UNIVERSITE DE NANTES UFR SCIENCES

STUE M2 BBEM

COMPOSITION PRIMAIRE ET NUTRITION / ALIMENTATION SECONDAIRE

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RECUEIL DE FIGURES ET TABLEAUX

TABLE 3.

Proximate composition of the nine species of macroalgae.

Species of Algae	Composition (% Dry Weight)				Moisture (%)
	Protein	Fat	Carbohydrate	Ash	
Red algae					
A. spicifera	$15.4 \pm 2.0^{c,d}$	$1.3 \pm 1.0^{d,e}$	$34.6 \pm 4.2^{d,e,f}$	$48.7 \pm 6.8^{a,b,c}$	93.2 ± 12.9^{a}
G. fisheri	$16.8 \pm 2.5^{b,c}$	$1.1 \pm 0.1^{e,f}$	57.2 ± 7.0^{a}	24.9 ± 2.5^{d}	81.2 ± 6.7^{a}
G. salicornia	$16.9 \pm 1.8^{b,c}$	$1.3 \pm 0.1^{d,e}$	$31.1 \pm 4.6^{e,f}$	$50.7 \pm 3.3^{a,b}$	90.3 ± 13.4^{a}
G. tenuistipitata	24.7 ± 2.1^{a}	0.7 ± 0.0^{g}	$52.0 \pm 6.7^{a,b}$	22.7 ± 1.5^{d}	84.9 ± 5.0^{a}
Green algae					
C. racemosa	19.4 ± 1.5^{b}	3.2 ± 0.2^{b}	$27.4 \pm 3.9^{f,g}$	$50.0 \pm 6.2^{a,b}$	93.8 ± 13.2^{a}
E. intestinalis	18.9 ± 2.5^{b}	3.8 ± 0.4^{a}	20.8 ± 2.0^{g}	56.6 ± 3.5^{a}	94.9 ± 6.7^{a}
Brown algae					
D. dichotoma	$14.0 \pm 0.7^{c,d}$	2.8 ± 0.3^{c}	$38.3 \pm 3.9^{c,d,e}$	$44.9 \pm 5.5^{b,c}$	89.6 ± 10.0^{a}
P. minor	12.3 ± 1.4^{d}	$0.8 \pm 0.0^{f,g}$	$46.2 \pm 2.4^{b,c}$	40.8 ± 4.7^{c}	87.0 ± 5.0^{a}
S. polycystum	9.2 ± 1.1^{e}	1.5 ± 0.2^{d}	$41.2 \pm 3.2^{c,d}$	$48.1 \pm 6.7^{a,b,c}$	87.4 ± 12.9^{a}

Means and standard errors are presented. The results of Duncan's multiple range test performed on the means of protein, fat, carbohydrate, ash (% dry weight), and moisture (%) are shown beside the means; the same letter identifies algae that are not significantly different ($p < 0.05$). The experiments were performed in triplicate.

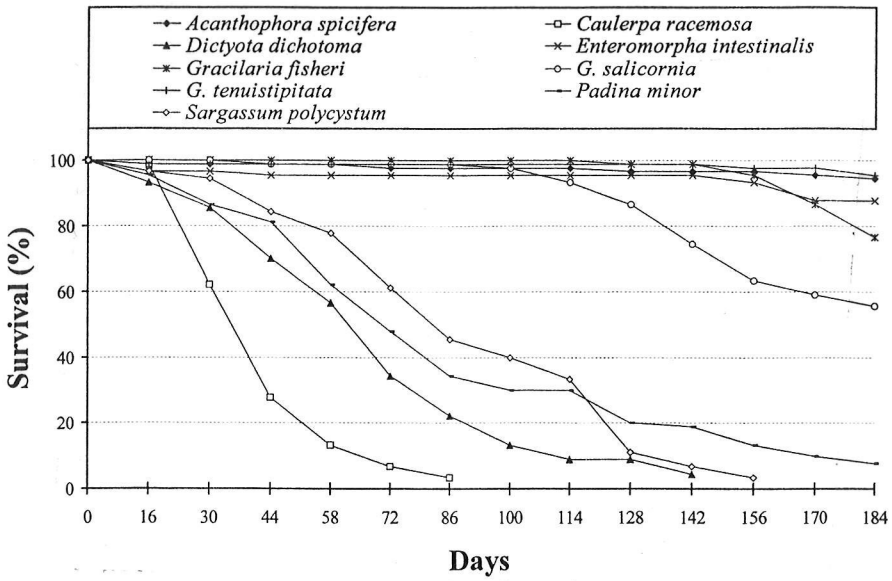


Figure 3. Percent survival of *H. asinina* fed nine species of macroalgae.

FCR of *H. asinina* fed nine species of macroalgae over a period of 184 days.

Species of Algae	Number and Total Weight of Abalone				Total Wet Weight Gain (g)	Total Dry Weight Gain (g)	Dry Weight Intake of Algae (g)	FCR*
	Initial		Final					
	Number	Weight (g)	Number	Weight (g)				
Red algae								
A. spicifera	90	37.8	85	294.3	85.5 ± 2.2^{b}	32.5 ± 0.8^{b}	186.5 ± 0.3	5.7 ± 0.2^{b}
G. fisheri	90	36.1	69	203.3	43.9 ± 5.4^{c}	16.7 ± 2.1^{c}	122.0 ± 1.7	7.4 ± 1.0^{b}
G. salicornia	90	37.5	50	148.4	36.9 ± 10.7^{c}	14.0 ± 4.1^{c}	201.2 ± 1.4	15.5 ± 4.0^{c}
G. tenuistipitata	90	36.6	86	410.3	124.4 ± 14.8^{a}	47.3 ± 5.6^{a}	151.6 ± 7.1	3.3 ± 0.6^{a}
Green algae								
C. racemosa	90	37.3	0	0	—	—	25.9 ± 0.4	—
E. intestinalis	90	37.7	79	194.1	52.1 ± 15.5^{c}	19.8 ± 5.9^{c}	178.3 ± 1.0	9.8 ± 2.7^{b}
Brown algae								
D. dichotoma	90	36.7	0	0	—	—	21.2 ± 1.8	—
P. minor	90	38.2	1	2.0	—	-4.5 ± 0.06^{d}	36.8 ± 7.2	—
S. polycystum	90	37.1	0	0	—	—	34.5 ± 4.6	—

Means and standard errors are presented. The results of Duncan's multiple range test performed on the means of total wet weight gain, total dry weight gain, dry weight intake of algae, and FCR are shown beside the means; the same letter identifies algae that are not significantly different ($p < 0.05$). The experiments were performed in triplicate.

* FCR = g. algae to produce 1.0 g. abalone wt. gain

Food conversion rate!

TABLE 1.

Growth rates of postlarval abalone fed unialgal diatom diets in laboratory experiments.

Abalone Species	Diatom Strain	Daily Growth Rate (μm SL/day)	Initial Abalone Size (μm SL)	Final Abalone Size (μm SL)	Digestion Efficiency* (%)	Temperature (°C)	Reference
H. discus hannai	*C. scutellum*	14.4	280	510–865	ND†	20	Kawamura and Takami 1995
	C. closterium‡	27.2	280	735–1,177	High		
	Navicula ramosissima	16.6	280	548–841	Low		
	Stauroneis constricta	21.6	280	724–865	Low		
H. discus hannai	*C. closterium*‡ growing on the chlorophyte *U. lens*	27	280	820	—§	22	Seki 1997
H. discus hannai	*Cocconeis* sp.	30.6	280	800	—§	17–18	Oghai et al. 1991
	C. closterium‡	24.1	280	690	—§		
	Navicula ramosissima	22.9	280	670	—§		
H. gigantea	*Actinocyclus tenuissimus*	12.8	321	552	—§	19	Ishida et al. 1995
	Cocconeis sp.	32.6	340	927	—§		
	Melosira moniliformis	12.8	352	518	—§		
	Navicula ramosissima	28.0	333	836	—§		
H. iris	*A. longipes*-1	33.7	570	1,245	93.5	17	Kawamura et al. 1998
	A. longipes-2	11.3	549	788	ND†		
	C. pseudomarginata	11.8	570	830	94.6		
	N. britannica	16.4	555	896	4.3		
	Navicula ramosissima	17.0	606	938	1.8		
	Navicula sp.	15.1	603	902	18.6		
	Nitzschia ovalis	15.4	568	886	32.3		
	Nitzschis sp.	35.3	553	1,280	92.7		
H. discus hannai	*A. brevipes*	57.2	1,230–1,540	1,960–2,470	64.3	20	Kawamura et al. 1995
	A. longipes	47.8	1,420–1,540	1,860–2,360	71.5		
	Amphora angusta	29.0	1,120–1,420	1,450–1,770	8.2		
	C. scutellum	46.4	1,050–1,310	1,460–1,950	84.3		
	C. closterium‡	50.1	920–1,300	1,270–2,190	100		
	Navicula ramosissima	21.1	1,120–1,590	1,470–1,790	16.5		
	Nitzschia sp.	13.6	1,120–1,600	1,260–1,750	8.5		
	Pleurosigma sp.	24.2	1,330–1,600	1,420–2,100	3.8		
	Synedra investiens	20.5	980–1,270	1,140–1,610	5.6		

* Digestion efficiency is the proportion of live cells that lose cell contents when eaten (Kawamura et al. 1995).
† Not determined; for these diatom strains, there were insufficient diatom cells in the feces to accurately assess digestion efficiency.
‡ *C. closterium* is often called *Nitzschia closterium.*
§ Data not available.

TABLE 4.

