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INTERNATIONAL STUDY ON *ARTEMIA*[1]
XXX. BIO-ECONOMIC EVALUATION OF THE NUTRITIONAL VALUE FOR CARP (*CYPRINUS CARPIO* L.) LARVAE OF NINE *ARTEMIA* STRAINS

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ABSTRACT

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The nutritional value of freshly hatched nauplii from nine geographical strains of brine shrimp, *Artemia*, was determined for larvae of the carp (*Cyprinus carpio*). After 2 weeks of culture, the survival of carp larvae was over 90% and no significant differences in survival among treatments were detected. The growth rate of the larvae, however, was a function of the *Artemia* strain used. The highest weight gains were recorded with parthenogenetic *Artemia*, the lowest with Chaplin Lake brine shrimp and intermediate results with the other bisexual strains. With the exception of the Chaplin Lake strain, the growth results were positively correlated with the size and weight of the nauplii used.

A bio-economic study revealed that although all *Artemia* strains supported good survival and growth in carp larvae, the selection of specific cyst sources may result in important savings of *Artemia* cyst use in aquaculture hatcheries.

INTRODUCTION

The recent increase in the number of commercial sources of *Artemia* cysts (Sorgeloos, 1979, 1980a) provides choice but also results in the problem of selecting the best suited source of cysts for each specific predator. Differences in nutritional value of *Artemia* nauplii from various geographical origins are well documented for marine fish and crustacean larvae (Sorgeloos, 1980b, 1983; Beck and Bengtson, 1982). However, no information is available for fresh water organisms. Moreover, the importance of data for commercially important species has been stressed by Sorgeloos (1983).

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TABLE I

Some important batch characteristics of the *Artemia* cysts used in this study

Source of cysts	Hatching output[a] (no. nauplii/g cysts)	Nauplii harvesting time (hours after incubation of cysts)	Nauplius dry weight[a] (μg)	ET50[b,d] (hours)	LT50[c,d] (hours)	Type of *Artemia* strain B: bisexual P: parthenogenetic
San Francisco Bay, CA, U.S.A. batch no. 288-2596	435.5	24	1.63	6.5	26	B
San Pablo Bay, CA, U.S.A. batch no. 1628	497.7	24	1.92	5.9	26	B
Macau, Brazil batch no. 871172	529.0	24	1.74	7.0	27	B
Great Salt Lake, UT, U.S.A. batch no. 185	467.0	24	2.43[e]	6.8	26	B
Shark Bay, Australia batch no. 114	537.5	29	2.47	5.9	37	P
Chaplin Lake, Canada harvest 1978	400.4	27	2.04	4.2	16	B
Lavalduc, France harvest 1979	561.8	31	3.08	8.0	38	P
Tientsin, People's Republic of China harvest 1978	400.5	29	3.09	6.8	33	P
Margherita di Savoia, Italy harvest 1977	488.2	29	3.33	7.6	36	P

[a] From Vanhaecke and Sorgeloos (1983).
[b] ET50: median effective time for 50% reduced swimming activity of nauplii transferred to freshwater (nauplii only moving their appendages at bottom of container).
[c] LT50: median lethal time for nauplii transferred to freshwater.
[d] From Vanhaecke and Aertsen (1982).
[e] Calculated value, using the correlation equation between nauplius dry weight and cyst size (Vanhaecke and Sorgeloos, 1980).

The purpose of this study was to evaluate the nutritional value of newly hatched *Artemia* nauplii from nine geographical strains, for larvae of the carp, a freshwater fish of considerable commercial importance. The experimental results have been related to the biometrical, chemical and energetic characteristics of the corresponding *Artemia* strains used. An attempt was made to evaluate the variation in production costs of carp larvae as a function of the *Artemia* cyst source used.

MATERIALS AND METHODS

The *Artemia* cyst sources used in this study and some of their characteristics are given in Table I.

