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Seasonal variation in the chemical composition and fatty acid profile of Pacific oysters (*Crassostrea gigas*)

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Abstract

The chemical composition and fatty acid profile of the tray-cultured Pacific oyster (*Crassostrea gigas*) were measured and compared over a 13 month period. Oysters (120–150 g) were cultured in Cork Harbour and samples taken for analysis at monthly intervals. The moisture, fat, protein, glycogen and ash contents of the flesh were analysed. The fatty acid profile of the flesh was analysed by gas chromatography. The condition indices of the oysters were determined. The chemical composition of the oysters grown in Cork Harbour was similar to literature values for the same species grown in Pacific waters. Ranges for the chemical composition (dry flesh weight basis) were: fat (7.8–8.7%), protein (39.1–53.1%), glycogen (21.6–38.9%) and ash (4.0–12.1%).
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1. Introduction

The Pacific oyster (*Crassostrea gigas*) is an introduced species farmed in Irish waters. It is faster-growing and more tolerant of a wider range of environmental conditions than the native Irish oyster (*Ostrea edulis*). It is also resistant to the parasite *Bonamia ostrea* which has decimated native stocks. The Pacific oyster has been cultured in Japan for centuries (Korringa, 1976) and was introduced to Britain in 1965 (Walne & Spencer, 1971). It has been cultured in Ireland since 1970. Very little work has been published on the proximate composition of Pacific oysters and the data reported were for oysters grown in Pacific waters (Masumoto, Masumoto, & Hibino, 1934; Tully, 1936; Jeng, Hsu, & Wang, 1979; Whyte & Englar, 1982; King, Childs, Dorsett, Ostrander, & Monsen, 1990). To our knowledge, no data have been published on the seasonal variation in chemical composition or the fatty acid composition of the Pacific oyster grown in Atlantic waters. Shimma and Taguchi (1964) and King et al. reported data on the fatty acid composition of *C. gigas* in comparative studies of fatty acids in shellfish in Pacific waters.

Production of *C. gigas* in Ireland and elsewhere in Europe continues to increase as stocks of native species decline. Data on seasonal variations in composition of the species grown in Atlantic waters provide useful background information for the European industry.

2. Materials and methods

2.1. Collection and storage of samples

Oysters were cultured on trestles at the University pilot scale farm in Cork Harbour. They were collected at monthly intervals over a 13 month period. The shells were cleaned of adherent epifauna and the oysters were weighed. They were then opened, the adductor muscle cut, the meat removed and allowed to drain for 5 min on Whatman No. 1 filter paper. The meat was then weighed and pooled (10 oysters per pool). Pools were prepared since individual oysters provided too small a sample on which to perform all the chemical analyses. Using a Waring Blender, the pooled samples were blended for 4 min at low speed and 2 min at high speed. The samples were frozen and stored at −20°C until analysis, apart from the fatty acid determination which was carried out on fresh samples.

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2.2. Pooling scheme validation

As each individual oyster was too small to be assayed for all of the chemical constituents of interest so a pooling scheme was adopted using 10 oysters per pool. The fundamental assumption involved in the use of such a pooling scheme is that the value for any assay obtained on the pool is the weighted average value for the same assay obtained upon analysis of each of the 10 individual oysters constituting the pool. This assumption was validated as follows. Ten oysters were weighed, homogenised individually and each oyster homogenate was assayed for ash, protein and moisture as outlined below. The weighted averages for ash, protein and moisture for the 10 oysters were calculated. The remaining homogenates of known weight from each of the 10 oysters were pooled and also assayed for ash, protein and moisture. The value obtained on the pooled homogenate was then compared to the weighted average of the individual 10 oysters constituting the pool.

2.3. Determination of condition indices

Condition indices may serve two purposes. The first is an economic one in which the index is used to designate the quality of a marketed product. The second is an ecophysiological one in which the index is used to characterise the apparent health of the oysters. Three condition indices were determined in this investigation. The first condition index was that of Imai and Sakai (1961) which is an economic one and is calculated as: $\text{thickness} \times [0.5(\text{length} + \text{width})]^{-1}$. Dimensions were measured using a Vernier callipers. The second index used was that of Booth (1983) which is calculated as wet flesh $\text{weight} \times \text{total weight}^{-1}$. A high value for this index indicates that a high percentage of the total weight is due to the actual flesh and not the intervalval fluid which can vary quite considerably in oysters (Lucas & Beninger, 1985). The third index examined was the ecophysiological one of Walne (1976) which is the dry flesh weight to dry shell weight ratio. The dry weight of the shells was determined by oven-drying at 80°C for 12 h.