Growth rates reported for juveniles of various *Haliotis* species fed different species of algae. (macro)

Species of Abalone	Observation Temperature (°C)	Initial Size: Weight (g)	Initial Size: Length (mm)	Species of Algae	Growth Rate: Weight (mg/day)	Growth Rate: Length (μm/day)	References
Haliotis discus hannai	18.9–20.6	1.9	24.0	*Laminaria japonica*	19.0	108.0	Uki 1981
		1.8	24.0	*Laminaria religosa*	18.0	101.0	
		1.9	24.0	*E. bicyclis*	16.3	48.0	
		1.9	24.0	*U. pinnatifida*	25.3	121.0	
Haliotis laevigata	18	0.4	15.0	*Gracilaria conifervoides*	6.7	—	Morrison & Whittington 1991
Haliotis rubra	18	7.0	—	*Jeannerettia lobata*	19.0	—	Gorfine & King 1991
					51.0	—	Fleming 1995
	10–20	7.0	—	*Phyllospora comosa*	8.0	—	Gorfine & King 1991
Haliotis refescens	10.6–14.2	8.3	38.3	*Macrocystis* sp.	80.3	69.0	Ebert & Houk 1984
Haliotis tuberculata	20 ± 0.5	0.2	10.0	*Palmaria palmata*	2.9	—	Kolke et al. 1979
		0.1	10.0	*Ulva lactuca*	2.1	—	
		0.1	9.0	*Laminaria digitata*	1.7	—	
Haliotis iris	15 ± 1	1.2	21.6	*Gracilaria chilensis*	9.7	45.5	Stuart & Brown 1994
		1.1	21.0	*Macrocystis pyrifera*	5.9	34.4	
Haliotis asinina	25	4.8	27.8	*Gracilaria salicornia*	51.1	51.2	Singhagraiwan 1991b
	25–28	9.7	31.1	*Laurencia* sp.	24.0	98.1	Kunavongdate et al. 1995
		10.9	31.3	*Gracilaria fisheri*	3.0	21.0	
		10.4	31.4	*Eucheuma* sp.	2.0	14.0	

TABLE 2.

Growth rates of young abalone reared on macroalgae and blue-green algae.

Abalone species	Algal Diet	Daily Growth Rate (μm SL/day)	Initial Abalone Size (mm SL)	Growth Period (days)	Temperature (°C)	Comments	Reference
H. discus discus	*Myrionema* sp.	23.3	1.3–2.0	30	—*	An early developmental stage which has disc shaped prostrate form was used in this experiment	Yotsui 1978
H. discus hannai	*U. pinnatifida*	42	1.3	107	11.6–13.8	Sliced fronds of *Undaria* were used.	Sakai 1976
H. discus hannai	*U. lens*	26.1	1.4–1.5	16	20	Green alga with a radially spreading prostrate form.	Kawamura 1994
H. discus discus	*Myrionema sp.*	138	3.7	30	16.9–21.0	Brown alga with a radially spreading prostrate form	Maesako et al. 1984
H. discus discus	*Colpomenia sinuosa*	109.7	3.5	30	14.0–19.3	Macroalga germlings	Maesako et al. 1984
	Ectocarpus siliculosus	107.2	3.6	30	16.9–21.0		
	Endarachne binghamiae	88.0	3.4	30	14.0–19.3		
	Enteromorpha spp.	110.0	3.7	30	16.9–21.0		
H. discus discus	*U. pinnatifida*	72	3.4	50	—*	The *Undaria* fronds were salted before they were fed to the abalone.	Fujii and Yotsui 1989
H. gigantea	*U. pinnatifida*	92	3.1	120	12.5–21.5	As above	Fujii 1996
H. discus discus	*A. litoralis*	0.0	3.5	30	14.0–19.3	Blue green algae	Maesako et al. 1984
	E. deusta	96.7	3.6	30	14.0–19.3		
	Plectonema calothrichoides	58.7	3.4	30	14.0–19.3		
	P. golenkiniatum	86.7	3.5	30	14.0–19.3		
	Phormidium fragile	60.3	3.6	30	14.0–19.3		
	Spirulina subsalsa	31.0	3.6	30	14.0–19.3		

* Data not available.

Table 9
AMINO ACID CONTENT OF ARTIFICIAL DIET AND MACROALGAE (PER 100 G DRY WEIGHT)

	Artificial diet (mg)	*Eisenia* sp. (mg)	*Laminaria* sp. (mg)
Lysine	774	114	17
Histidine	262	19	5
Arginine	845	76	17
Aspartic acid	1107	286	52
Threonine	548	76	17
Aspartic acid	1107	286	52
Threonine	548	114	17
Serine	679	114	17
Glutamic acid	2667	229	86
Proline	1202	114	17
Glycine	667	133	34
Alanine	821	95	34
Cysteine	214	38	17
Valine	690	114	17
Methionine	405	19	17
Isoleucine	583	57	17
Leucine	1250	95	17
Tyrosine	512	95	17
Phenylalanine	750	76	17

- Tryptophan ?

(From Anonymous, Nihon Nosan Kogyo K.K. Research Center, Jpn, Patent Public. No. 55-1586, Material No. 3, 1981.)

Table 10
THE GROWTH OF 1 TO 2 CM ABALONE FED DIFFERING DIETS

Diet	Growth (μm/day)
Artificial diet	83—133
Eisenia sp.	80
Undaria sp.	82
Laminaria sp.	83
Undaria (frozen)	80
Laminaria (dried)	43

(From Anonymous, Nihon Nosan Kogyo K.K. Research Center, Jpn. Patent Public. No. 55-1586, Material No. 3, 1981.)

Table 11
PERCENT CONTENT OF ABALONE FED DIFFERING DIETS

	Seaweeds		Artificial diet	
	Wet weight	Dry weight	Wet weight	Dry weight
Moisture	78.0	—	76.4	—
Crude protein	13.6	61.8	15.6	66.1
Crude fat	1.3	5.9	2.0	8.5
Crude ash	2.4	10.9	2.8	11.9
Crude fiber	0	0	0	0
NFE	4.7	21.4	3.2	13.6

(From Anonymous, Nosan Kogyo K.K. Research Center, Jpn. Patent Public. No. 55-1586, Material No. 3, 1981.)

Table 8
CRUDE CHEMICAL COMPOSITION OF MARINE ALGAE LAMINARIALES (A) GROWTH SEASON OF ALGAE; (B) REPRODUCTION SEASON OF ALGAE

	Wet weight (%)					Dry weight(%)			
	Moisture	**Protein**	**Lipid**	**Ash**	**Carbohydrates**	**Protein**	**Lipid**	**Ash**	**Carbohydrates**
A									
Eisenia bicyclis	86.0	2.63	0.171	4.28	6.92	18.8	1.22	30.6	49.4
Kjellmaniella gyrata	88.9	1.84	0.098	—	—	16.6	0.88	—	—
Laminaria angustata var. *longissima*	89.4	1.39	0.088	4.38	4.72	13.4	0.85	41.3	44.5
L. diabolica	89.4	1.20	0.071	4.71	4.62	11.3	0.67	44.4	43.6
L. japonica	88.1	1.48	0.097	5.11	5.22	12.5	0.81	43.4	43.3
L. japonica f. *membranacea*	88.7	1.63	0.061	4.93	4.69	14.4	0.54	43.6	41.5
L. religiosa	90.5	0.88	0.077	4.15	4.39	9.3	0.81	43.7	46.2
Undaria pinnatifida	89.7	2.06	0.147	4.25	3.84	20.0	1.45	41.3	37.3
B									
Eisenia bicyclis	84.8	1.49	0.157	4.76	8.80	9.8	1.03	31.3	57.9
Laminaria diabolica	85.8	1.36	0.091	5.00	7.75	9.6	0.64	35.2	54.6
L. japonica	88.8	1.04	0.098	3.97	6.10	9.3	0.87	35.7	54.1
L. japonica f. *membranacea*	88.1	1.25	0.080	4.07	6.50	10.5	0.67	34.2	54.6
L. religiosa	88.0	1.11	0.131	4.07	6.69	9.3	1.08	34.3	55.4
L. religiosa with bryozoa	87.0	1.83	0.085	6.57	4.52	14.1	0.65	50.5	34.8

(From Uki, N., *Bull. Tohoku Reg. Fish. Res. Lab.*, 42, 19, 1981. With permission.)

Table 12
PERCENT CONTENT OF ARTIFICIAL DIET AND MACROALGAE

	Artificial diet		***Eisenia* sp.**		***Laminaria* sp.**	
	Wet weight	**Dry weight**	**Wet weight**	**Dry weight**	**Wet weight**	**Dry weight**
Moisture	16.0	—	47.5	—	42.0	—
Crude protein	30.0	35.7	9.7	18.5	5.2	9.0
Crude fat	3.5	4.2	0.3	0.6	1.3	2.2
Crude fiber	2.0	2.4	3.1	5.9	3.5	6.0
Crude ash	12.0	14.3	12.9	24.6	16.3	28.1
NFE	36.5	43.5	26.5	50.5	31.7	54.7
Calcium	2.9	3.4	1.2	2.2	0.6	1.0
Phosphorus	1.4	1.6	0.2	0.3	0.1	0.2

(From Anonymous, Nihon Nosan Kogyo K. K. Research Center, Jpn. Patent Public. No. 55-1586, Material No. 3, 1981.)

Table 3
GROWTH RATE OF JUVENILE (10 MM) *H. DISCUS HANNAI* FED MONOCULTURES OF MICROALGAE AND REARED AT 20°C

Species	Growth (μm/day)	Ref.
Navicula britanica	200	25
N. ulvacea	200	25
Nitzschia divergens	221	25
N. pseudohybrida	220	25
Platymonas sp.	23	25
Prasinocaldus marinas	126	25
Nitzschia divergens and *Navicula agnita*	270	26
Nitzschia divergens and *Amphora* sp.	260	26

Table 5
GROWTH PRODUCED BY MACROALGAE FOUND ALONG THE PACIFIC COAST OF JAPAN (GROWTH HAS BEEN STANDARDIZED RELATIVE TO *EISENIA BICYCLIS*)

Species	Daily increase in SL[a] (μm)	Monthly growth rate (%)	Daily feeding rate (%)	FCE[b] (%)	Relative growth index	
					SL	BW[c]
Eisenia bicyclis	86	24	9.3	8.2	1.00	1.00
Laminaria japonica					1.10	1.17
Laminaria japonica *f. membranacea*					1.04	1.27
L. religiosa	83	32	16.5	5.6	1.44	1.47
L. angustata var. *longissima*					1.04	1.18
L. diabolica					1.18	1.66
Costaria costata	90	46	19.3	6.5	1.56	2.12
Undaria pinnatifida	90	44	17.5	6.9	1.56	2.04
Alaria crassifolia	137	46	19.3	6.5	1.41	1.14
Desmarestia ligulata	79	28	14.8	5.5	1.37	1.29
Porphyra yezoensis	91	26	5.2	14.9	0.94	1.04
Palmaria palmata	99	51	20.4	7.6	1.72	2.36
Chondria crassicaulis	90	26	15.4	5.0	1.27	1.28
Ulva pertusa	41	23	7.1	9.1	0.71	1.04
Enteromorpha sp.	62	23	10.9	6.3	0.87	1.13
Codium divaricatum	43	22	31.6	2.1	0.75	1.02

[a] SL = shell length.
[b] FCE = food conversion efficiency.
[c] BW = body weight.

