International Council for the Exploration of the Sea

C.M.1977/E:18
Fisheries Improvement Committee

Krill, *Euphausia superba*, and blue mussel, *Mytilus edulis*, as supplementary food in aquaculture experiments

by

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Abstract

The present paper treats of aquarium experiments that were carried out to test the nutritional value of two primary consumers, baltic blue mussel, *Mytilus edulis*, and antarctic krill, *Euphausia superba*, as additional protein sources in aquaculture. On an experimental basis, tested on rainbow trout, *Salmo gairdneri*, both organisms were superior to pellets if used as only food, blue mussel more so than krill. As additional food one substitution per week of pellets by an equal amount of krill or blue mussel on a dry weight basis enhanced growth, two substitutions per week of the pellet ration by krill or mussels or both did not. Health and meatquality were better in all groups receiving mussels and/or krill as a substitution of part of the pellet rations.

Résumé

La valeur nutritive de deux invertébrés, la moule, *Mytilus edulis*, et le krill antarctique, *Euphausia superba*, a été étudiée en aquarium en vue d'une application en aquaculture de ces deux consommateurs primaires comme source de protéine additionnelle pour des truites arc-en-ciel, *Salmo gairdneri*. Expérimentalement, ces deux invertébrés, administrés comme unique aliment, se révélaient supérieurs aux granulés du commerce, plus particulièrement la moule. Administrés comme aliment additionnel, en substituant la ration de granulés une fois par semaine par une portion de moules ou de krill égale en poids sec à une portion de granulés, ils amélioraient la croissance comparé à la ration de granulés seuls. Les rations de granulés substituées deux fois par semaine par une portion de moules ou de krill ou des deux, influencaient la croissance négativement. Par contre, toutes les rations contenant moules ou krill ou les deux, amélioraient aussi bien la santé des truites que la qualité de leur chair.

Introduction

The prospect of increasing intensification of aquaculture throughout the world is accompanied by a prospect of stagnation if not decrease of conventional protein sources for fish feed, a prospect which made it look worthwhile to search for new animal protein sources practicable in aquaculture.

In an attempt to identify such new sources of animal protein for aquaculture, two marine invertebrate species occurring in considerable quantities were tested for their value as food for rainbow trout, *Salmo gairdneri*: baltic blue mussel, *Mytilus edulis*, and antarctic krill, *Euphausia superba*. Blue mussel was chosen for its availability in the western Baltic, where it is hardly exploited at all, and for its known high nutritional value. Through new fishing and treatment techniques and ever rising prices of fishmeal the use of krill may become worthwhile considering in a near future.

The first three experiments of a series in progress are presented here:

Experiment I: Pure *M. edulis* diets in different quantities/day, compared on a dry weight basis with a pure commercial pellet diet.

Experiment II: Pure *E. superba* diets in different quantities/day, compared on a dry weight basis with a pure commercial pellet diet.

Experiment III: A commercial pellet basis diet which was once or twice a week substituted by a mussel- and/or krillration equivalent to the pelletration on a dry weight basis.

Material and methods

Blue mussels were dredged at regular intervals in the Eckernförde Bight (Western Baltic), pressure-cooked, hand shucked and deep-frozen. The krill originated from the catches of the "German Antarctic Expedition 1975/76" and was landed in raw-frozen plates. Proximate composition of *M. edulis*, *E. superba* and the pellets used in these experiments is shown in table 1.

Table 1: Proximate composition of feedstuffs

Feedstuff	Dry subst. % wet sub.	Protein %dry sub.	Lipids %dry sub.	Carbohydrates %dry subst.	Ash %dry sub.
M. edulis	28	63.0	13.2	7.7[+]	8.4
E. superba	24	55.8	27.6	.1[+]	15.1
Ewos F 83 (exp. I)	92	60.4[++]	13.2[++]	13.2[++]	11.0[++]
Trouvit 17 (exp.II+III)	91	51.6[++]	8.8[++]	---[+++]	---[+++]