2.4. Determination of chemical composition

All reagents used were of 'AnalaR' grade. Two subsamples from each pooled sample were analysed in duplicate; if the difference between the mean of the two duplicates was more than 1% a third sub-sample was analysed. Glycogen was measured by the method of Carroll, Longley, and Roe (1956). Lipid content was measured by the method of Bligh and Dyer (1959). Ash and moisture contents were determined as described by AOAC (1984) and protein was determined by the Kjeldahl procedure using a Tecator Digestion System, Model 1015 (Tecator Ltd., Bristol, UK) and a Kjeltec 1026 Distillation Unit (Tecator Ltd.). Percent protein was calculated as % N×6.25. The fatty acid profile was determined by the method of Marmer and Maxwell (1981) using a Pye Unicam PU4500 gas–liquid chromatograph equipped with a flame ionization detector and a 2.4 m by 6.25 mm pyrex column packed with Silar 10. Chromatographic conditions were as follows: injection port temperature 300°C; flame ionization detector 300°C; initial oven temperature 165°C; temperature programme: 5 min at 165°C and then increased at 3°C min^{-1} to 225°C (final hold 5 min); carrier gas, nitrogen (20 ml min^{-1}). Retention times and peak areas were computed by a Shimadzu C-R3A Chromatopac recorder. Compounds were identified by comparison with the retention times of Fatty Acid Methyl Ester (FAME) standards (Sigma Chemical Company, Poole, UK).

3. Results and discussion

3.1. Pooling scheme validation

The results of the pooling scheme validation study are shown in Table 1. It is clear that there is close agreement between the values for moisture, protein and ash determined in the pooled sample and the weighted averages determined from analysis of the same parameters in the individual oysters constituting each pool.

3.2. Condition indices

Table 2 shows the seasonal variation in the condition indices measured. A high value of Imai and Sakai's (1961) index indicates a large oyster. A maximum value of 0.754 was reached in December but, apart from that month, values ranged from 0.425 to 0.51. These values represent oysters that were on average 9.03 cm long, 5.48 cm wide and 3.74 cm thick over the 13 month period. The condition index of Booth (1983) reached a maximum value of 0.233 in September and a minimum of 0.107 in December. Comparison of the two indices shows that a maximum in the condition index of Imai and Sakai was reached in December while the index of Booth was at a minimum. The reason for the difference is that, although the physical dimensions of the shells

Table 1
Validation of the pooling scheme for analysis of *Crassostrea gigas*

Assay	Pool	Weighted average (%)	Pooled average (%)
Moisture	1	75.7	76.1
	2	75.7	75.9
Protein	1	10.7	10.9
	2	10.5	11.2
Ash	1	2.8	2.8
	2	2.0	2.0

Table 2
Seasonal variation in condition indices of *Crassostrea gigas*

Index	Month												
	March	April	May	June	July	August	September	October	November	December	January	February	March
Imai and Sakai (1961)	0.425	0.551	0.498	0.452	0.508	0.529	0.529	0.502	0.505	0.754	0.520	0.483	0.418
Booth (1983)	0.155	0.154	0.173	0.149	0.169	0.178	0.233	0.211	0.191	0.107	0.164	0.151	0.158
Walne (1976)	0.048	0.047	0.053	0.046	0.053	0.057	0.074	0.061	0.052	0.048	0.037	0.042	0.046

Table 3
Seasonal variation in the chemical composition of *Crassostrea gigas*[a]

	Month												
	March	April	May	June	July	August	September	October	November	December	January	February	March
Moisture	74.3	74.1	74.0	74.5	74.1	73.0	73.5	75.0	76.8	76.2	79.5	77.3	76.1
Glycogen	31.7	34.7	38.9	37.0	28.5	23.0	22.1	21.8	23.9	21.6	28.1	31.8	31.6
Protein	43.1	41.8	39.1	41.3	49.4	53.1	47.2	49.2	46.5	49.4	48.5	44.5	45.6
Fat	8.2	7.9	8.2	8.1	8.0	8.5	7.8	7.9	8.4	8.7	8.1	8.2	8.6
Ash	6.8	6.9	4.0	4.7	6.9	8.1	7.2	12.1	7.8	6.8	6.3	10.4	10.1

See text for details of analysis. Data are means of duplicate analysis of pooled homogenates.
[a] Glycogen, protein, fat and ash are expressed as % dry flesh weight.

