T. formicarius. The mean number of beetles caught by the traps with different dispensers; I = ipslure, I + *exo*-B = ipslure plus *exo*-brevicomin, L = (+)-lineatin, L + α-p = (+)-lineatin plus α-pinene, L + α-p + et = (+)-lineatin with addition of both α-pinene and ethanol and control without dispenser. The catches each year followed by the same letter are not significantly different (Mann Whitney U-test; 5% significant level).

Type of dispensers	1984 Mean of catches	SD	Number of traps	1985 Mean of catches	SD	Number of traps	1986 Mean. of catches	SD	Number of traps
I (10 cm)	3.0[a]	1.4	2	2.4[ac]	0.54	5	2.0[a]	1.0	3
I (50 cm)				4.0[b]	0.81	4			
I (10 cm) + *exo*-B (9 mg)				1.6[a]	0.54	5			
I (50 cm) + *exo*-B (60 mg)				4.0[b]	0.0	4			
L	3.0[a]	1.0	3	3.7[abc]	2.0	6	3.0[a]	1.0	3
L + α-p	5.0[a]	4.5	3	2.3[ac]	0.6	3			
L + α-p + et	5.0[a]	2.8	2						
Control	0[b]	0.0	5	0.2[d]	0.4	9	0[b]	0.0	3

found that addition of α-pinene and ethanol to (+)-lineatin or *exo*-brevicomin to ipslure did not significantly influence the capture of *T. formicarius*. This is in accordance with electrophysiological data which showed no specific receptor cells for α-pinene, ethanol and *exo*-brevicomin in this species[3]. An expected increase of catches with larger amount of compounds occurred for ipslure and ipslure plus *exo*-brevicomin. Although statistically significant, this increase was small, which can be ascribed to the general low number of *T. formicarius* caught and their low population in these areas.

The present results confirm the suggestions made previously that the pheromone of *T. lineatum* is an olfactory cue (kairomone) for *T. formicarius*, which may thus use adult *T. lineatum* as prey, especially early in the season before the main prey, e.g. *Ips typographus*, appears. In Scandinavia the flight periods of both *T. formicarius* and *T. lineatum* are early, in late April and early May, whereas *I. typographus* is flying about three weeks later[8,9]. In the laboratory *T. formicarius* feed on *T. lineatum* when these are available.

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* The standard dispenser (ipslure) used for mass-trapping *I. typographus* is a 100-cm plastic strip containing 1500 mg 2-methyl-3-buten-2-ol, 70 mg *cis*-verbenol and 15 mg ipsdienol made by Borregaard Industries Ltd., Norway. The lineatin dispensers (Borregaard) contain 2 mg (+)-lineatin.

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Why do parent birds swallow the feces of their nestlings?

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Summary. Goldfinches *(Carduelis carduelis)* consume the feces of their nestlings until the digestive efficiency of nestlings and adults is nearly equal. With increasing nestling age from the first day onwards, the energy content of the nestlings' feces decreases. The percentage of fecal pellets swallowed by the adults during the course of the nestling period is negatively correlated with their energy content. It may be concluded that adults use the feces of their young as an energy source.
Key words. Goldfinch; feces consumption; nestling; energy.

Passerine nestlings produce feces enclosed in gelatinous sacs. Adults normally eat the feces of the young nestlings, but those of older ones are normally carried away and dropped at some distance from the nest or deposited by the nestlings on the rim. The aim of this paper is to point out that, by swallowing the feces of its nestlings, a female goldfinch *(Carduelis carduelis* L.) may gain a considerable amount of energy by recycling them. The consumption of feces stops when it becomes inefficient from an energy point of view. This suggests that at least in seed-eating finches, where the female has to brood the young in the first days and is fed by the male, it is beneficial for her to swallow the droppings of the chicks as an additional source of energy.

The consumption of feces is supposed to have the following functions: a) Nest sanitation[1,2]; perhaps stimulated by an agreeable taste of the feces[1]. b) Gain of water; as the young usually discharge a product of lower solute concentration than the adults, the latter may gain some free water by feeding on the fecal sacs[3]. For the mountain white-crowned sparrow *(Zonotrichia leucophris oriantha)*[4] and the roadrunners *(Geococcyx californianus)*[5] the water from the fecal sacs may add a significant amount of water to the daily

balance although precise quantitative estimates are not available. c) Gain of energy; in at least some species small young seem to have a low digestive efficiency and the adult may recover substantial quantities of food by consuming the sacs. Bullfinch nestlings *(Pyrrhula pyrrhula)*, for example, digest only a small fraction of the seeds mixed in with their insect diet until after some days of growth[6]. In this paper I shall demonstrate that in the goldfinch, adults eat the feces in order to recycle energy.