For *H. discus*

(From Uki, N., Sugiura, M., and Watanabe, T., *Bull. Jpn. Soc. Sci. Fish.*, 52(2), 257, 1986. With permission.)

Table 6.
GROWTH, FEEDING RATIO, AND FOOD CONVERSION EFFICIENCY OF ABALONE FED ON 13 KINDS OF MARINE ALGAE (A) GROWTH SEASON OF ALGAE; (B) REPRODUCTION SEASON OF ALGAE

Species	Daily increase in SL[a] (μm)	Monthly weight gain (%)	Daily feeding rate (%)		Food conversion efficiency (%)	
			Wet weight	Dry weight	Wet weight	Dry weight
A.						
Eisenia bicyclis	98	26.5	10.1	1.42	7.7	55
Kjellmaniella gyrata	79	25.4	13.7	1.52	5.5	50
Laminaria angustata var. *longissima*	102	31.3	22.6	2.34	4.0	39
Laminaria diabolica	116	43.9	15.7	1.66	7.6	72
Laminaria japonica	108	31.1	19.3	2.25	4.8	40
Laminaria japonica f. *membranacea*	102	33.7	16.8	1.91	5.7	50
Laminaria religiosa	101	29.7	21.6	2.06	4.0	42
Undaria pinnatifida	121	39.8	13.1	1.35	8.4	82
B.						
Eisenia bicyclis	48	23.0	8.3	1.26	8.3	54
Laminaria diabolica	45	21.9	11.8	1.67	5.6	39
Laminaria japonica	46	23.8	12.9	1.43	5.5	50
Laminaria japonica f. *membranacea*	43	21.3	9.9	1.18	6.5	55
Laminaria religiosa	42	21.9	10.1	1.19	6.6	55
Laminaria religiosa with bryozoa	56	33.7	15.3	2.65	6.3	49

[a] SL = Shell length.

(From Unki, N., *Bull. Tohoku Reg. Fish. Res. Lab.*, 42, 19, 1981. With permission.)

Table 7
RELATIVE FOOD VALUES, *EISENIA* EQUIVALENT (1.00), OF LAMINARIALES

Species	Growth season		Reproduction season	
	Shell length	Body weight	Shell length	Body weight
Kjellmaniella gyrata	0.81	0.96	—	—
Laminaria angustata var. *longissima*	1.04	1.18	—	—
L. diabolica	1.18	1.66	0.94	0.95
L. japonica	1.10	1.17	0.96	1.03
L. japonica f. *membranacea*	1.04	1.27	0.90	0.93
L. religiosa	1.03	1.12	0.88	0.95
L. religiosa with bryozoa	—	—	1.17	1.47
Undaria pinnatifida	1.23	1.50	—	—

(From Uki, N., *Bull. Tohoku Reg. Fish. Res. Lab.*, 42, 19, 1981. With permission.)

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UTILIZATION OF DIETARY PROTEIN, LIPID, AND CARBOHYDRATE BY ABALONE *HALIOTIS DISCUS HANNAI*: A REVIEW

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ABSTRACT Feeding *Haliotis discus hannai* depends mainly on the use of macroalgae such as *Undaria* sp. or *Laminaria* sp., although the species is an important mariculture shellfish in Korea. Research on the utilization of protein, lipid, and carbohydrate in formulated diets by *H. discus hannai* has been conducted, and the results have been reviewed. *H. discus hannai* fed a formulated diet showed better growth performance than those fed a macroalgae based-diet. Casein, fish meal, soybean meal, cottonseed meal, and wheat germ meal are all good sources of dietary protein for *H. discus hannai*. The optimum dietary lipid content for *H. discus hannai* is from 2% to 5%. Marine fish oil, for instance squid liver oil, is a good dietary lipid source for *H. discus hannai*. Oil supplementation in diets is not necessary when fish meal as main protein source is used for *H. discus hannai* diets. Comparative growth rates were observed when *H. discus hannai* were fed diets containing each of the following carbohydrate sources: wheat flour, dextrin, sucrose, potato starch, or as a mixture combined with practical ingredients such as soybean meal, corn gluten meal, cotton seed meal, and wheat flour. These results may be used in developing practical feed formulation and improving aquaculture production of abalone.

KEY WORDS: *Haliotis discus hannai*, formulated diet, protein, lipid, carbohydrate

PROTEIN Three replicate groups of *H. discus hannai* averaging 110 ± 7 mg were fed one of ten diets containing casein, white fish meal (WFM), meat meal (MM), feather meal (FM), blood meal (BM), soybean meal (SM), corn gluten meal (CGM), cotton seed meal (CSM), *Undaria* powder (UP), or wheat flour (WF) as a dietary protein source.

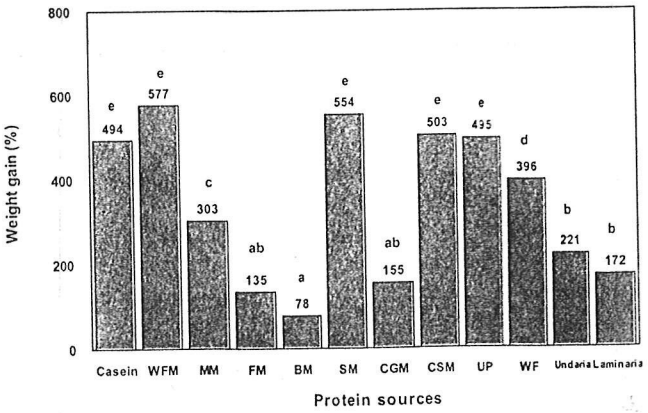


Figure 2. Weight gain [(final weight-initial weight) × 100/initial weight] of *Haliotis discus hannai* fed the diets containing various protein sources and macroalgae (*Undaria* and *Laminaria*) for 17 wk. Data with different letters were reported as significantly different using ANOVA and a multiple range test with $P < 0.05$ (data from Lee et al. 1998a).

. Three replicate groups of *H. discus hannai* averaging 151 ± 5 mg were fed the casein-based diets containing 5% squid liver oil (SO), 5% corn oil (CO), 5% beef tallow (BT), 2.5% SO + 2.5% CO, and 2.5% SO + 2.5% BT for 20 wk.

LIPID

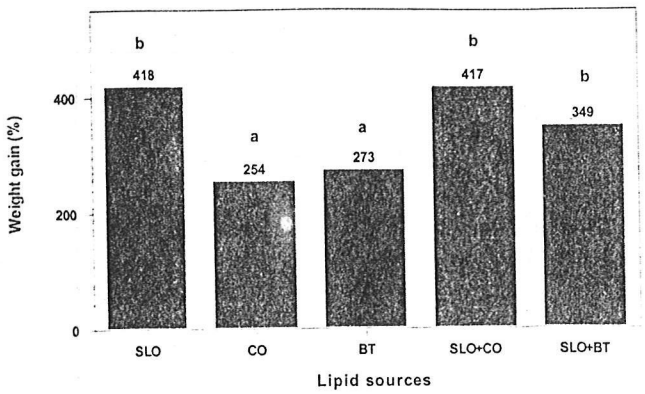


Figure 3. Weight gain [(final weight-initial weight) × 100/initial weight] of *Haliotis discus hannai* fed the diets containing various lipid sources for 20 wk. Data with different letters were reported as significantly different using ANOVA and a multiple range test with $P < 0.05$(data from Lee & Park 1998).

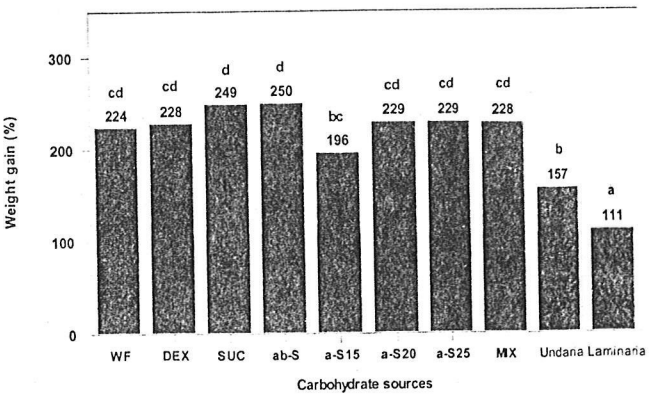


Figure 4. Weight gain [(final weight-initial weight) × 100/initial weight] of *Haliotis discus hannai* fed the diets containing various carbohydrate sources and macroalgae (*Undaria* and *Laminaria*) for 20 wk. Data with different letters were reported as significantly different using ANOVA and a multiple range test with $P < 0.05$ (data from Lee et al. 1998b).

CARBOHYDRATES

Four replicate groups of *H. discus hannai* averaging 125 ± 1.1 mg were fed one of eight diets containing 24.2% wheat flour (WF), 20% dextrin (DEX), 20% sucrose (SUC), 10% α-potato starch + 10% β-potato starch (ab-S), 15% α-potato starch (a-S15), 20% α-potato starch (a-S20), 25% α-potato starch (a-S25), or mixture of carbohydrates (MIX) with practical ingredients such as soybean meal, corn gluten meal, cotton seed meal, and wheat flour. These formulated diets were compared against *Undaria* or *Laminaria*.

Table 11-1 Classification of lipids

Lipid type	*Backbone*
Complex (saponifiable)	
Acylglycerols	Glycerol
Phosphoglycerides	Glycerol 3-phosphate
Sphingolipids	Sphingosine
Waxes	Nonpolar alcohols of high molecular weight
Simple (nonsaponifiable)	
Terpenes	
Steroids	
Prostaglandins	

Figure 11-11
General structure of phosphoglycerides in a form emphasizing their amphipathic nature. Usually the fatty acid in the 2 position is unsaturated.

