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Changes in body calorific values during nestling development of penguins of the genus *Pygoscelis* *

ABSTRACT: Changes in water and ash contents in the body and calorific values of dry and wet body weight during nestling development of *Pygoscelis antarctica* and *P. papus*. were examinted. It was found that water content in the tissues of both species decreases from 85% to less than 65% whereas the content of mineral substances in dry body weight increases from 9% to about 12%, at the time. Caloricity indices are high and increase during the development of nestlings. A particularly intense increase (from 0.8 kcal·g^{-1} to 2.2 kcal·g^{-1}) characterizes calorific value of 1 gram of biomass.

KEY WORDS: Antarctic, penguins, calorific values body

1. Introduction

In ecological studies on the functioning of various types of ecosystems one of the most important elements is a thorough investigation of the ways of the flow of energy through these systems. To this end it is necessary to come to know the value of the production of the populations of the main species entering into the composition of biocenoses (Grodziński, Klekowski and Duncan 1970, Petrusewicz and MacFadyen 1970). One of the purposes of the Polish Antarctic Program is to get to know the normal pattern of the functioning of the near shore antarctic ecosystem, exemplified by the observations made at Admiralty Bay and the surrounding shores (Rakusa-Suszczewski 1980).

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The complex ecological investigations, conducted during the last few years at the Arctowski Station, indicate that penguins belong to the most important consumers of a higher order in that environment. Bioenergeics of these birds, however, is relatively little known. In the literature only scarce reports on their metabolism can be found (Fedak, Pinshaw and Schmidt-Nielsen 1974, Pinshaw et al. 1975).

In the region of Admiralty Bay penguins form in the summer season a range of breeding colonies numbering in total about 45 thousand nests (Jabłoński in prep.). The knowledge of the effectiveness of utilization of the energy in the production processes by such a large population, the biomass exceeding processes by such a large population, the biomass exceeding on the average 360 tons, is indispensable for the correctness of deliberations upon the role of penguins in the investigated ecosystem.

For that reason it was resolved to investigate thoroughly changes in the body calorific values during the development of the nestlings of penguins of the most numerous in Antarctica order *Pygoscelis*. Changes in the content of water and mineral substances in the tissues occurring at that time, were also examined.

2. Material and methods

Changes in calorific values and water and ash content in the body during the nestling development were examined in 46 nestlings of *Pygoscelis antarctica* Forster and 38 nestlings of *Pygoscelis papua* Forster. The investigations were conducted at the Arctowski Station from mid-December 1977 until the end of February 1978. The birds were from the rookery at Point Thomas, King George Island, South Shetland Islands (62°09′8″ S, 58°28′6″ W) and were used at the same for other physiological and ecological studies.

The material consisted of nestlings from the moment of coming forth from the egg till the end of moulting. The nestlings under examination were not marked immediately after hatching, so their age was determined by means of their body weight. It seems that in this case the error was not too great, since the curves of growth of the nestlings from that rookery are known for the three succeeding breeding seasons: 1977/78, 1978/79, 1979/80. (Volkman and Trivelpiece 1980, Jabłoński in prep., Taylor in prep.).

All the birds were killed, weighed and after the removal of the stomach content additionally weighed and desiccated in a dried at the temperature of 70°C, then sealed in polyethylene bags. They were transferred from the Antarctic into laboratories of the Institute of Ecology of the Polish Academy of Sciences in a refrigerator. In the laboratories they were dried up additionally in a vacuum drier to constant weight. From the differences between the weight before and after drying the content of water in the bodies of penguins was calculated. The dried up birds were ground in an electric grinder. From the thoroughly mixed material 3 samples, weighing about one gram each, were taken and burned in a Berthelotte system Kl-4 calorimeter. The mean values from the three combustions was used in all calculations.

These data allow to calculate calorific values of one gram of dry body weight and of one gram of the biomass of the nestlings of both species. The ash left after combustion was weighed and the relative content of mineral components in the examined samples was calculated.

