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# Seasonal changes of carbohydrate content in Antarctic krill (*Euphausia superba* Dana)

ABSTRACT: Antarctic krill carbohydrate content was followed during 1983—84 Eighth Polish Antarctic Expedition. The Admiralty Bay (King George Island) was the area of study. The following average values of three estimated fractions were obtained: 3.77±1.51%, 0.47±0.34% and 3.30±1.33% for total, TCA-soluble and TCA-insoluble carbohydrates, respectively. Percentage contribution of the estimated fractions to dry weight varied seasonally (1.48—7.41%, 0.15—1.83% and 1.28—6.28%, respectively). The carbohydrate content showed a clearcut cycle of changes over the calender year, with a minimum in autumn-winter and a maximum in spring-summer.

Key words: Antarctic krill, carbohydrate fractions, seasonal variations.

## Introduction

The average content of carbohydrates in the Antarctic krill is commonly held to be rather low and to amount to about 5% of dry weight (Grantham 1977) although mean values reported in the literature vary fairly widely, from 2.1% (Ferguson and Raymont 1974) to 10.9% (Yanase 1971) and even to 19.0% (Burkholder, Mandelli and Centeno 1967). For this reason, in spite of data evidencing that "... carbohydrate content in krill remained at almost constant level during the Antarctic summer season" (Mori and Yasuda 1976), a hypothesis is tested here that differences in krill carbohydrate content are season-dependent. The aim of this work was to follow total as well as TCA-soluble and insoluble cyrbohydrate content of Antarctic krill during one year period.

## Material and methods

Antarctic krill samples were collected between 28 December 1983 and 24 November 1984. A pelagic trawl with a 2×1 m rectangular mouth, towed by motor boat "Dziunia" was used for krill collection in Admiralty Bay area (main sampling site coordinates: 61°08′S, 58°26′W).

Immediately after capture the live krill catch was brought to the laboratory and, after short (5—15 min) period in aerated sea:water, sampled for the assays. 200—400 krill specimens from each catch were homogenized and the obtained homogenate was analysed for water content as well as TCA-soluble, TCA-insoluble and total carbohydrates. The homogenate was dried up to a constant weight (approx. 5 g sample at 105°C for 6 hrs). Total carbohydrates were estimated by the anthrone method (Aswell 1967) using glucose as a standard (dried samples were hydrolysed in the presence of 30% KOH for 1 h at 100°C). Soluble carbohydrates were extracted by trichloroacetic acid from dried samples. 10 g sample was homogenized in the presence of 300 ml 4.1% $CCl_3COOH$ (13000 rpm, 60 sec., 3 times, MPW-309 universal laboratory aid). The filtrate was analysed for carbohydrates by the anthrone method. TCA-soluble fraction was calculated as a difference between total and TCA-soluble carbohydrates.

To analyse carbohydrate content of krill cephalothorax and abdomen separately, each specimen was frozen individually and kept at −28°C until analysed (6—9 months). Then the temperature of the specimen was increased to −5°C and cephalothorax was cut off from abdomen. Further procedure applied to analyse carbohydrate content was the same as described above.

## Results and discussion

Table 1 summarizes the data obtained for average annual (1984) and season-dependent content of carbohydrate fractions analyzed in Antarctic krill. Estimated average annual content of total, TCA-soluble and TCA--insoluble carbohydrates were found to be 3.77±0.51%, 0.47±0.34% and 3.30±1.33%, respectively. The above values varied depending on season from 1.48 to 7.41% for total, from 0.15 to 1.83% for TCA-soluble and from 1.28 to 6.28% for TCA-insoluble carbohydrates.

Results obtained for total carbohydrates are similar to those obtained by others. Since most of the literature data refer to krill collected during spring-summer period the average value obtained by us for that period (4.6% dry weight) could be compared with the results of Grantham (1977) — 5.70% and Roschke and Schreiber (1977) — 3.77%. Since no reports exist in the literature on winter and autumn krill carbohydrate content any comparison was possible.

