium

to nitrate consumes 1.8 mole of dissolved oxygen (GUNDERSEN and MOUNTAIN, 1973).

The decomposition rate of pellets was highest at the beginning of the experiment, whereas later the ammonium concentrations increased at a lower rate and maximum concentrations were obtained between days 8 and 20. VON BRAND *et al.* (1937) also reported maximum concentrations of ammonium after a similar time period during the decomposition of phytoplankton whereas no nitrite was found. They suggested that the ammonification process is dominant during this time period whereas nitrification is negligible, and a simple two-parameter model of kinetic reaction of the first order may be applied for the ammonium production.

The rate of decomposition of organic nitrogen from food pellets is about 10% per day. It is not dependent on the initial pellet concentration. This is higher than the decomposition rate constant obtained from phytoplankton, which is about 5% per day (GRILL and RICHARDS, 1964). Heterotrophic population metabolizes amino acids and thereby maintain their C:N ratio. The lag stage is followed by a dramatic increase of amino acid accumulation and ammonium release (HALLIBAUGH, 1978). The rate of amino acid oxidation in the sea water is highest in the late summer and early autumn (0.04 to 0.1 day^{-1}) and lowest in winter (ANDREWS and WILLIAMS, 1971). Physical association of bacteria, substrates and dissolved enzymes, is important for protein decomposition (HALLIBAUGH and AZAM, 1983). The density of proteolytic bacteria in the area where the sea water for this experiment was taken from, was highest in autumn (KRSTULOVIĆ and ŠOLIĆ, 1988).

Since proteins contain 16% of nitrogen it may be assumed that an initial concentration of protein nitrogen for turnover into ammonium is

$$N^{o}_{org} = 0.16 f_{prot} C_P$$

where f_{prot} is the mass fraction of protein in food. According to the declaration of pellets (Trouvit), the proportion of total proteins is 46%, providing a nitrogen content of 0.074. The proteins of animal origin made up 40%, and N^{o} is estimated to 0.064. These product values slightly exceeded the value of 0.05 obtained in this experiment. Product value of 0.05 is possible when relative content of the protein in the food is 31%, or the part of nitrogen is not available for degradation. The low value of product is possible and than when some of the ammonium was nitrified.

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Proizvodnja amonijaka u morskoj vodi za vrijeme razgradnje peletirane hrane za ribe

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SAŽETAK

Posude s 20 litara nefiltrirane morske vode s koncentracijama peletirane hrane za ribe od 10, 20, 40, 80 i 160 mg dm^{-3} inkubirane su u mraku uz snažnu aeraciju pri 17°C 26 dana. Svaka dva dana uzet je uzorak vode u kojem je određena koncentracija ukupnog amonijaka. Vremenske promjene koncentracije amonijaka opisane su kinetikom prvog reda. Konstanta razgradnje organskog dušika bila je 0.098 dan^{-1} i ne ovisi o količini peleta u morskoj vodi. Početna koncentracija organskog dušika i konačna koncentracija ukupnog amonijaka bila je proporcionalna koncentraciji peleta.