3. Results and discusion

The content of water in the tissues of the two examined species of penguins decreases fairly regularly throughout the period of nestling development (Fig. 1). Immediately after the coming forth from the egg

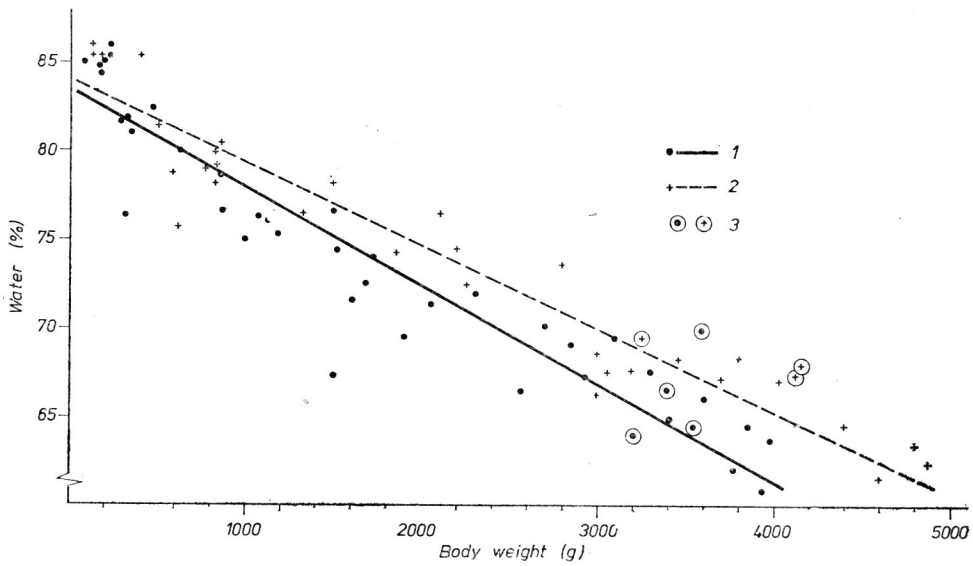

Fig. 1. Water content (%) in the body of Pygoscelid penquins during their development
1 — *P. antarctica*: $y = 83.34—0.0055\ x$, 2 — *P. papua*: $y = 84.02—0.0046\ x$, 3 — birds during and immediately after moulting

the chicks of *P. antarctica* and *P. papua* contain 85% of water in the body, which approximates the values of the water content in the tissues of the nestlings of the temperature zones (Myrcha, Pinowski and Tomek 1970). The content of water in the tissues of birds starting fledging drops below 65%. The difference in this value between the two examined species is unimportant. However, the content of water in the body of *P. papua* is always slightly higher.

Changes in the percentage of the content of mineral substances in the body of nestlings of both species of penguins during their development follow the same course (Fig. 2). The dry body weight of the nestlings immediately after hatching contains 9% of ash and in the period preceding molt 11.5%—12.5%. The increase in the absolute content of mineral components, however, is at that time very high (about hundred-

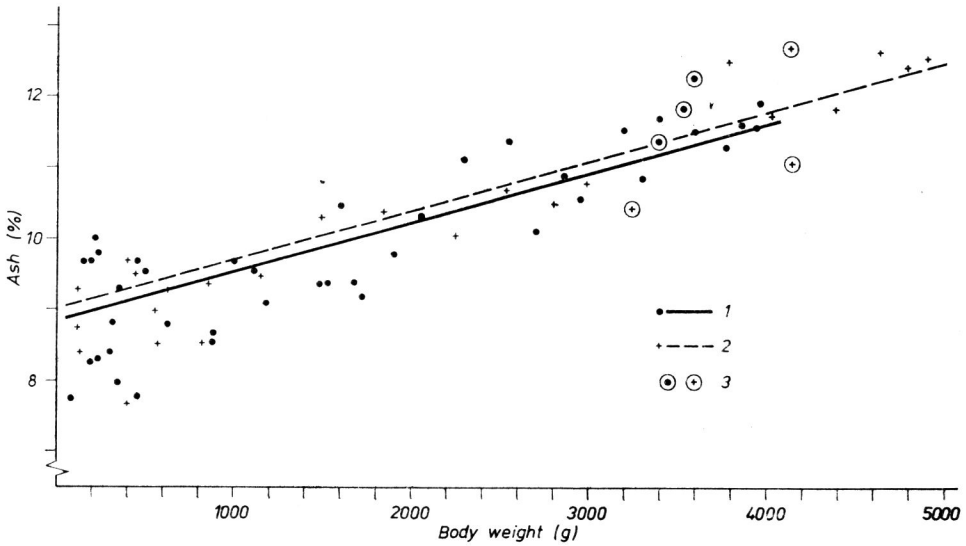

Fig. 2. Ash content (%) in the dry body weight of Pygoscelid penguins during their development

1 — *P. antarctica:* y — 8.88 + 0.00070 x, 2 — *P. papua:* y = 8.94 + 0.00075 x, 3 — birds during and immediately after moulting

fold) exceeding twice the increase in body weight (forty five-fifty-fold).