Table 1

Relationship between catch season (1984), carbohydrate content and dry weight of Antarctic krill (*Euphausia superba* Dana)

| Antarctic season | Period | Number of assays (N$\bar{x}$) $N_i$ | Carbohydrate (% dry weight) total | soluble | insoluble (bound) | Dry weight (%) |
|---|---|---|---|---|---|---|
| Summer | 1 January — 10 February | (10) 30 | 4.40±1.01 (2.96–6.67) | 0.668±0.302 (0.407–1.262) | 3.73±1.10 (279–6.25) | 19.09± 2.02 (17.71–22.86) |
| Autumn | 27 March — 10 May | (7) 21 | 1.76±0.23 (1.57–2.25) | 0.286±0.036 (0.250–0.320) | 1.48±0.22 (1.28–1.93) | 20.66± 0.12 (20.50–2089) |
| Winter | 6 August 21 September | (7) 21 | 3.03±0.72 (1.48–3.46) | 0319±0.093 (0.237–0.505) | 2.72±0.69 (1.24–3.22) | 19.81± 0.96 (18.07–20.42) |
| Spring | 25 September 23 November | (13) 39 | 4.75±1.32 (3.95–7.41) | 0496±0.463 (0.150–1.826) | 4.26±0.94 (3.11–6.28) | 16.73± 1.45 (14.62–20.42) |
| Year 1984 | 1 January 23 November | (37) 111 | 3.77±1.51 (1.48–7.41) | 0469±0.344 (0.150–1.826) | 3.30±1.33 (1.28–6.28) | 18.84± 2.06 (14.63–2286) |

Over the calendar year, the carbohydrate content of krill dry weight exhibited a clear-cut character of changes. The lowest content of total and covalently bound carbohydrates was observed in krill collected during May-June and of soluble compound fraction during June-July period. The highest carbohydrate content in krill was found after analysis of November--December and December-January catches.

An attempt was made to describe the changes with a sinusoidal equations: a standard one (y') and an exponential one (y"). Both the equations were found to fit sinuosidal character of the changes. The curve plotted following the second of equations gave, however, slightly better fit (Figs. 1 and 2). This curve shows minimum content of total and bound carbohydrates to occur in late May — early June, late June — early July being the time of minimum content of soluble carbohydrates. The maximum content of the latter occurred in the first decade of January, while total and insoluble carbohydrates had their maximum in the first decade of December.

On the other hand, the first equation (y') produced a more reliable amplitude value (b) than did the second equation. The amplitude expressed as a percentage of harmonic mean (a) was 80.9% for TCA-soluble, 65.1% for total and 64.4% for TCA-insoluble carbohydrates. The obtained results indicate seasonal changes of soluble carbohydrates fraction to be the most pronounced camparing with insoluble and total ones.

The cyclic course of carbohydrate content over the year with a maximum in warm season and a minimum in cold one could be related to the rates of carbohydrates storage and consumption during respective periods. A question emerges, however, to what extent the cyclic course of changes