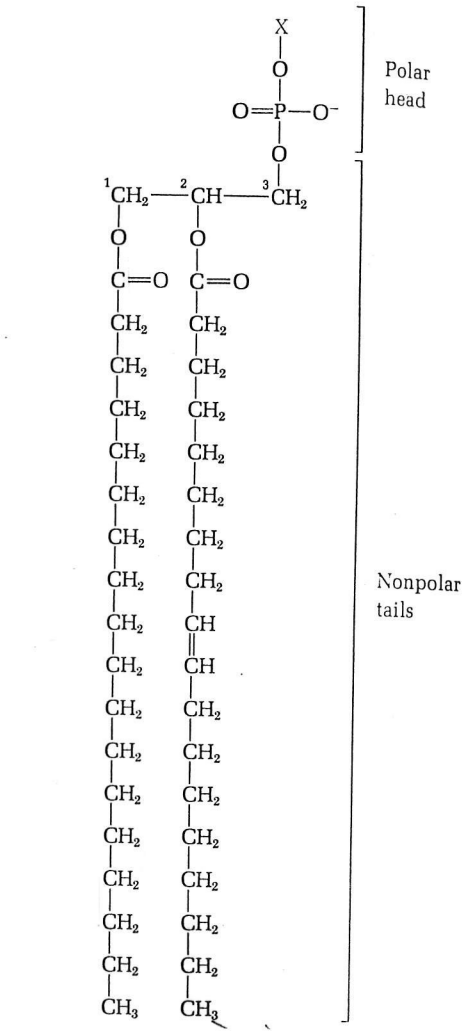


Figure 11-4
Glycerol and mono-, di-, and triacylglycerols.

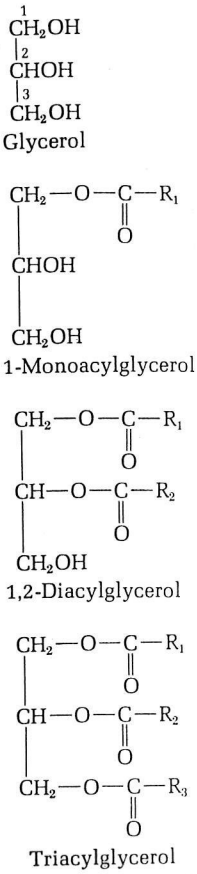


Figure 11-1
Two common fatty acids.

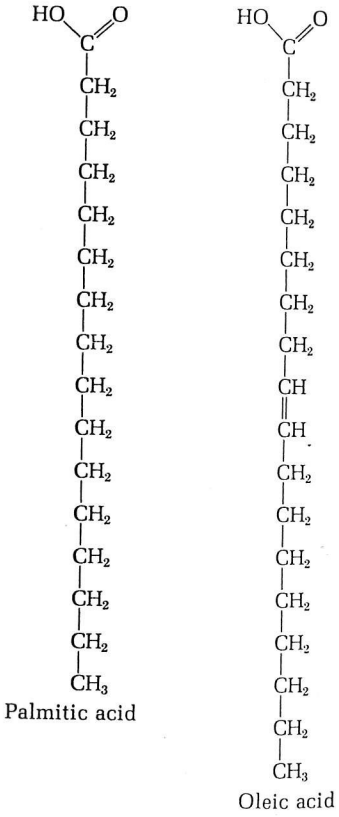
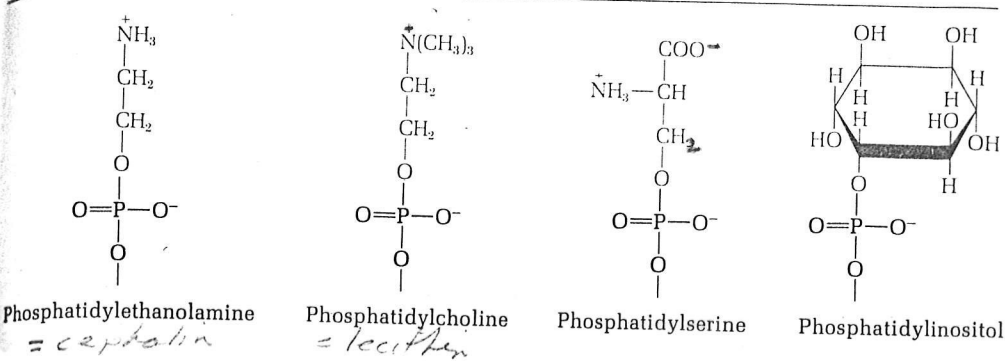


Table 11-5 Polar head groups of the phosphoglycerides

The head alcohols are shown in color. The open bonds on the phosphoric residues are to position 3 of 1,2-diacylglycerol.



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INFLUENCE OF DIETARY LIPID SOURCES ON GROWTH AND FATTY ACID COMPOSITION OF JUVENILE ABALONE, *HALIOTIS DISCUS HANNAI* INO

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ABSTRACT A study was conducted to evaluate the effects of dietary lipid sources on the growth and fatty acid composition of juvenile abalone *Haliotis discus hannai* Ino. Four triplicate groups of juvenile abalone (initial weight: 0.13 ± 0.04 g; initial shell length: 10.23 ± 1.48 mm) were fed with one of four semipurified diets containing 3.5% of dietary lipid from either tripalmitin (TP), soybean oil (SO), linseed oil (LO), or 20:5n-3-enriched fish oil (FO), respectively, and were reared for 120 days in a recirculation water system. Results showed that the growth rate of abalone was significantly affected by dietary lipid sources ($P < 0.05$). The dietary lipid, FO produced the highest weight gain rate (WGR, 413.2%), closely followed by LO (389.0%) and SO (382.4%). These three WGR values were not significantly different to each other. However, abalone fed the TP diet showed a significantly lower WGR (267.3%). Carcass moisture and protein were independent of dietary treatment, but the TP diet resulted in significantly lower carcass lipid. The fatty acid profile in abalone carcass reflected that of dietary lipids, especially the unsaturated fatty acids. It appears that *H. discus hannai* have a capacity to synthesize 20:5n-3, 20:4n-6 and 22:6n-3 from 18-carbon PUFAs and even from 16:0 through elongation and desaturation. However, the capacity seems to be insufficient to support the maximum growth of abalone.

TABLE 2.

Fatty acid composition of dietary lipid sources (% area).

	Lipid Source[b]		
Fatty Acid	SO	LO	FO
14:0	0.51	0.22	ND
16:0	9.42	6.41	ND
16:1	0.24	0.16	ND
18:0	3.82	3.58	2.02
18:1n-9	21.81	21.31	3.43
18:1n-7	0.90	1.20	1.05
18:2n-6	50.60	15.49	0.82
18:3n-3	5.70	49.03	3.11
20:4n-6	ND	ND	1.09
20:5n-3	ND	ND	49.77
22:6n-3	ND	ND	21.60

ND, undetectable (<0.01 g/100 g fatty acids); SO, soybean oil; LO, linseed oil; FO, fish oil.

TABLE 3.

Effects of the experimental diets supplemented with different lipid sources on growth, survival of juvenile abalone, *Haliotis discus hannai*.

Diets	Initial Weight (mg)	Final Weight (mg)	Weight Gain Rate (%)	Initial Shell Length (mm)	Final Shell Length (mm)	DISL (μm/day)	Survival Rate (%)
TP	132.00 ± 8.51	508.83 ± 12.27[b]	267.32 ± 7.89[b]	10.35 ± 0.11	17.35 ± 0.08	58.26 ± 1.36	92 ± 6.93
SO	128.70 ± 8.60	620.12 ± 30.49[a]	382.43 ± 19.36[a]	10.15 ± 0.06	17.80 ± 0.57	63.28 ± 5.13	92 ± 4.00
LO	125.33 ± 8.20	610.53 ± 25.86[a]	389.04 ± 46.82[a]	10.20 ± 0.06	18.02 ± 0.36	65.47 ± 3.21	90 ± 9.24
FO	131.33 ± 7.57	671.50 ± 34.30[a]	413.19 ± 53.09[a]	10.21 ± 0.09	18.30 ± 0.42	67.14 ± 4.88	96 ± 0.00
ANOVA							
F	0.41	19.01	9.22	3.00	3.04	2.86	0.43
P	0.75	0.00	0.01	0.10	0.09	0.10	0.74

DISL, daily increment in shell length.

TP, Tripalmitin; SO, soybean oil; LO, linseed oil; FO, fish oil.

[a–b] Means in the same column sharing a common superscript letter were not significantly different ($P > 0.05$) as determined by Tukey's test.

Mean ± SD, $n = 3$.

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TABLE 4.

Effects of the experimental diets supplemented with different lipid sources on fatty acid compositions in the carcass of juvenile abalone, *Haliotis discus hannai*.

Fatty Acid	TP	SO	LO	FO	ANOVA F	ANOVA P
14:0	2.65 ± 0.09	2.08 ± 0.30	2.57 ± 0.37	2.90 ± 0.15	1.02	0.43
16:0	18.99 ± 1.99	15.57 ± 1.19	15.64 ± 0.42	15.29 ± 2.05	3.77	0.06
16:1	1.15 ± 0.06	0.97 ± 0.02	1.05 ± 0.08	1.05 ± 0.08	0.15	0.92
18:0	5.29 ± 1.22	5.85 ± 0.38	5.69 ± 0.32	5.39 ± 0.64	0.17	0.91
18:1n-9	7.43 ± 0.24	6.71 ± 0.41	6.51 ± 0.58	5.95 ± 0.17	0.37	0.77
18:1n-7	5.55 ± 0.41	4.48 ± 0.28	5.34 ± 0.52	4.36 ± 0.37	1.74	0.23
18:2n-6	1.29 ± 0.09^{ab}	1.64 ± 0.07^{a}	0.65 ± 0.04^{ab}	0.28 ± 0.01^{b}	4.91	0.03
18:3n-3	0.49 ± 0.02^{b}	0.39 ± 0.02^{b}	2.97 ± 0.49^{a}	0.58 ± 0.03^{b}	54.95	0.00
20:4n-6	4.78 ± 0.90^{ab}	6.03 ± 0.52^{a}	4.03 ± 0.34^{b}	3.55 ± 0.46^{b}	9.70	0.01
20:5n-3	5.87 ± 0.64^{c}	4.61 ± 0.01^{c}	7.86 ± 0.36^{b}	12.00 ± 1.15^{a}	53.48	0.00
22:6n-3	0.89 ± 0.02^{b}	0.93 ± 0.03^{b}	1.28 ± 0.13^{b}	2.59 ± 0.10^{a}	48.19	0.00

TP, Tripalmitin; SO, soybean oil; LO, linseed oil; FO, fish oil.