Cysts were incubated in standard hatching conditions (25°C, 35‰, 1000 lux) at 3 g cysts/l seawater. In view of their tremendous increase in hatching output at low salinity, Chaplin Lake cysts were incubated at 5‰ instead of 35‰ (Vanhaecke and Sorgeloos, 1983). Upon separation from the hatching debris, the nauplii were thoroughly washed with tapwater, blotted for 1 min on a paper towel and weighed to the nearest 0.1 mg. It has been verified that after this treatment the water content of the nauplii was not significantly different from one source of *Artemia* to another, i.e. 80.2 ± 0.6%. The nauplii were then resuspended in 100 ml of seawater and stored in a refrigerator (12—14°C) in cylindrical tubes under mild aeration. Every day a fresh stock of newly hatched nauplii was prepared.

Carp eggs, obtained after artificially induced spawning, were incubated in a 80-l flow-through unit (flow rate: 20 l/h) at 21 ± 1°C. Hatching occurred after 4 days. Two days later, each experimental tank was stocked with 70 larvae with absorbed yolk sacs (individual wet-weight: 1.40 mg). Feeding started the following day. The experimental setup comprised a series of 8-l aquaria which were constantly supplied with aerated tapwater at a rate of 4 l/h. In order to prevent losses of nauplii, overflow tubes were fitted with a 200 μm screen. The temperature was kept constant at 22.6 ± 0.7°C (S.D.) and the photoperiod at 14 h light. Dissolved oxygen levels were checked daily; they never dropped below 4.5 mg/l. For each *Artemia* strain three duplicate aquaria were set up.

The feeding schedule, expressed in % of live body-weight/day, was based on the data by Bryant and Matty (1980), namely: days 1—4, 200%; days 5—6, 150%; day 7, 125%; days 8—12, 100%; days 13—14, 75%. The amounts of food to be offered were determined according to growth-rate data for carp larvae, obtained in a preliminary experiment under identical conditions. Daily food rations were distributed over five feeding periods between 9 a.m. and 7 p.m. Unconsumed *Artemia* and faeces were siphoned off every morning.

Dead larvae were removed daily. On day 8, a subsample of 10—15 fish larvae per aquarium was removed and weighed. On day 15, the wet weight of all remaining fish larvae was determined. After blotting on a paper towel for about 10 s, the fish larvae were weighed to the nearest 0.1 mg in aluminium foil trays.

Both survival and wet-weight data were analysed for statistical significance with a one-way analysis of variance (Model I; Sokal and Rohlf, 1969). Survival data were normalized through an arcsin $\sqrt{\%}$ transformation. Duncan's Multiple Range test was used to identify individual treatment differences (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Compared with results reported for marine predators, where high mortalities were encountered at least with San Pablo Bay *Artemia* (Beck et al., 1980; Johns et al., 1980, 1981; Klein-MacPhee et al., 1980), in this study very high survival of carp larvae was obtained with all *Artemia* sources (Table II). No significant differences could be detected among cyst sources. Usher and Bengtson (1981) also obtained good survival of larval *Cyprinodon variegatus* fed with a San Pablo Bay diet. However, the observation that carp, a freshwater species, survives better on a San Pablo Bay diet than do marine species, supports the hypothesis of Schauer et al. (1980) that the low level of the fatty acid 20:5ω3 in San Pablo Bay nauplii is the cause of poor survival of marine fish larvae. Indeed, the fatty acid requirement of freshwater fishes can be met by short chain C18 polyunsaturated fatty acids, whereas marine organisms have a very limited ability to elongate and desaturate C18 polyunsaturates to ω3 series HUFA (Watanabe et al., 1978; Tacon and Cowey, 1983).