Caloricity of the dry body weight of the examined species of penguins is similar and changes during the time of their development in a similar way (Fig. 3). This index is high already in the first day of

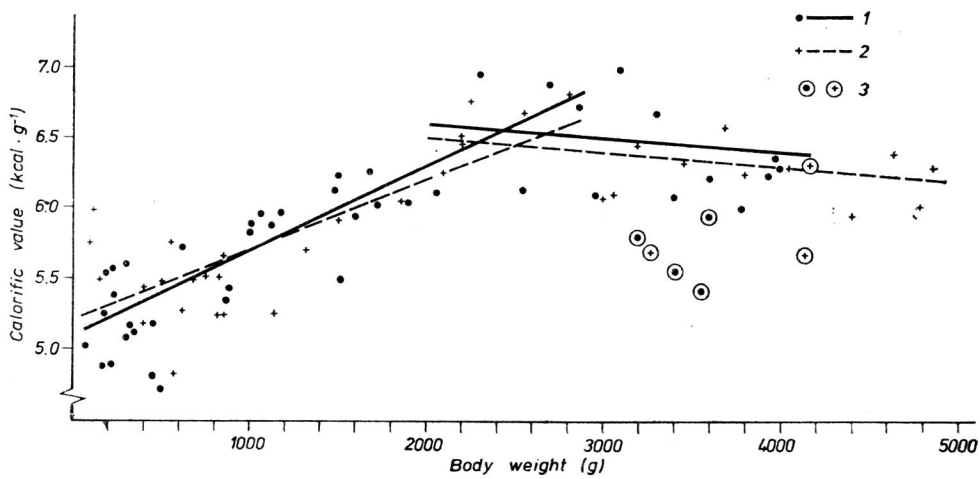

Fig. 3. Calorific value of dry body weight of Pygoscelid penguins during their development

1 — *P. antarctica:* 1-y = 5.032 + 0.000623 x, 2-y = 6.727 + 0.00081 x, 2 — *P. papua:* 1-y = 5.181 + 0.000514 x, 3 — birds during and immediately after moulting

the nestlings life and increases until about the half of the period of their nestling development, when the birds grain in weight 55%—60% of their ultimate body weight (Volkman and Trivelpiece 1980, Jabłoński in prep.). The calorific value of one gram of dry body weight reaches then the level of 6.5 kcal. From that moment a slight, statistically insignificant, decrease is observed and immediately before fledging of the nestlings of both species this value averages about 6.25 kcal·g^{-1}.

Caloricity of the wet body weight increases intensively in the first half of the development of both species chicks (Fig. 4). This increase