[+] only glykogen

[++] calculated from declaration

[+++] not declared

Rainbow trout were purchased from a commercial trout farm as uniformly in size and weight as possible (Exp. I: $\bar{w}$=62.7 g, s=7.57; $\bar{l}$=17.44 cm, s= .76. Exp. II: $\bar{w}$=27.41, s=6.25; $\bar{l}$=12.40 cm, s= .91.
Exp. III: $\bar{w}$=66.56 g, s=2.88; $\bar{l}$=17.28 cm, s= .19). They were kept in cylindrical tanks (250 l) with a conical bottom designed for better evacuation of faeces and trash food. The water supply was untreated tapwater (not chlorinated) at a rate of 5-7 l/min. In all experiments each tank received a group of 40 fish. In biweekly intervals all fish were individually measured and weighed after anaesthesia with MS 222 (Sandoz). The diets of the different groups in the three experiments are represented in table 2.

Table 2: Diets. Quantities apportioned to each group in % body weight per day and dry weight equivalent of pelletration

Group:	1	2	3	4	5	6	7
Exp.I, %BW	4 P	2 M	3 M	4 M	5 M	6 (excess) M	–
part 1 PE	1	.15	.23	.30	.38	.46	
Exp.I %BW	2.3 P	2 M	–	4 M	–	7-8 (excess) M	–
part 2 PE	1	.26		.53		.93-1.06	
Exp.II %BW	1.5 P	3 K	4 K	5 K	6 K	–	–
PE	1	.53	.70	.88	1.05		
Exp.III %BW	1.3	1.3	1.3	1.3	1.3	1.3	1.3
PE	1	1	1	1	1	1	1
rations/week	6P	5P+1M	5P+1K	4P+2K	4P+M+K	4P+1/2MK	4P+2M

%BW = %body weight per day

PE = pellet equivalent on a dry weight basis

P = pellets, M = mussels, K = krill

Since the nature of the food tested (wet vs/+ dry food) does not permit the conversion factor (weight gain/weight of food) to be used as a criterium for food quality, conversion efficiency (CE = gain in dry weight of fish X 100/dry weight of food) and protein equivalent rate (PER = gain in wet fish weight/weight of food protein) were chosen instead.

Results

Growth, conversion efficiency and protein equivalent rate

Experiment I: The growth curves for the three experiments are shown in figures 1, 2 and 3. The two parts of experiment I (first part from 7°C to 10°C, second from 10°C to 15°C) differ in the increase of growth in the pellet fed-group once the temperature had passed 10°C (fig 1). Before the water reached this temperature, the pellet-fed group (No 1) showed the poorest growth together with group No 2, though receiving 3.85 times as much food (dry weight). Once the temperature passed 10°C the growth patterns changed: the pellet diet became much more effective, it even resulted in better relative growth than the 4% mussel diet whereas the 2% mussel diet became insufficient to maintain growth in group No 2 at about 14°C. Groups 3 and 5 have not been drawn in fig 1, their growth curves were exactly intermediate between groups 2 and 4, respectively 4 and 6. If compared on a dry weight basis, mussels sustained a far better growth than pellets.

As the growth curves already indicated, both conversion efficiency (CE) and protein equivalent rate (PER) confirm that mussels were very efficiently utilized at low temperatures (7-10°C) by trout, whereas pellets had low CE and PER values (figs. 4a and 5a). At a higher temperature (10-15°C) the PER and CE data for the groups fed with mussels were lower but still good, except for the lowest ration (2%) which was obviously below maintenance level. The group fed with pellets nearly doubled its CE (figs. 4b and 5b).

Experiment II: The krill diet experiment, conducted at low temperatures (7-10°C), showed a less spectacular influence on growth by the pure krill diets: on a dry weight basis, the krill diet equivalent to the pellet diet resulted in a better weight gain (this group was killed by a technical breakdown halfway the experiment), the next lower krill diet showed about the same weight gain as the pellet diet (fig. 2). The CE figures were significantly lower than those for trout fed with mussels at the same temperature (figs. 4c and 5c) whereas the PER levels were only slightly lower.