$^{a-c}$ Means in the same line sharing a common superscript letter were not significantly different ($P > 0.05$) as determined by Tukey's test.

Mean ± SD, $n = 3$.

Research Article

Growth, nutritional quality and safety of oysters (*Crassostrea gigas*) cultured in the lagoon of Venice (Italy)

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KEYWORDS

bivalve molluscs • oyster • *Crassostrea gigas* • aquaculture • nutritional quality • safety

ABSTRACT

Quality aspects of oysters (*Crassostrea gigas*) from a suspended culture in the lagoon of Venice (Valle Dogà) were examined in different seasons over a 1-year period. Ecophysiological and commercial quality indicators (condition index, content of meat, shell and intervalvar fluid), nutritional quality parameters (proximate and mineral composition, glycogen content, fatty acid profile, cholesterol, plant sterols, fat-soluble vitamins content) and levels of organic pollutants (polychlorinated biphenyls and organochlorine pesticides) were determined at different times of the year. Seasonal variations were observed in the nutrient content, with particular regard to moisture (ranging from 866.8 g kg^{-1} in June to 938.8 g kg^{-1} in September), protein (23.9 g kg^{-1} in September to 76.6 g kg^{-1} in June), ash (22.5 g kg^{-1} in February to 29.5 g kg^{-1} in July), lipid (3.0 g kg^{-1} in September to 8.8 g kg^{-1} in June) and glycogen (0.7 g kg^{-1} in September to 11.5 g kg^{-1} in February). In spite of this variability, the nutritional quality of the oysters was generally good, especially just before gamete release when the concentration of nutrients was at its maximum. Low levels of organochlorine chemicals were detected in the edible meat of oysters but, because only a limited number of samples were analysed, no general conclusion can be drawn on the safety of seafood from this area. Copyright © 2004 Society of Chemical Industry

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10.1002/jsfa.1896 About DOI

Tab. 1 Chemical composition of oysters (*C. gigas*) from a suspended culture in Valle Dogà (Lagoon of Venice): seasonal variation (g kg^{-1} wet wt)[†].

	2001				2002					
	June		September		February		July		September	
pH	6.21	± 0.01[a]	6.43	± 0.05[c]	6.31	± 0.08[b]	6.18	± 0.03[a]	6.20	± 0.06[a]
Moisture	866.8	± 5.2[a]	938.8	± 0.8[e]	897.2	± 2.4[c]	886.7	± 2.5[b]	909.6	± 0.8[d]
Protein	76.6	± 2.4[e]	23.9	± 1.1[a]	49.2	± 2.1[c]	61.1	± 1.0[d]	40.4	± 0.2[b]
Total lipid	8.8	± 0.3[e]	3.0	± 0.2[a]	6.6	± 0.4[c]	7.2	± 1.1[d]	4.4	± 0.0[b]
Glycogen	6.3	± 0.1[b]	0.7	± 0.1[a]	11.5	± 0.1[c]	4.6	± 1.8[b]	5.8	± 0.8[b]
Nonprotein N	3.0	± 0.2[d]	1.1	± 0.0[a]	2.3	± 0.0[c]	2.4	± 0.0[c]	1.8	± 0.1[b]
Ash	26.5	± 0.8[b]	26.3	± 0.8[b]	22.5	± 0.8[a]	29.5	± 0.3[d]	28.2	± 0.6[c]

[†]) Means ± standard deviations (n=3). Within a row, values not sharing the same superscript letter are significantly different ($P \leq 0.05$).

Tab. 2 Mineral content of oysters (*C. gigas*) from a suspended culture in Valle Dogà (Lagoon of Venice): seasonal variation[†].

	2001				2002					
	June		September		February		July		September	
	g kg^{-1} wet wt									
Na	2.79	± 0.41^{a}	7.68	± 0.08^{c}	2.34	± 0.06^{a}	3.69	± 0.42^{b}	3.72	± 0.29^{b}
K	1.79	± 0.02^{d}	0.77	± 0.05^{a}	1.53	± 0.03^{c}	1.58	± 0.02^{c}	1.19	± 0.04^{b}
Mg	1.00	± 0.01^{b}	1.09	± 0.01^{c}	0.8 0	± 0.01^{a}	1.13	± 0.01^{cd}	1.16	± 0.03^{d}
Ca	1.68	± 0.02^{b}	1.61	± 0.07^{ab}	1.95	± 0.07^{c}	1.48	± 0.04^{a}	2.40	± 0.08^{d}
	mg kg^{-1} wet wt									
Zn	0.19	± 0.02^{a}	0.12	± 0.01^{a}	0.12	± 0.01^{a}	0.15	± 0.01^{a}	0.13	± 0.01^{a}
Fe	19.22	± 1.37^{b}	11.26	± 0.74^{a}	11.93	± 0.91^{a}	18.49	± 3.34^{b}	17.22	± 2.10^{ab}
Se	0.46	± 0.04^{b}	0.18	± 0.05^{a}	0.35	± 0.07^{b}	0.34	± 0.03^{b}	0.30	± 0.02^{ab}
Cr	0.14	± 0.01^{a}	0.07	± 0.01^{a}	0.06	± 0.02^{a}	0.18	± 0.05^{a}	0.11	± 0.01^{a}
Co	0.06	± 0.01^{bc}	0.03	± 0.01^{a}	0.03	± 0.01^{a}	0.07	± 0.01^{c}	0.04	± 0.01^{ab}

[†]) Means ± standard deviations (n=3). Within a row, values not sharing the same superscript letter are significantly different ($P \leq 0.05$).

Tab. 3 Fatty acid composition of total lipid from oysters (*C. gigas*) collected in Valle Dogà (Lagoon of Venice): seasonal variation (% of total fatty acid)[†].