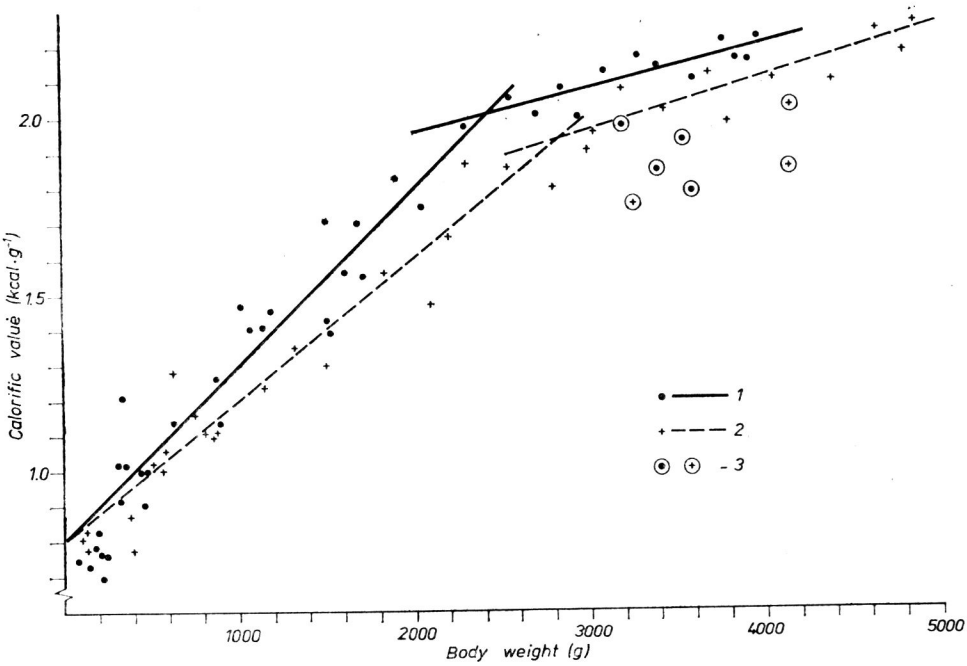

Fig. 4. Caloricity of the biomass of Pygoscelid penguins during their development 1 — *P. antarctica:* 1-y = 0.762 + 0.000516 x, 2-y 1.700 + 0.000126 x, 2 — *P. papua:* 1-y = 0.778 + 0.00040 x, 2-y = 1.461 + 0.0016 x, 3 — birds during and immediately after moulting

in *P. antarctica* exceeds 160% and in *P. papua* 140% of the value of this index in the first day of the nestlings life. Further changes are considerably smaller and until the time of fledging the calorific value of 1 g of biomass of these birds increases additionally only by 10%—15%. At the end of the nestlings development caloricity of the wet body weight of both species attains a very high level of 2.2 kcal·g^{-1}. This value is much higher as compared with the values noted in small and large birds of the temperature zones (Brisbin 1968, Myrcha, Pinowski and Tomek 1970).

The intense increase in the value of that index is caused on the one hand by a regular decrease of the water content in the tissues and on the other by accumulation of large reserves of fat. In the body of

the chicks of the genus *Pygoscelis* the subcutaneous adipose tissues accumulates very quickly, playing an important role in the thermoregulatory processes (Taylor, in prep.). Further deposition of fat in the tissues is associated with accumulation of energetic reserves for, among others, very costly process of molt. The course of changes in the examined indices shows that fat is accumulated most intensively in the first half of the period of the nestlings development.

On the whole, in the period from the first day of life till the beginning of molt, the nestlings of *P. antarctica* use for the building up of their body structure about 8.400 kcal and the young of *P. papua* as much as 11.000 kcal. During the process of molt the body weight of the bird and calorific values of dry and wet weight decrease considerably (Figs. 3 and 4). The decrease in caloricity indices is over 15%. At that time young *P. antarctica* use from their reserves of fat about 2550 kcal of energy and *P. papua* 3850 kcal. Net production of energy from the moment of hatching till the beginning of independent life averages in the case of *P. antarctica about* 5850 kcal and of *P. papua* about 7300 kcal.

These data confirm the existence of differences in the biology of these closely related species, even in the case of the populations setting-up breeding colonies in the same area. The nestlings of *P. antarctica* are characterized by about two-week shorter nestling period, as compared with *P. papua* (Volkman and Trivelpice 1980, Jabłoński in prep.). They accumulate the relatively similar quantities of fat in a shorter time and they fledge earlier. During the moulting period the total quantity of energy in the body of young *P. antarctica* decreases by about 30% and in *P. papua* by 35%.

It seems that these differences result from a better adaptation of *P. antarctica* to the colder climatic conditions prevailing in the natural environment of this species in the areas farther soutwards (Watson 1975, Croxall and Kirkwood 1979).

4. Summary

Changes in the water content and ash content in body and calorific values of dry and wet body weight were examined during the nestling development of *Pygoscelis antarctica* and *P. papua*. Investigations were conducted in the summer season of 1977/1978, at the Arctowski Station, King George Island, South Shetland Islands (62°09′8″ S, 58°28′6″ W).

It was found that the water content in the tissues of both species decreases regulary from 85% to less than 65% throughout the entire period of their nestling development (Fig. 1). Ash content in the dry body weight of the investigated penguin chicks increases at that time from 9% to 11.5%—12.5% (Fig. 2).

Calorific values of dry and wet body weight increases intensively until about the half of the nestling period (Figs. 3 and 4). Then the calorific values of the dry body weight does not change any more. Caloricity of the biomass still increases, by another 10%—15%, and at the end of the period of the nestling development reaches a very high level of 2.2 kcal·g^{-1} in both species.