In comparison with data by Bryant and Matty (1980), specific growth rates of 40.9—44.8% per day after 1 week and 33.1—35% per day after 2 weeks in-

TABLE II

Survival and weight of carp larvae fed *Artemia* nauplii from various geographical origins

Source of cysts	Survival (%)	Mean individual weight after 7 days (mg)		Mean individual weight after 14 days (mg)	
		$\bar{X}$	S	$\bar{X}$	S
Margherita di Savoia	94.3	31.9^{a1}	2.0	188.4^{a1}	8.0
Tientsin	96.7	32.2^{a}	2.1	184.9^{a}	5.3
Shark Bay	95.7	31.8^{a}	2.1	$180.4^{a,b}$	5.2
Lavalduc	95.2	31.0^{a}	2.8	$179.5^{a,b}$	5.5
Macau	95.7	30.3^{a}	2.2	$173.1^{b,c}$	2.9
Great Salt Lake	93.3	29.7^{a}	1.5	$170.7^{b,c}$	2.3
San Pablo Bay	93.3	28.9^{a}	2.3	$169.5^{b,c}$	5.1
San Francisco Bay	93.3	29.9^{a}	3.6	166.4^{c}	12.3
Chaplin Lake	95.2	24.6^{b}	0.9	143.4^{d}	0.2
Unfed control	6.0[2]	—	—	—	—

[1] All results grouped by the same letter are not significantly different at the $P < 0.05$ level.
[2] The starved control was once fed by mistake.

dicate that all *Artemia* strains supported good growth of carp larvae. From Table II it is clear, however, that the growth rates depend on the source of *Artemia* cysts used. After 7 days of culturing, larvae fed with Chaplin Lake *Artemia* performed significantly less well than all other treatments. At the end of the experiment this trend was even more accentuated. Furthermore, parthenogenetic *Artemia* appear to assure the fastest growth in carp larvae.

The dependance of larval growth on the *Artemia* strain used as food is well documented (see review by Sorgeloos, 1980b). The critical role of the size of *Artemia* nauplii in fish rearing was reported by Smith (1976) and Beck and Bengtson (1982). Since the size of the food particle is also considered to be an important parameter in larval carp rearing (Kouril, 1981; Kouril et al., 1981), a detailed correlation analysis was made between the biometrical characteristics of *Artemia* and the wet-weight production data obtained with the carp larvae. The Chaplin Lake strain was omitted from this calculation because involvement of another limiting factor was suspected (see below). The highly significant ($P < 0.01$) correlation between the size and the weight of the nauplii and the growth of the carp larvae (Table III; Fig. 1) clearly indicates that larval growth in carp can be optimized by using *Artemia* strains that produce large nauplii. This provides confirmation of an earlier formulated hypothesis, namely, that as long as the prey size does not interfere with the ingestion mechanism of the predator (e.g. in carp rearing), the use of large *Artemia* nauplii will be beneficial (Vanhaecke and Sorgeloos, 1980).

The significantly poorer results obtained with Chaplin Lake nauplii cannot be explained by their size nor by their fatty acid composition (Seidel et al., 1982). The data on the mobility and survival of *Artemia* nauplii in freshwater (see Table I) indicate, however, that Chaplin Lake nauplii are at the predator's disposal for only a short period of time, which might explain their poorer performance as a food source for freshwater fish larvae. Furthermore, it is interesting to note that Lake Chaplin, unlike the other thalassohaline biotopes, is a sulphate-rich salt lake (Hammer, 1978), and that nauplii from this source have a relatively low energy content and consume much energy during their hatching and early development (Vanhaecke et al., 1983).