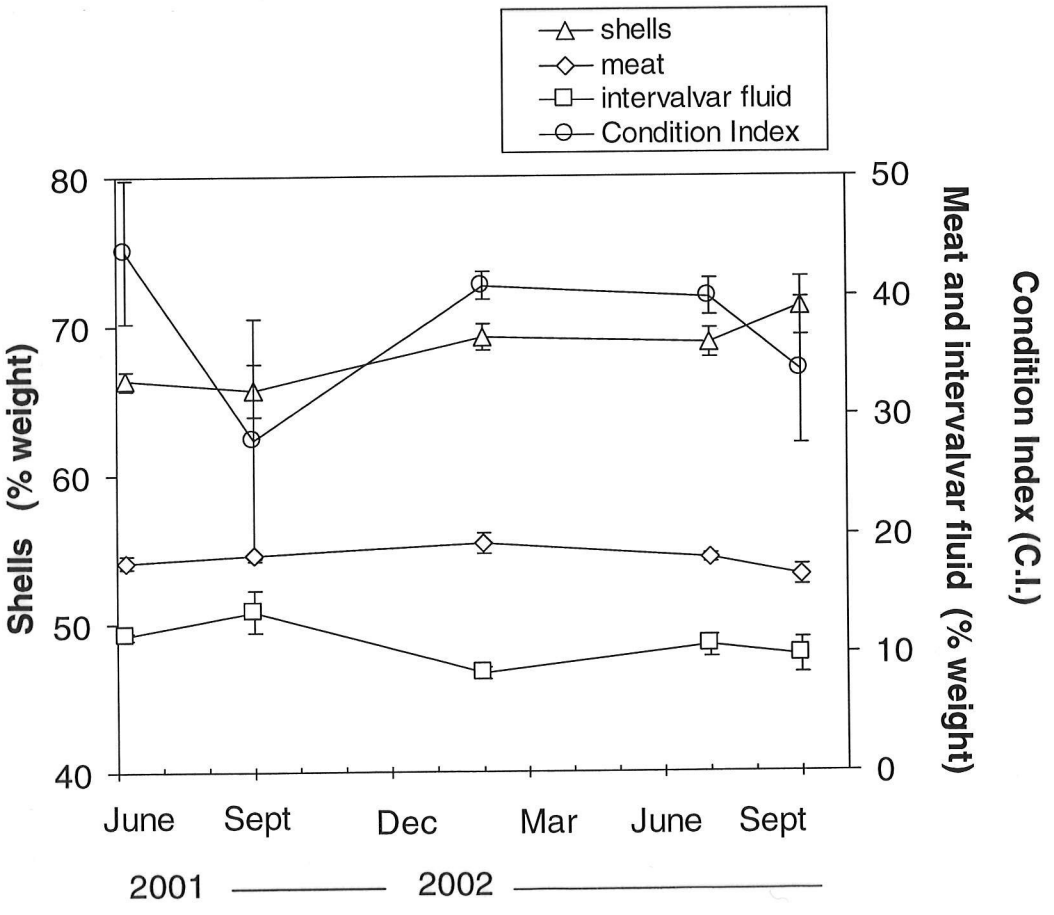
	2001			2002		
	June	September	February	July	September
C 12:0	0.09 ± 0.04^{a}	0.18 ± 0.05^{a}	0.08 ± 0.01^{a}	0.12 ± 0.05^{a}	0.08 ± 0.01^{a}
C 13:0	0.03 ± 0.00^{a}	0.07 ± 0.01^{c}	0.03 ± 0.00^{a}	0.06 ± 0.01^{bc}	0.05 ± 0.01^{b}
C14:0	2.46 ± 0.32^{a}	2.47 ± 0.86^{a}	1.81 ± 0.22^{a}	2.54 ± 0.57^{a}	1.64 ± 0.12^{a}
C15:0	0.73 ± 0.05^{a}	1.40 ± 0.19^{b}	0.86 ± 0.03^{a}	1.24 ± 0.07^{b}	1.19 ± 0.07^{b}
C16:0	28.21 ± 1.40^{c}	19.08 ± 0.33^{a}	19.95 ± 0.28^{a}	27.18 ± 1.54^{c}	24.04 ± 1.12^{b}
C17:0	1.27 ± 0.05^{a}	1.55 ± 0.21^{ab}	1.48 ± 0.06^{ab}	1.70 ± 0.01^{b}	2.07 ± 0.11^{c}
C18:0	5.44 ± 0.21^{b}	5.51 ± 0.19^{b}	4.07 ± 0.01^{a}	5.90 ± 0.17^{b}	5.98 ± 0.59^{b}
C20:0	0.04 ± 0.06^{a}	0.14 ± 0.20^{a}	0.04 ± 0.05^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
C 21:0	0.30 ± 0.03^{c}	0.14 ± 0.02^{a}	0.39 ± 0.01^{d}	0.20 ± 0.01^{b}	0.21 ± 0.00^{b}
Total saturated	38.55 ± 1.60^{bc}	30.51 ± 0.87^{a}	28.70 ± 0.40^{a}	38.94 ± 2.41^{c}	35.25 ± 0.59^{b}
C 14:1	0.04 ± 0.01^{a}	0.08 ± 0.05^{a}	0.07 ± 0.01^{a}	0.04 ± 0.01^{a}	0.02 ± 0.03^{a}
C161 n-7	2.56 ± 0.65^{a}	5.19 ± 1.88^{a}	3.61 ± 0.02^{a}	3.09 ± 0.15^{a}	4.26 ± 0.06^{a}
C18:1 n-9	6.95 ± 0.11^{a}	9.95 ± 3.26^{a}	6.76 ± 0.69^{a}	5.03 ± 0.01^{a}	5.72 ± 0.59^{a}
C18:1 n-7	3.20 ± 0.11^{a}	4.66 ± 0.28^{c}	4.49 0.04^{c}	4.01 ± 0.04^{b}	4.54 ± 0.16^{c}
C20:1 n –9	0.83 ± 0.25^{ab}	1.21 ± 0.18^{bc}	1.58 ± 0.06^{c}	0.62 ± 0.01^{a}	1.04 ± 0.17^{b}
C22:1 n-9	0.05 ± 0.06^{a}	0.08 ± 0.11^{a}	0.05 ± 0.06^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Total monounsaturated	13.62 ± 0.11^{a}	21.14 ± 1.44^{c}	16.53 ± 0.69^{b}	12.77 ± 0.22^{a}	15.58 ± 0.24^{b}
C18:2 n-6	2.94 ± 0.18^{a}	4.39 ± 3.80^{a}	2.62 ± 0.21^{a}	2.77 ± 0.10^{a}	2.14 ± 0.11^{a}
C18:3 n-6	0.17 ± 0.04^{a}	0.19 ± 0.04^{a}	0.19 ± 0.01^{a}	0.25 ± 0.08^{a}	0.14 ± 0.04^{a}
C18:3 n-3	6.92 ± 0.45^{d}	1.71 ± 0.40^{a}	4.33 ± 0.14^{c}	3.37 ± 0.07^{b}	4.45 ± 0.18^{c}
C18:4 n-3	5.39 ± 0.60^{c}	2.00 ± 0.34^{a}	6.75 ± 0.08^{d}	3.23 ± 0.02^{b}	3.41 ± 0.07^{b}
C20:2 n-6	0.32 ± 0.01^{b}	0.24 ± 0.01^{a}	0.45 ± 0.01^{c}	0.33 ± 0.06^{b}	0.24 ± 0.01^{a}
C20:4 n-6	1.11 ± 0.02^{a}	2.42 ± 0.62^{b}	1.66 ± 0.06^{ab}	2.13 ± 0.27^{b}	2.11 ± 0.04^{b}
C20:5 n-3	10.05 ± 0.47^{a}	9.11 ± 1.48^{a}	14.73 ± 0.69^{b}	10.54 ± 0.16^{a}	9.42 ± 0.18^{a}
C22:4 n-3	0.16 ± 0.01^{a}	0.63 ± 0.10^{c}	0.23 ± 0.02^{a}	0.26 ± 0.01^{ab}	0.38 ± 0.08^{b}
C22:5 n-3	1.15 ± 0.05^{a}	1.74 ± 0.34^{a}	1.19 ± 0.03^{a}	1.49 ± 0.04^{a}	1.51 ± 0.08^{a}
C22:6 n-3	14.66 ± 0.23^{a}	19.95 ± 2.60^{a}	17.65 ± 0.59^{a}	18.96 ± 1.66^{a}	20.40 ± 0.87^{a}
Total polyunsaturated	42.84 ± 1.48^{a}	43.36 ± 2.31^{a}	49.78 ± 1.09^{b}	43.31 ± 2.20^{a}	44.18 ± 0.84^{a}
Total n-3 fatty acids	38.16 ± 1.25^{a}	34.51 ± 5.16^{a}	44.63 ± 1.19^{a}	37.59 ± 1.80^{a}	39.19 ± 0.87^{a}
Total n-6 fatty acids	4.69 ± 0.23^{a}	8.85 ± 2.84^{a}	5.14 ± 0.10^{a}	5.72 ± 0.40^{a}	4.99 ± 0.03^{a}
Ratio n-3/n-6	8.15 ± 0.14^{b}	4.21 ± 1.94^{a}	8.69 ± 0.40^{b}	6.58 ± 0.13^{b}	7.85 ± 0.23^{b}

[†])Means ± standard deviations (n=3). Within a row, values not sharing the same superscript letter are significantly different ($P \leq 0.05$).

Tab. 4 Unsaponifiable lipid components in oysters (*C. gigas*) from a suspended culture in Valle Dogà (Lagoon of Venice): seasonal variation[†].

	2001		2002		
	June	September	February	July	September
mg kg^{-1} wet wt.					
Cholesterol	210.5 ± 7.1^{d}	85.5 ± 26.4^{a}	168.1 ± 10.3^{bc}	195 ± 14.3^{cd}	149.3 ± 2.7^{b}
Stigmasterol + Campesterol	115.6 ± 1.0^{c}	31.6 ± 4.5^{a}	72.6 ± 9.9^{b}	43.4 ± 12.8^{a}	33.6 ± 0.1^{a}
α-Tocopherol	1.9 ± 0.1^{b}	0.5 ± 0.3^{a}	2.5 ± 0.5^{b}	1.8 ± 0.6^{b}	0.7 ± 0.1^{a}
ß-Sitosterol	31.9 ± 1.6^{a}	13.9 ± 2.8^{a}	22.2 ± 2.1^{a}	31.5 ± 10.9^{a}	21.9 ± 1.4^{a}
Fucosterol + Brassicasterol	26.0 ± 11.0^{a}	11.7 ± 7.3^{a}	41.6 ± 10.3^{a}	35.2 ± 6.2^{a}	36.5 ± 0.0^{a}
Desmosterol	3.4 ± 1.0^{b}	1.2 ± 0.7^{a}	5.3 ± 0.9^{c}	2.6 ± 0.3^{ab}	1.9 ± 0.1^{ab}
Ergosterol	6.1 ± 0.3^{b}	2.2 ± 2.2^{a}	7.1 ± 0.7^{b}	9.0 ± 2.3^{b}	8.7 ± 0.0^{b}
7 –Dehydrocholesterol	29.2 ± 3.4^{a}	7.9 ± 11.2^{a}	18.1 ± 1.4^{a}	27.8 ± 7.2^{a}	20.4 ± 0.7^{a}
µg kg^{-1} wet wt					
α-Carotene	52.5 ± 6.4^{c}	21.3 ± 2.4^{b}	23.4 ± 6.5^{b}	6.1 ± 1.0^{a}	7.7 ± 1.9^{a}
ß-Carotene	39.2 ± 6.6^{bc}	47.9 ± 0.3^{c}	44.5 ± 9.4^{c}	24.9 ± 6.5^{ab}	18.4 ± 2.2^{a}

[†]) Means ± standard deviations (n=3). Within a row, values not sharing the same superscript letter are significantly different ($P \leq 0.05$).



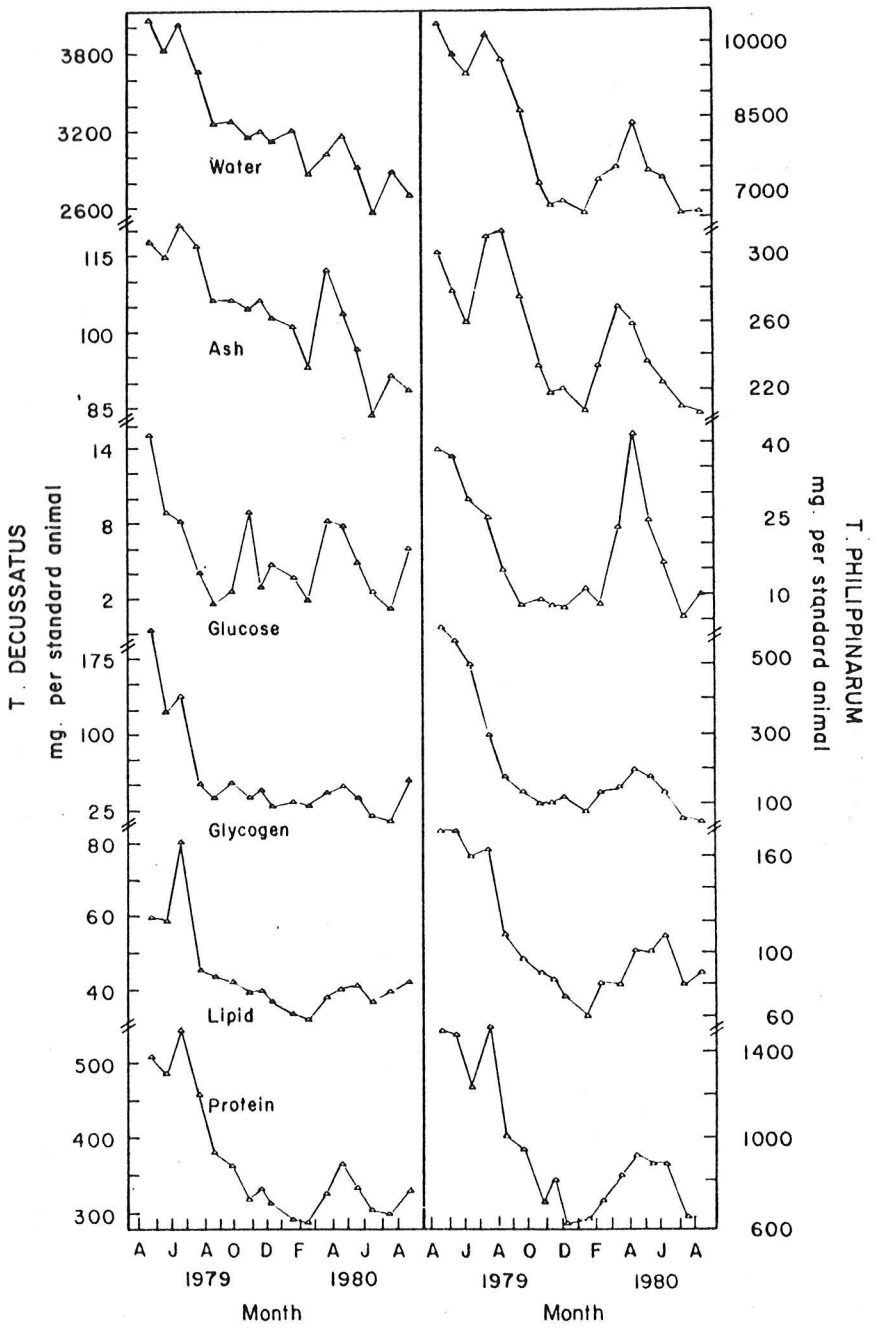


Fig. 3. Monthly variation of the gross biochemical composition of a standard animal of *T. decussatus* and *T. philippinarum*.