During the nestling period, when the golfinches being observed fed themselves and their young on yellow goatsbeard *(Tragopogon pratensis)*, I collected 80 fecal samples from individual young birds from five different nests. The age of the nestlings ranged from a few hours to 10 days. With regard to an exact comparison of digestive efficiency of adult and young birds, I always checked the contents of the crop pouches[7,8] to be sure that the birds were fed with *T. pratensis*. In a parallel experiment six adult goldfinches were fed in the laboratory with the milky ripe seeds of *T. pratensis*. Before estimating the energy content of the excrements the samples were dried at 100 °C to a constant weight, then subjected to calorimetric estimation in a microbomb calorimeter.

During the first days of the nestling period the female covers the young and is fed by the male on the nest 18 to 38 times a day. The female distributes the food in small portions to the young. The fecal sacs are normally ejected immediately after feeding, with the adult waiting until they appear.

During the nestling period, the percentage of consumed feces decreases with increasing age of the young (fig. 2). After 13 days the adult birds no longer consume the nestlings' feces. The mean energy content of the feces is very high during the first three days after hatching (more than 30 kJ/g) and drops to about 15 kJ/g when the young are 10 days old (fig. 1).

The nestlings can digest their food more efficiently as they grow older; consequently the energy content of feces decreases:

Energy content: (kJ/g) = 54.47 − 16.45 in *age of nestlings* (n = 27, r = 0.87, p < 0.001). The energy content of feces and the percentage eaten by the adults in the course of the nestling period are related (fig. 3).

Percentage swallowed: 100.91 − 574.07 / *energy content* (kJ/g feces) (n = 13, r = 0.87, p < 0.001). This clearly shows that the less energy the feces contain, the lower the percentage the adults use.

Adult goldfinches (n = 6) feeding on Tragopogon achieved an overall digestive efficiency of 90 to 92% and the excrements contained between 15 − 18 kJ/g. When the nestlings reach an age of about ten days, the digestive efficiency of parents and young is almost equal. From this time onwards it is energetically no longer efficient for the parents to eat the feces of their chicks.

In finches all food consumed is first stored in crop pouches and then after a time the chyme is portioned to the digestive system, or when feeding young, the chyme is regurgiated from the crop pouches. When the adults bird swallows the feces they are possibly also stored in the crop pouches and might be fed once or even several times to the young. This question of possible multiple recycling has to be clarified in further investigations.

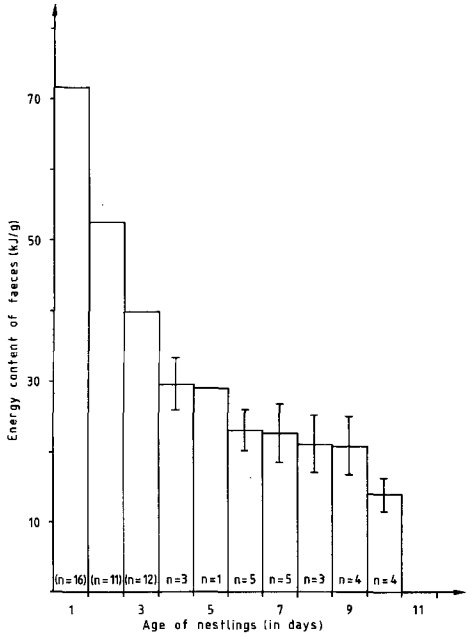

Figure 1. Mean energy content and SD of feces (kJ/g) depending on the age of nestling goldfinches. n = number of samples; (n =) number of samples included for one measurement procedure.

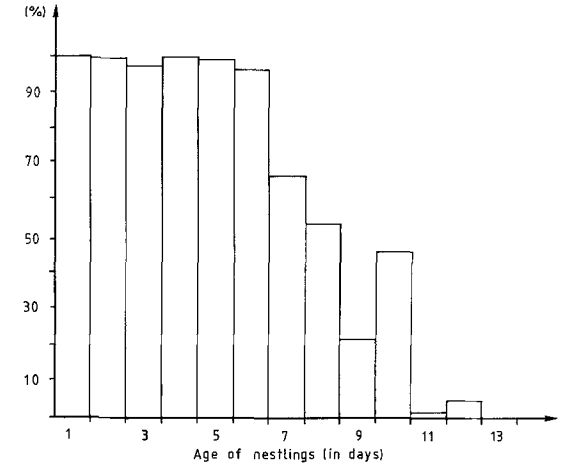

Figure 2. Percentage of feces swallowed by the adults, from daily observations (between 7 and 15 h) of one nest containing five nestlings.