Table 4
Seasonal variation in the fatty acid composition of *Crassostrea gigas*

Fatty Acid[a]	Month												
	March	April	May	June	July	August	September	October	November	December	January	February	March
14:0	4.27	3.33	3.97	4.53	5.13	5.43	5.2	4.91	4.01	4.31	4.09	4.75	4.54
16:0	15.09	15.35	16.24	16.74	17.09	17.90	18.17	15.62	15.51	15.24	15.23	15.42	15.79
16:1	3.14	3.44	3.56	4.21	4.61	4.95	5.64	4.81	4.69	5.24	5.39	5.11	4.75
18:0	3.95	4.16	4.27	3.87	3.52	3.28	3.02	2.51	2.59	2.81	3.11	3.47	3.35
18:1	12.94	13.36	12.51	11.75	11.49	10.90	9.40	9.94	9.99	10.62	10.42	10.98	11.43
18:2	1.75	1.82	1.93	1.42	1.75	1.53	1.99	1.67	1.65	1.74	1.92	1.84	1.78
18:3	6.24	6.46	6.19	5.75	5.94	5.31	6.39	6.28	6.44	5.91	6.02	5.34	6.21
20:1	2.14	2.07	2.11	1.89	1.74	1.50	1.74	1.80	1.87	1.92	2.14	2.07	2.27
18:4	4.17	4.35	3.94	4.11	3.84	3.78	5.18	5.41	5.46	4.95	4.25	3.72	4.14
20:4	4.22	5.88	4.94	5.24	4.97	4.74	5.20	5.08	5.41	4.84	5.10	4.61	5.34
20:5	14.87	15.24	14.59	13.75	12.27	10.79	12.72	14.13	14.79	14.11	14.25	13.72	14.29
22:6	12.91	12.15	11.42	11.04	10.98	10.35	11.64	12.89	13.57	14.97	15.50	14.23	13.74

[a] Expressed as a percentage of total fatty acids.

were quite large, the amount of flesh present was quite small in comparison.

The annual cycle in the condition index of Walne (1976) reached a maximum value of 0.074 in September with a minimum value of 0.037 in January. The values obtained in this study were quite satisfactory and indicated that the oysters were in good condition. A low value for this index indicates that a major biological effort has been expended, either as maintenance energy under poor environmental conditions or disease, or in the production and release of gametes during spawning. Assuming that the decrease in condition observed between September and January was due primarily to the production and release of gametes, it appears that the Pacific oysters grown in Cork Harbour began to spawn in August/September. This would agree with data of Whyte and Englar (1982) and Jeng et al. (1979).

3.3. Chemical and fatty acid composition

Seasonal variation in chemical composition of the oysters is shown in Table 3. Oysters begin to form and store glycogen after spawning and glycogen content reaches a maximum a few months before the next spawning. It is used as an energy source during the rapid proliferation of sex cells and by the end of the reproductive cycle it is at a minimum (Galstoff, 1964). Our data indicate that the oysters began to store glycogen from December (21.6% dry flesh weight) to a maximum in May (38.9%). Glycogen levels then began to

decrease and reached a minimum from August to December. Based on the changes in glycogen levels and the condition index of Walne (1976) reported above, it appears that the oysters began to spawn in August/September. Similar fluctuations in glycogen content were observed by both Jeng et al. (1979) and Whyte and Englar (1982).

The protein content of the oysters fluctuated throughout the 13 month study period, ranging from a maximum of 53.1% (dry flesh weight basis) in August to a minimum of 39.1% in May. Jeng et al. (1979) observed a similar cycle but reported a maximum protein content of 65%. Whyte and Englar (1982) also reported a peak protein content in August.

Moisture content of oysters in this study fluctuated from a maximum value of 79.5% in January to a minimum of 73.0% in August. Lipid concentration in the oysters remained relatively constant when compared to other constituents. The average lipid content was 8.2% (dry flesh weight basis) with a maximum of 8.7% observed in December and a minimum of 7.8% observed in September.