Experiment III: Next to the pure mussel and pure krill diets we tested both organisms for their influence on growth as supplementary food. The growth curves revealed a slightly better growth for the groups receiving once a week a mussel- or a krill ration than for the pure pellet group. The results for the other groups receiving twice a week a substitute for the pellet ration, whether only mussel, only krill or both, were grouped closely around the result for the pure pellet diet (fig. 3). Only the CE value for the "once a week mussels" group was somewhat higher than the pure pellet group which equalled the "once a week krill" group. All other groups had lower CE values. The PER was highest for the control group (pure pellet diet). The "once a week mussels" and "once a week krill" groups were quite better than the remaining groups (figs. 4d and 5d).

Health and meatquality

All three experiments had one unexpected and outstanding result: all groups fed on mussels or krill, whether pure diets or in addition to pellets, were obviously in better health than the groups fed on pellets only; skin lesions healed without showing any infections, whereas in the controls fed on pellets only skin lesions became infected without healing. At the end of the experiments from 50 to 80 % of the fish fed on pellets suffered from finrot, a disease which occurred only in a few individuals spread over the other groups. The overall impression was that mussel and krill fed groups were more vigorous than the controls, the krill fed fish more so than the mussel fed fish.

One group of experiment I was carried on after the end of the main experiment and continuously fed a mussel diet. After the stock of frozen mussels was exhausted, we started feeding spent mussels caught in summer. The first reaction of the fish was a total refusal of these mussels; after a week's starvation, they slowly started feeding until they developed an appetite near normal. After three months of feeding on these mussels the first fish began to show abnormal behaviour and died two or three weeks later. Dissection revealed the following symptoms: partly dissolved kidney, disconnection of bones from the backbone along the kidney, dissolution of the overlying muscle tissue (in dying fish!). Flüchter (1974) found a deficiency of a few amino acids in mussels to be responsible for the inability of dover soles to develope their gonads completely, if mussels are the only food. They also showed a general poor condition, discoloration of the blind side, haematoms and skin lesions. As no infection could be detected by our means, we supposed the spent mussels to cause the symptoms described above, thus krill was fed instead. Mortality stopped after about four weeks and the then remaining fish recovered completely. Not having been able to pin down the exact cause of the mortality we suspect a deficiency in some constituent of the spent mussels.

Meat-quality of the fish, as can be judged by colour, firmness and taste, was positively influenced by mussels and krill, both as only and additional food. While a pellet diet will give white muscle tissue, a mussel diet causes the fillet to take a pinkish-yellow colouring, whereas krill will colour the fillet from pale-pink over salmon-red (depending on the amount of krill fed), to bright red when used as sole food. The fillets of mussel and krill fed trout were firmer than those of the pellet fed fish. Though no regular organoleptic tests were carried out, we can confirm that mussel and especially krill fed trout tasted far better than the pellet fed fish and that their fillet had a firmer texture.

Conclusions

The results presented here seem to indicate that blue mussel was better utilized at a temperature below 10°C than above. On the other hand, pellets became more effective above 10°C. The high content of polyunsaturated fatty acids in mussels during the winter may be responsible for this good growth (Lee and Sinnhuber 1972). Since aquaculture in many regions has to cope with low winter temperatures, specific temperature-range adapted diets would be beneficial.

Small amounts of natural food organisms fed in addition to pellets ameliorated growth, meatquality and health of rainbow trout, larger amounts of the two organisms tested here influenced growth negatively for reasons unknown. On the other hand, pure diets of mussels and krill were clearly superior to pellets if compared on a dry weight basis.