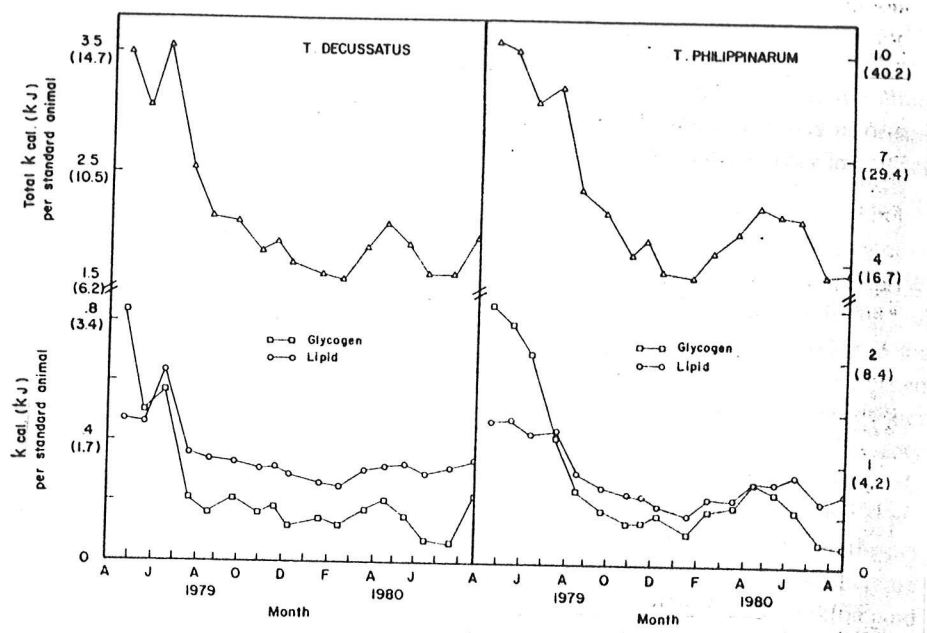


Fig. 4. Monthly variation of the energy content of the standard animal of *T. decussatus* and *T. philippinarum*: Δ, total energy content; energy content of glycogen (□) and lipid (○) components.

Fatty acids of two clam populations

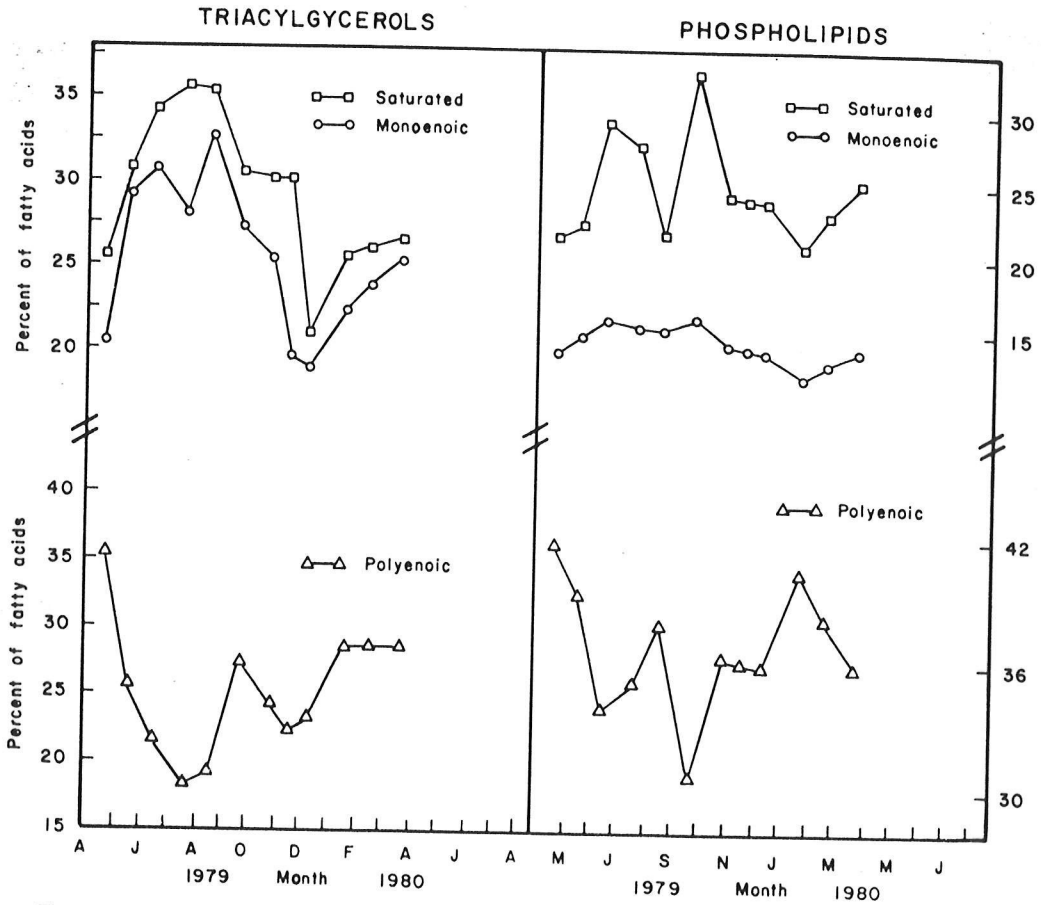


Fig. 3. Variations in the levels of total saturated, monoenoic and polyenoic fatty acids of the triacylglycerols and phospholipids of *T. decussatus*, April 1979–March 1980.

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The use of larval fatty acids as an index of growth in *Mytilus edulis* L. larvae

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Abstract

Continuous cultures of *Chaetoceros muelleri*, *Skeletonema costatum* and *Rhinomonas reticulata* of controlled biochemical compositions were fed to *Mytilus edulis* larvae over a 2-week period and the larval growth was assessed. The eggs as well as the larvae which subsequently developed were analyzed for their relative fatty acid profile and content; 27 fatty acids were identified by means of GC/MS. Larval 15:0 and saturated fatty acids, in general, were found to be negatively correlated with larval growth, while polyunsaturated and $n-3$ fatty acids were positively correlated with growth. It is therefore proposed that the proportions of certain fatty acids and groups of fatty acids may be used as indices of growth and condition in *M. edulis* larvae. © 2000 Elsevier Science B.V. All rights reserved.

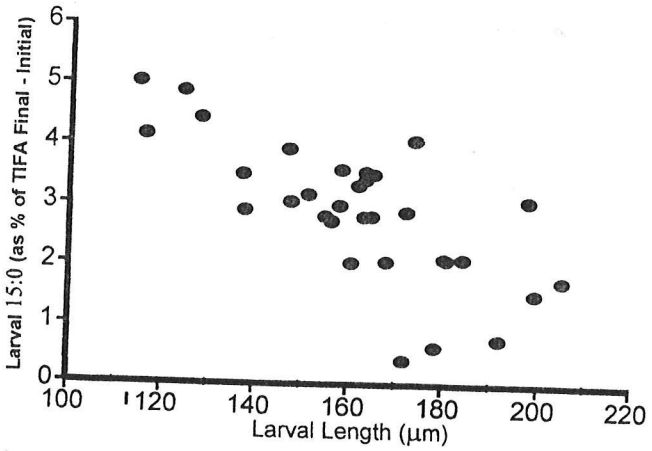


Fig. 1. Relationship between larval 15:0 fatty acid expressed as final minus initial values of the percentage of total identified fatty acids and corresponding length of the larvae achieved after the 14-day feeding trial.

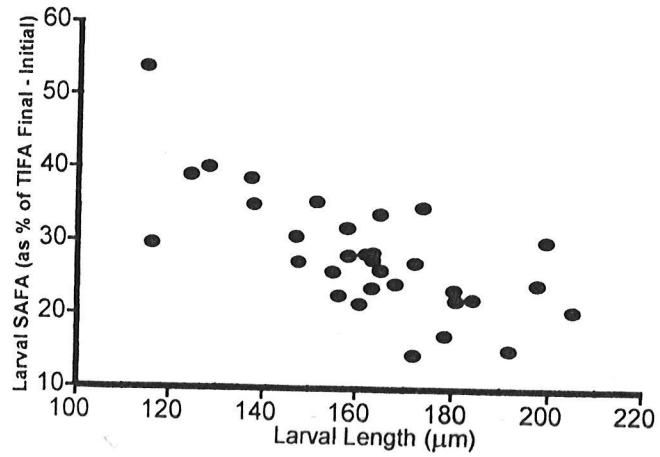


Fig. 2. Relationship between larval SAFA expressed as final minus initial percentage of total identified fatty acids and corresponding length of the larvae achieved after the 14-day feeding trial.