Whyte and Englar (1982) reported an average lipid content of 7.35% for tray-cultured oysters while Jeng et al. (1979) found an average of 8.7% with a maximum of 12.9% in February and a minimum of 7.15% in June. Ash content varied significantly over the 13 month study period with a maximum in October of 12.1% (dry flesh weight basis) and a minimum of 4% in May. Jeng et al. (1979) reported variations in ash content from approximately 10 to 20% while Whyte and Englar (1982) reported concentrations from approximately 9 to 14%.

The seasonal variation in the fatty acid composition of *C. gigas* is shown in Table 4. Fatty acids from myristic (14:0) to docosahexaenoic (22:6) were observed. It is apparent that the fatty acid profile remained relatively constant during the 13 months study with high concentrations of ω-3 fatty acids (18:3, 20:5 and 22:6) and low overall concentrations of saturated fatty acids (14:0, 16:0 and 18:0) observed. Palmitic acid (16:0) and oleic acid (18:1) were the main saturated and monounsaturated fatty acids, respectively.

References

AOAC (1984). *Official methods of the Association of Official Analytical Chemists* (14th ed., pp. 330–342). Washington, DC: AOAC.

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology, 37*, 911–917.

Booth, J. D. (1983). Studies on twelve common bivalve larvae and bivalve spawning seasons. *New Zealand Journal of Marine Freshwater Research, 17*, 231–265.

Carroll, N. V., Longley, R. W., & Roe, J. J. (1956). The determination of glycogen in liver and muscle by use of anthrone reagent. *Journal of Biological Chemistry, 220*, 583–593.

Galstoff, P. S. (1964). The American oyster, *C. virginica*. Fishery Bulletin of Fish Wildlife Service (Vol. 64, pp. 14–80). Washington, DC: US Government Printing Office.

Imai, T., & Sakai, S. (1961). Study on the breeding of the Japanese oyster, *Crassostrea gigas. Tohoku Journal of Agricultural Research, 12*, 125–171.

Jeng, S. S., Hsu, S. Y., & Wang, G. S. (1979). Chemical composition of Taiwan's oysters and clams. *Bulletin of the Institute of Zoology, Academia Sinica, 18*, 1–10.

King, I., Childs, M. T., Dorsett, C., Ostrander, J., & Monsen, E. (1990). Shellfish: proximate composition, minerals, fatty acids and sterols. *Journal of the American Dietetic Association, 90*(5), 677–685.

Korringa, P. (1976). Farming the Pacific oyster (Crassostrea gigas) in Hiroshima Bay, Japan. In *Farming the cupped oysters of the genus* Crassostrea (pp. 153–182). London: Elsevier Scientific.

Lucas, A., & Beninger, P. G. (1985). The use of physiological condition indices in marine bivalve aquaculture. *Aquaculture, 44*, 187–200.

Marmer, W. N., & Maxwell, R. J. (1981). Dry column method for the quantitative extraction and simultaneous class separation of lipid from muscle tissue. *Lipids, 16*, 365–371.

Masumoto, B., Masumoto, M., & Hibino, M. (1934). A study on oysters: *Crassostrea gigas* and *Ostrea edulis. Journal of Science of Hiroshima University, A4*, 47–56.

Shimma, Y., & Taguchi, H. (1964). A comparative study on fatty acid composition of shellfish. *Bulletin of the Japanese Society of Scientific Fisheries, 30*, 153–160.

Tully, J. P. (1936). The nutritive value of marine products, XIV. Proximate analyses of fresh British Colombian oysters. *Journal of Fish Research Board Canada, 2*, 477–484.

Walne, P. R. (1976). Experiments on the culture in the sea of the Butterfish *Venerupis decussata 1. Aquaculture, 8*, 371–381.

Walne, P. R. & Spencer, B. E. (1971). The introduction of the Pacific oyster (*Crassostrea gigas*) into the United Kingdom. *Shellfish Information Leaflet* (No. 21). UK: Ministry of Agriculture, Fisheries and Food. HMSO, London.

Whyte, J. N. C., & Englar, J. R. (1982). Seasonal variation in the chemical composition and condition indices of Pacific oyster, *Crassostrea gigas*, grown in trays or on the seabed. *Canadian Journal of Fish Aquatic Science, 39*, 1084–1094.