The data from the nutritional experiment together with the hatching output figures (Vanhaecke and Sorgeloos, 1983) allow a first bio-economic evaluation of the use of *Artemia* cyst sources. Since in most cases the use of live food in

TABLE III

Correlations between biometrical characteristics of *Artemia* cysts and nauplii, and larval growth of carp

Variables		Correlation equation	r-value
X	Y		
Nauplius volume index	Wet weight of carp larvae	$Y = 145.64 + 3.00\ X$	0.90
Diameter decapsulated cysts	Wet weight of carp larvae	$Y = 101.42 + 0.32\ X$	0.93
Nauplius dry weight	Wet weight of carp larvae	$Y = 150.39 + 10.66\ X$	0.89
Nauplius length	Wet weight of carp larvae	$Y = 84.71 + 0.17\ X$	0.82

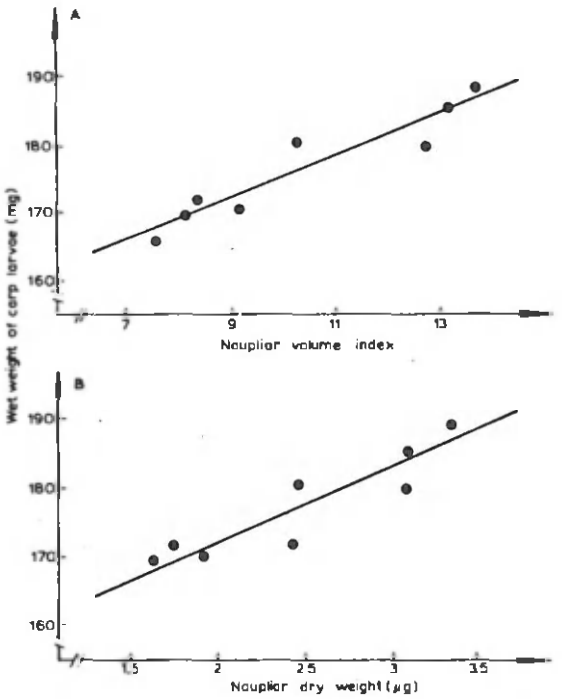

Fig. 1.Correlation between the naupliar volume (A) and naupliar weight (B) and the weight of 2-week-old carp larvae.

TABLE IV

Bio-economic evaluation of the use of specific *Artemia* cyst batches from various geographical origins for carp larvae

Source of cysts	Quantity of cysts needed for one carp larva (mg)		Quantity of cysts needed for the production of 1 g carp biomass (g)	
	In 1 week	In 2 weeks	In 1 week	In 2 weeks
Lavalduc	24.6	174.0	0.78	0.98
Shark Bay	25.7	181.9	0.81	1.01
Macau	26.1	184.8	0.86	1.08
Margherita di Savoia	30.2	217.7	0.95	1.16
San Pablo Bay	27.8	196.4	0.96	1.17
Great Salt Lake	29.6	209.3	1.00	1.24
San Francisco Bay	31.7	224.6	1.06	1.36
Tientsin	34.6	244.1	1.07	1.32
Chaplin Lake	34.6	244.1	1.40	1.72

carp culture is restricted to about 1 week (Coche and Bianchi, 1979), the weight data after 1 week have also been considered. During the experimental period each carp larva was offered 97.75 mg nauplii (dry weight); 13.82 mg was given during the first 7 days. The cyst quantities required for larval carp production are shown in Table IV. It is clear that the quantity of cysts to be used per unit of carp biomass varies considerably from one cyst source to another. The differences among cyst sources which are established after 1 week remain approximately the same after 2 weeks. The cyst quantity needed seems to be largely determined by the hatching quality of the cysts. Except for Chaplin Lake, production results with the carp larvae do not vary much with the *Artemia* source used. Anyhow, it is clear that, although all cyst sources studied are a suitable diet for carp larvae, careful selection can result in a substantial economy of cysts. Among the cyst sources (and batches) studied, the use of Lavalduc or Shark Bay cysts is to be recommended. In comparison with other cyst sources, savings can amount to 10—75%.

In practice the selection of a specific cyst strain and even batch (see Vanhaecke and Sorgeloos, 1983) should be based on a comparison of the cyst price and the hatching quality. When prices and hatching quality are comparable, preference should be given to *Artemia* strains producing large nauplii.

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