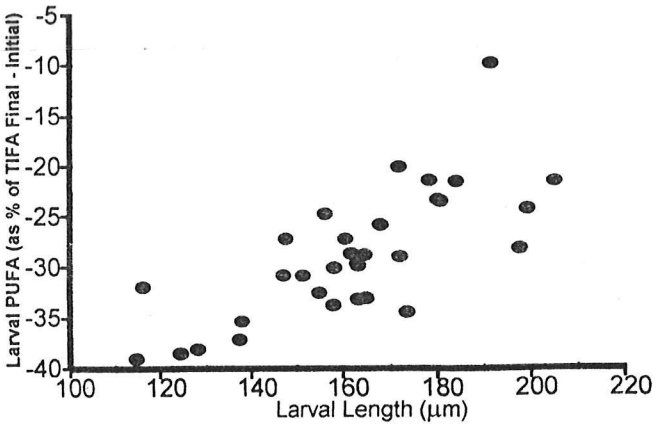


Fig. 3. Relationship between larval PUFA expressed as final minus initial percentage of total identified fatty acids and corresponding length of the larvae achieved after the 14-day feeding trial.

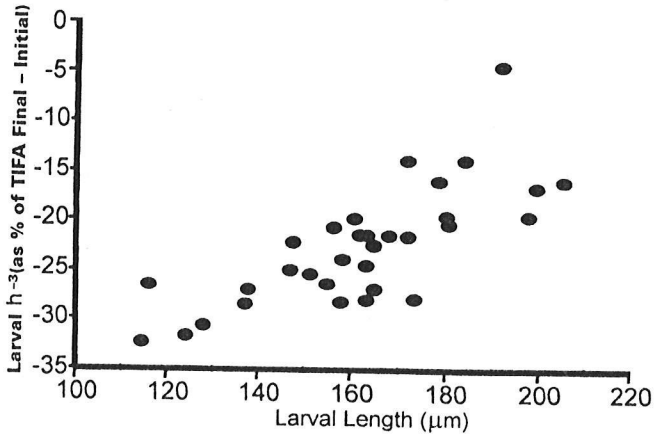


Fig. 4. Relationship between larval $n-3$ fatty acids ($n-3$ FA) expressed as final minus initial percentage of total identified fatty acids and corresponding length of the larvae achieved after the 14-day feeding trial.

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Impact of the supplementation of a docosahexaenoic acid–rich emulsion on the reproductive output of oyster broodstock, *Crassostrea gigas*

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Abstract Pacific oyster [*Crassostrea gigas* (Thunberg)] broodstock were hatchery-conditioned with either a mixed algal diet of *Dunaliella tertiolecta*, *Tetraselmis suecica* and *Rhodomonas* sp. [1:1:1, on a dry weight (DW) basis] (Control), a single diet of *D. tertiolecta* (Duna) or a single diet of *D. tertiolecta* supplemented with an emulsion rich in eicosapentaenoic (20:5*n*-3) and particularly docosahexaenoic acid (22:6*n*-3) (Duna + Em). Oysters were spawned after a conditioning period of 7 and 8 weeks and larvae were reared for 1 week on an *Isochrysis galbana* (clone T-Iso) diet. The percentage recovery of D-larvae from eggs of Control-fed oysters and Duna + Em-fed oysters was not significantly different (80% and 63% after 7 weeks of conditioning; 87% and 74% after 8 weeks of conditioning, respectively] but was much higher than from eggs produced by Duna-fed oysters (24% and 41% after 7 and 8 weeks of conditioning, respectively). A reduction in the percentage recovery of D-larvae as a result of temperature or salinity stress was most severe in eggs from Duna-fed oysters. Neither the broodstock diet nor the conditioning period affected the size of eggs or D-larvae, larval performance, or lipid content and lipid class distribution of the eggs. The fatty acid composition of the eggs was modified by the fatty acid composition of the algal diet and the lipid emulsion. The supplementation of the emulsion resulted in a pronounced increase in the percentage of 22:6*n*-3 in the polar (PL) and neutral lipids (NL) of the eggs (4.0–13.4% and 8.5–14.7% in NL and PL, respectively). The egg lipids (7–8 ng egg^{-1}) contained about 62% NL and were dominated by triglycerides (TAG), which made up 65% of the NL. The major phospholipids were phosphatidylethanolamine (PE), ceramide aminoethylphosphonate and phosphatidylinositol (CAEP + PI), phosphatidylserine (PS) and phosphatidylcholine (PC). Regardless of the broodstock diet treatment, the PL fraction contained high percentages of non-methylene-interrupted dienes (NMID) and plasmalogens (detected as dimethyl acetals).

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P. Sorgeloos

Effect of lipid emulsions on production and fatty acid composition of eggs of the scallop *Argopecten purpuratus*

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Abstract The impact of supplementing lipid emulsions rich in eicosapentaenoic acid (EmEPA), docosahexaenoic acid (EmDHA) or saturated fatty acids (EmCOCO) to a standard algal diet [3:1 mixture of *Isochrysis galbana* (T-iso) and *Chaetoceros neogracile*, St-diet] on *Argopecten purpuratus* broodstock was evaluated. Broodstock fecundity was compared as well as the egg quality in terms of lipid content, fatty acid composition and lipid class distribution. Fecundity was defined as the number of eggs released in the spawning process, since spawning was virtually complete. Results indicated that the total lipid content of the eggs of *A. purpuratus* was diet independent. A greater energy reserve was spent on a larger number of oocytes and not on bigger sized oocytes with a higher lipid content. The lipids supplied through the emulsions were at least partially allocated to the eggs, demonstrating that the fatty acid composition of the eggs could be manipulated, especially the neutral lipid fraction. Levels of EPA changed more rapidly than DHA levels, supporting the observation that they fulfilled an energetic and structural role, respectively. The St-diet supplemented with 50%EmCOCO resulted in a significantly higher fecundity compared to the algal diet supplemented with 25%EmEPA+25%EmDHA and the non-supplemented algal diet. It would seem that saturated fatty acids (SAFA) were more easily or preferentially incorporated in the female gonads of *A. purpuratus*. The relative content of SAFA and 18:2(*n*-6) in these eggs rose significantly. The relative content of the highly unsaturated fatty acids, EPA and DHA, on the other hand was substantially lower in the neutral lipid fraction, but hardly affected in the polar lipid fraction. It appeared that the maintenance of an adequate DHA/EPA ratio (approximately 1.2) was more important than the absolute levels of the two fatty acids, as long as a threshold value was reached.

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Dietary impact of algal and artificial diets, fed at different feeding rations, on the growth and fatty acid composition of *Tapes philippinarum* (L.) spat

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Abstract

The effect of lipid supplementation and algal ration on growth and fatty acid composition of juvenile clams, *Tapes philippinarum* was investigated. A diet of *Tetraselmis suecica* was supplemented with a lipid emulsion and fed at a daily ration of 0.5, 1.0 and 1.5% WW DW^{-1} day^{-1}. A mixed algal diet of *Isochrysis galbana* (clone T-Iso) and *T. suecica* (1:1 on DW basis) and starvation functioned as positive and negative control treatments, respectively. *T. suecica*, which contains eicosapentaenoic acid (20:5$n-3$) but no docosahexaenoic acid (22:6$n-3$), was supplemented with 50% (% of algal dry weight) of a 22:6$n-3$-rich emulsion. Higher growth rates of *T. philippinarum* were associated with higher *T. suecica* feeding rations. Lipid supplementation resulted in significantly better growth rates of *T. philippinarum* at a *T. suecica* ration of 0.5, 1.0 and 1.5% WW DW^{-1} day^{-1}. The growth promoting effect of lipid supplementation was significantly reduced during 4 consecutive weeks or by increasing the algal feeding ration. Increasing *T. suecica* rations were associated with a decrease in the % composition of 22:6$n-3$ while the 20:5$n-3$% composition was hardly affected in the total lipids of *T. philippinarum*. On the contrary, the absolute concentration of 22:6$n-3$ (μg per gram dry weight, μg g DW^{-1}) in the total lipids of *T. philippinarum* was similar at all *T. suecica* rations while the 20:5$n-3$ concentration significantly increased. The major effect of lipid supplementation on the fatty acid composition of the clams, was a significant increase of the 22:6$n-3$% composition in the total lipids, polar lipids and triglycerides. In contrast with 20:5$n-3$, the effect of lipid supplementation on the absolute 22:6$n-3$ content (μg g DW^{-1}) was more pronounced at a higher *T. suecica* ration. After a starvation period of 4 weeks, the concentration (μg g DW^{-1}) of all fatty acids was significantly reduced, except the $n-7$ monoenoic fatty acids (MUFA) and the non-methylene interrupted dienoic fatty acids (NMID). The concentration (μg g DW^{-1}) of the NMID in starved

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The effect of lipid supplementation on growth and fatty acid composition of *Tapes philippinarum* spat

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Accepted 5 January 1998

Abstract

The present study investigated the possible use of emulsions as an artificial lipid supplement to live algae for seed of the Manila clam *Tapes philippinarum*. The uptake and assimilation of an emulsion, rich in docosahexaenoic acid (DHA, 22:6$n-3$) and eicosapentaenoic acid (EPA, 20:5$n-3$) and fed at concentrations of 20 and 40% of the algal dry weight, were verified analytically by fatty acid analysis of the animals and their diets. Dietary requirements for $n-3$ highly unsaturated fatty acids (HUFA) were examined by supplementing *Dunaliella tertiolecta*, which contains no polyunsaturated fatty acids longer than 18:3$n-3$ and *Tetraselmis suecica*, which contains EPA but only trace amounts of DHA. An algal mixture of *Isochrysis galbana* (clone T-Iso) and *Chaetoceros neogracile* (1:1, on dry weight basis) was used as the control diet. After 4 weeks, the lipid supplementation resulted in a significant increase of the DHA level in the seed compared to the animals fed non-supplemented *Dunaliella* (from 9.5 to 19.8 and 22.0% at a supplementation of 20 and 40%, respectively) or *Tetraselmis* (from 3.4 to 24.8 and 26.9%, at a supplementation of 20 and 40%, respectively) diet. Feeding solely *D. tertiolecta* resulted in a significantly lower daily growth rate (DGR) compared to animals fed *T. suecica* or the mixed algal diet. Lipid supplementation improved the DGR of the clams fed *D. tertiolecta* while hardly any effect could be detected in those fed *T. suecica*. The poor nutritional value of *D. tertiolecta* was indicated by the continuous decrease of the DGR and resulted in a DGR that was no longer significantly different from the starved ones at the end of the experiment. © 1998 Elsevier Science B.V. All rights reserved.