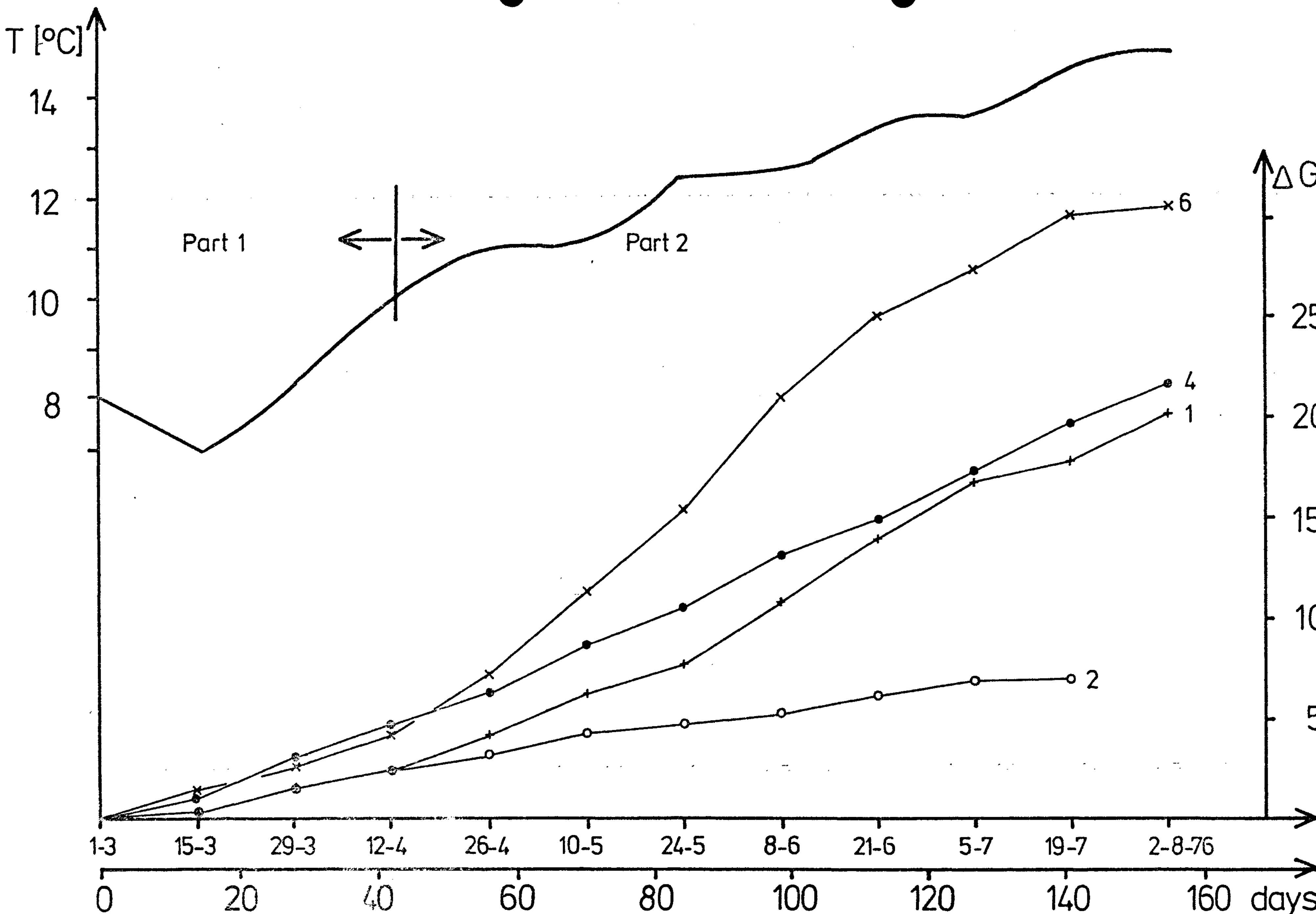
If mussels are used as fish food, they should be caught in early winter. Spent and spawning mussels seem to be deficient in some constituent which still has to be determined.

References

Flüchter, J. & Trommsdorf, H. 1974: Nutritive stimulation of spawning in common sole (Solea solea L.). Ber. dt. wiss. Komm. Meeresforsch., 23, 4:352-359

Lee, D.J. & Sinnhuber, R.O. 1972: Lipid requirements. in: Fish nutrition. Halver (ed). Academic Press, Inc. New York, N.Y.