5. Резюме

Исследовались изменения гидратации тела и содержания в нем минеральных веществ а также калорийности сухой и свежей массы тела во время гнездового развития *Pygoscelis antarctica* и *P. papua*. Исследования проводились летом 1977/1978 г. на станции Арцтовского, Остров Кинг Джордж Южные Шетланды (62°09′8″ S, 58°28′6″ W).

Было установлено, что гидратация тела обоих видов на протяжении их гнездового развития постепенно снижается от ок. 85% до ок. 65% (рис. 1). Содержание минеральных веществ в сухой массе тела птенцов исследуемых видов повышается за это время от 9% до 11,5—12,5% (рис. 2).

Калорийность сухой и свежей массы тела интенсивно растет почти до половины периода гнездового развития (рис. 3 и 4). Затем калорийность сухой массы тела уже не изменяется, а калорийность биомассы увеличивается на ок. 10—15%. В конце периода гнездового развития последний показатель достигает у обоих видов чрезычайно высокого уровня—2,2 kcal g^{-1}

6. Streszczenie

Zbadano zmiany uwodnienia ciała i zawartości w nim popiołu oraz kaloryczności suchej i świeżej masy ciała podczas rozwoju gniazdowego *Pygoscelis antarctica* i *P. papua*. Badania przeprowadzono w sezonie letnim 1977/1978 na Stacji Arctowskiego. Wyspa Króla Jerzego, Południowe Szetlandy (62°09′8″ S, 58°28′6″ W).

Stwierdzono, że uwodnienie tkanek obu gatunków pingwinów zmniejsza się dość równomiernie w ciągu całego okresu ich rozwoju gniazdowego od około 85% do poniżej 65% (rys. 1). Zawartość popiołu w suchej masie ciała piskląt badanych pingwinów wzrasta w tym czasie od 9% do 11,5%—12,5% (rys. 2).

Kaloryczność suchej i świeżej masy ciała rośnie intensywnie do około połowy okresu gniazdowego (rys. 3 i 4). Potem wartość kaloryczna suchej masy ciała już nie ulega zmianie, a kaloryczność biomasy zwiększa się jeszcze o około 10%—15%. W końcowym okresie rozwoju gniazdowego ten ostatni wskaźnik osiąga u obu gatunków bardzo wysoki poziom 2,2 kcal·g^{-1}.

7. References

1. Brisbin I. L. 1968 — A determination of the caloric density and major body components of large birds — Ecology, 49: 792—794.
2. Croxall J. P., Kirkwood E. S. 1979 — The distribution of penguins on the Antarctic Peninsula and islands of the Scotia Sea — Brit. Antarct. Surv. Bull.
3. Fedak M. A., Pinshow B., Schmidt-Nielsen K. 1974 — Emperor and Adelie penquins energy cost of walking — Antarct U. S., 9: 97—98.
4. Grodziński W., Klekowski R. Z., Duncan A. 1970 — Methods for ecological bioenergetics — IBP Handbook 24, Blackwell Sci. Publ., Oxford, 367 pp.
5. Myrcha A., Pinowski J., Tomek T. 1970 — Energy balance of nestlings of Three Sparrows, *Passer m. montanus* (L.) and House Sparrows, *Passer d. domesticus* (L) (In: Productivity, population dynamics and systematic of granivorous birds, Eds. S. C. Kendeigh, J. Pinowski) — Warszawa, 59—83.

6. Petrusewicz K., MacFadyen A. 1970 — Productivity of terrestrial animals — principles and methods — Blackwell Sci. Publ., Oxford, 156 pp.
7. Pinshow B., Battles D .R., Pinshow H., Schmidt-Nielsen K. 1975 — Emperor penguins: thermoregulation and locomotion — Antarct. U. S., 10: 127—129.
8. Rakusa-Suszczewski S. 1980 — Environmental conditions and the functioning of Admiralty Bay (South Shetland Islands) as part of the near shore Antarctic ecosystem — Pol. Polar Res., 1: 11—27.
9. Volkman N. J., Trivelpiece W. 1980 — Growth in pygoscelid penguin chicks — J. Zool., Lond., 191: 521—530.
10. Watson G .E., 1975 — Birds of the Antarctic and sub-Antarctic — Amer. Geophysic. Union, Washington, 325 pp.

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