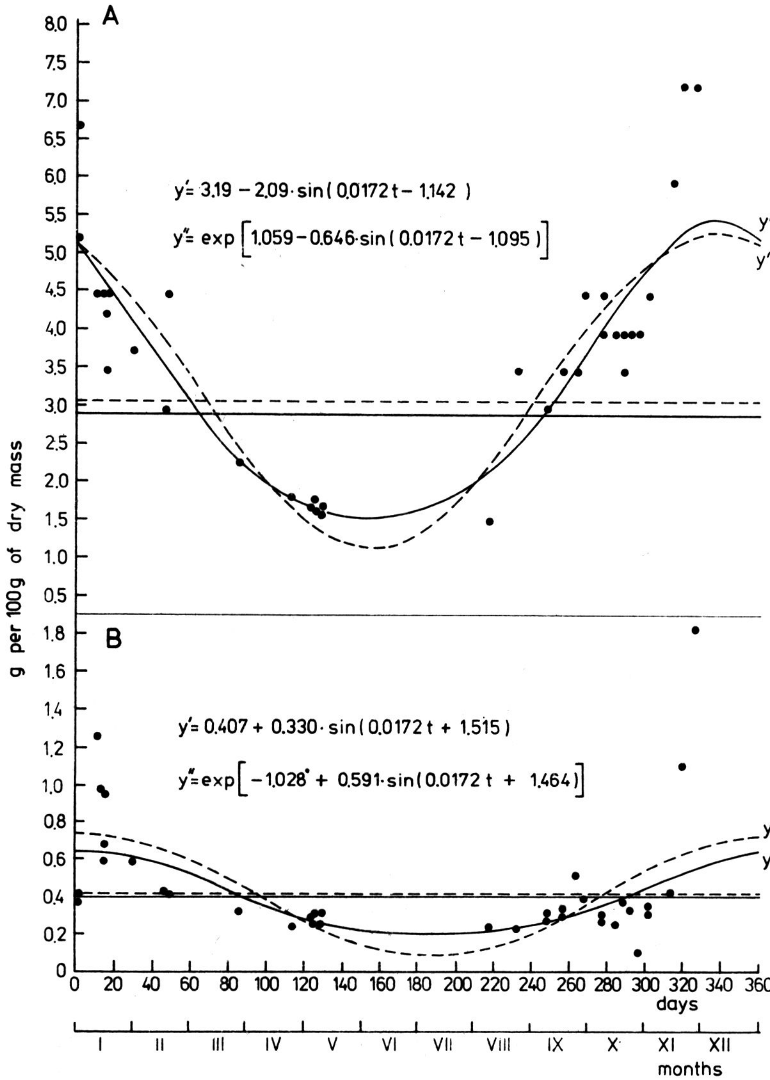


Fig. 1. Seasonal changes of total (A) and TCA-soluble (B) carbohydrate in Antarctic krill

in the carbohydrate content depends on the degree of krill gut filling and how it depends on carbohydrate deposition in the body outside the alimentary tract. To answer this question, additional analyses were performed. Carbohydrate content of krill abdomen and cephalothorax separately, were estimated. The experiments were carried out on frozen krill samples collected between 21 August and 11 November, 1984. This period was deliberately chosen for sampling since the whole body carbohydrate content of krill was observed to increase rapidly. Seasonal changes in carbohydrate content were found to occur in both krill body parts examined. However, the changes

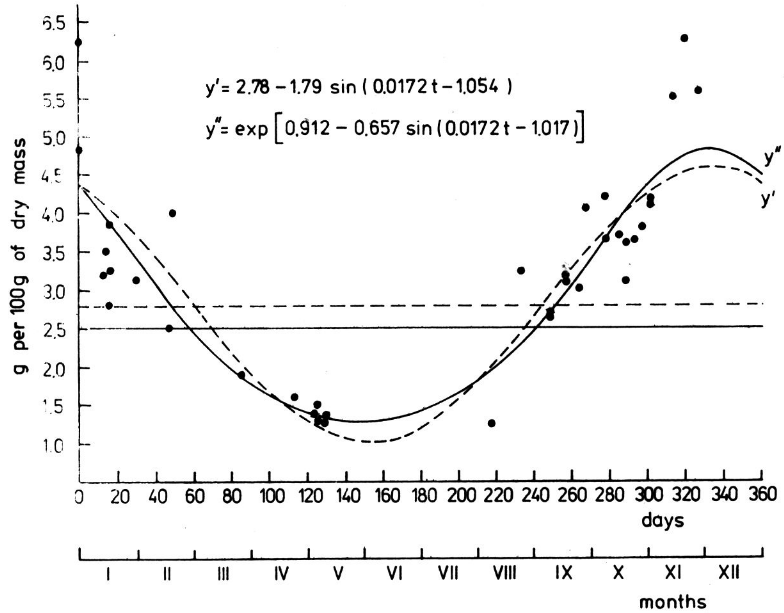


Fig. 2. Seasonal changes of insoluble (bound) carbohydrate in Antarctic krill

of cephalothorax carbohydrates were to be more pronouced than those of abdomen (Fig. 3).

Thus it can be suggested that gut filling cannot be the only cause of seasonal changes in krill carbohydrate content. The changes are related also to physiological and metabolic process in krill tissues. More rapid accumulation of TCA-insoluble carbohydrates than that of TCA-soluble fraction could suggest enhanced glycoprotein synthesis in the tissues of krill to occur. It is probable that such a phenomenon takes place during physiological activity related to growth of the krill in the discussed period of time.

The seasonal increase of covalently bound carbohydrates is supposed to cover also the anti-freezing glycoproteins which were reported to be present in Antarctic invertebrates (Rakusa-Suszczewski and McWhinnie 1976).

The carbohydrates accumulated by krill tissues can serve as an easily accessible source of "kinetic" energy during the period of increased feeding activity of the animal. This conclusion is supported by the rapid increase of krill carbohydrate content, particularly in the cephalothorax, starting from the second decade of November, i.e., when the period of intensive feeding begins ("green krill").

Fluctuations of krill carbohydrates content can also be associated with chitin synthesis during the moult stages as found in an isopod crustacean (Parvathy 1971).

Some more unequivocal conclusions on the mechanism of qualitative