Figure 1: Relative growth Experiment I



1=pellets,2=2% mussels,4=4% mussels,6=6-8% mussels (excess)

Figure 2: Relative growth Experiment II

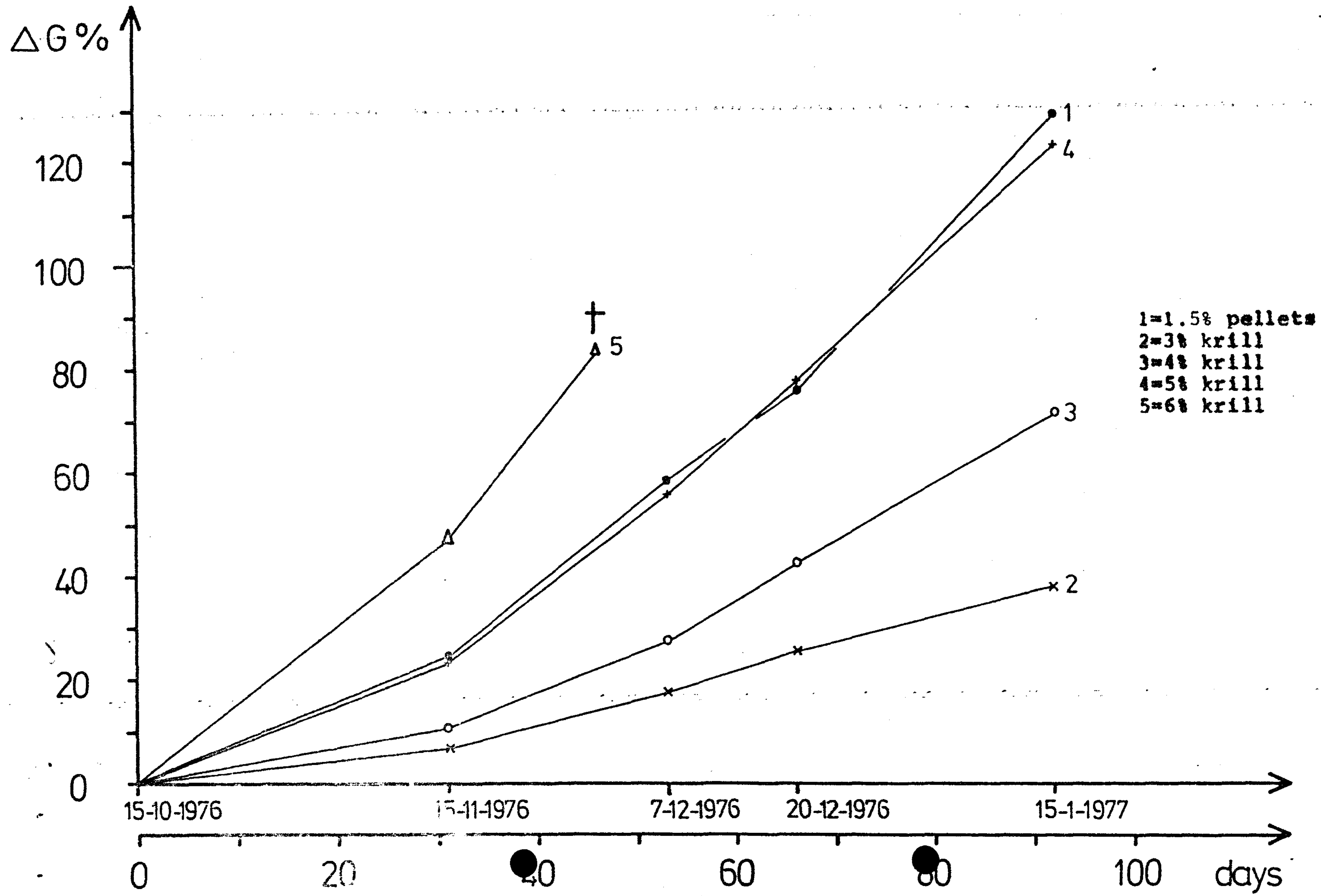
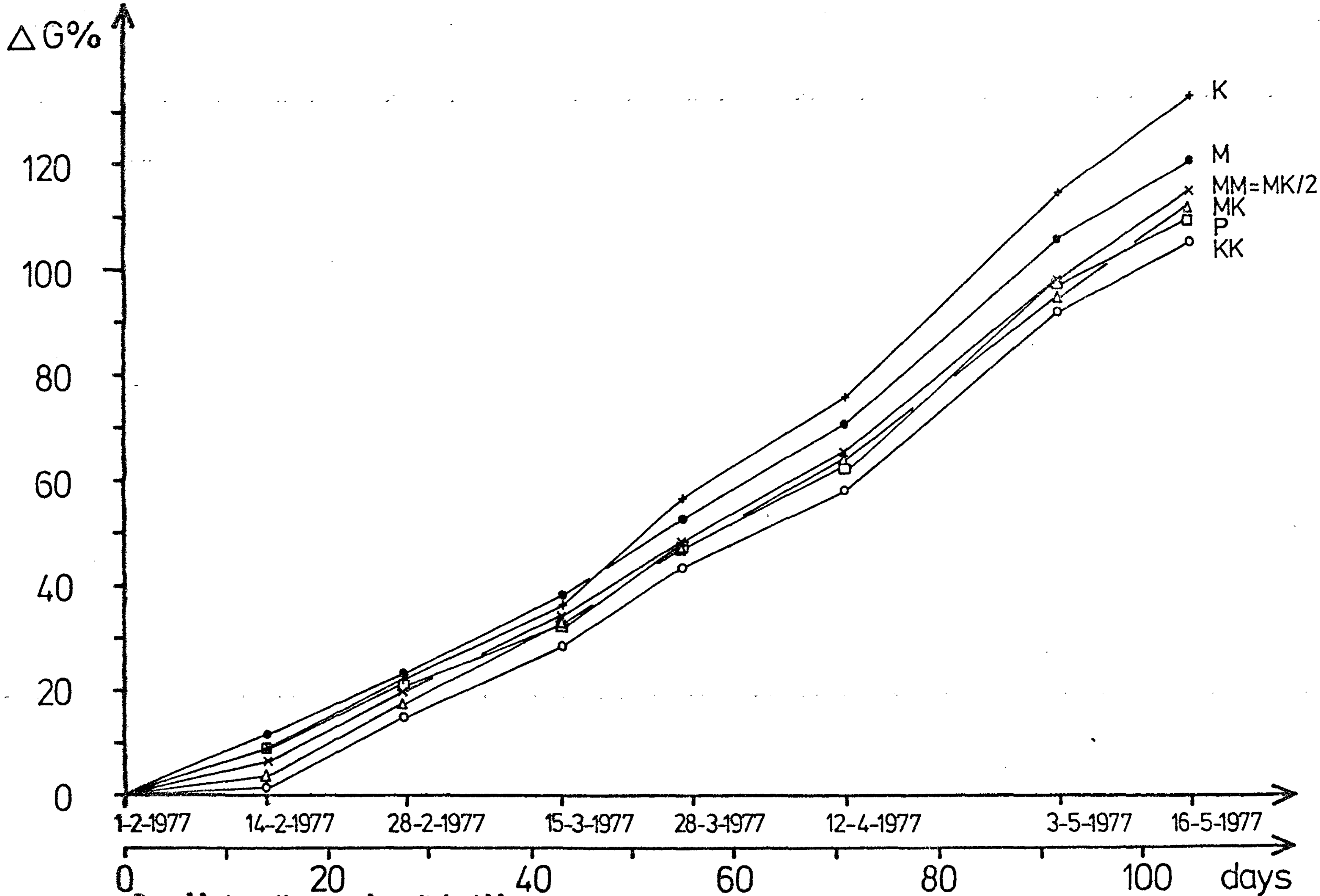


Figure 3: Relative growth Experiment III



P=pellets, M=mussels, K=krill

Figure 4: Conversion efficiency

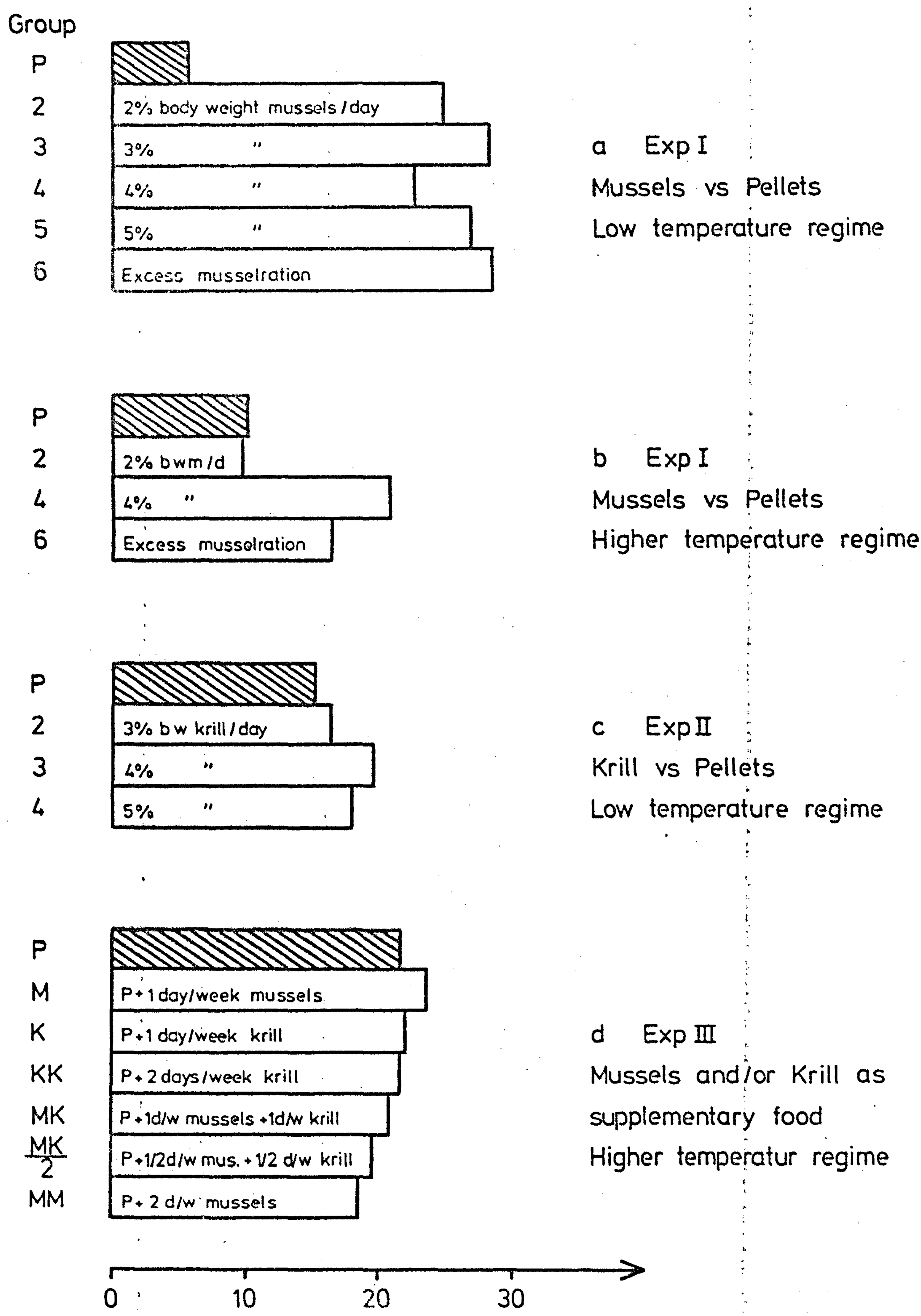


Figure 5: Protein equivalent rate