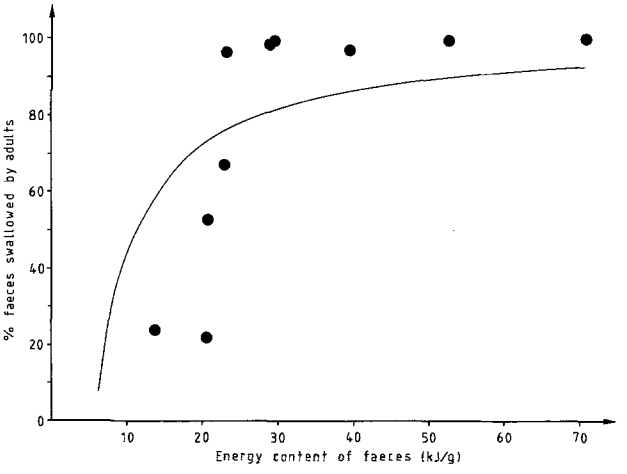

Figure 3. Percentage of fecal pellets swallowed by the adults, depending on the energy content of feces (kJ/g).

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Occurrence of heavy metal binding phytochelatins in plants growing in a mining refuse area

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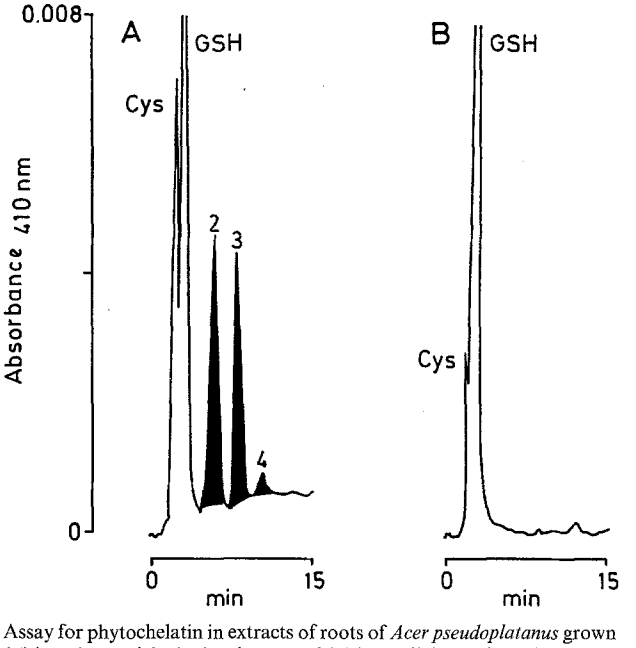
Summary. Phytochelatins were identified in roots of heavy metal-sensitive *Acer pseudoplatanus* and -resistant *Silene cucubalus* plants grown in zinc-rich soil of a mine dump. Both plants, when collected from a metal-uncontaminated stand, located nearby, revealed no phytochelatins. Thus, we concluded that metal-binding phytochelatins are specifically induced in plants of heavy metal enriched ecosystems.
Key words. Phytochelatin; heavy metal; detoxification.

Plants are to a certain degree tolerant to heavy metals. The mechanism by which plants could detoxify these ions has recently been elaborated[1,2]. The detoxifying function is assigned to small, cysteine-rich peptides capable of binding heavy metal ions via thiolate coordination; molecules we have named phytochelatins. An analogous mechanism for metal sequestration is provided in animals and certain fungi by the low molecular weight protein metallothionein[3]. Phytochelatins are induced upon exposure of plant suspension cultures to a wide range of heavy metals. The general structure of phytochelatins is $[\gamma\text{-Glu-Cys}]_n-\text{Gly}$ ($n = 2-11$), and they are inducible in the whole plant kingdom ranging from the phylogenetically simple algae[4] to the highly advanced orchids[2]. An exception is found in the order *Fabales* where the carboxyl-terminal Gly of phytochelatins is replaced by β-alanine, which leads to the homologous series of homo-phytochelatins[5]. The chemical structure of phytochelatins induced in plant cell cultures upon heavy metal stress has independently been verified[6]. Up to now, however, the occurrence of heavy metal induced phytochelatins has not been reported in plants grown in the ecosystem. In order to test the ecological relevance of phytochelatins as a heavy metal detoxification system of plants we investigated plants growing on heavy metal contaminated soil. For this purpose we chose a mining refuse area, located at the Rauschberg (N 47° 44′30″; E 12° 43′28″) near Inzell in Upper Bavaria, a site of former zinc and lead workings derelict for over 160 years and colonized by a range of plant species. The heavy metal sensitive *Acer pseudoplatanus* and the metal-resistant *Silene cucubalus* were collected in mid July 1987. Control plants of the same two species growing on uncontaminated forest soil about 100 m northwest of the mine dump were also taken. The soil of the mining area yielded 28 g total Zn/kg dried soil, while the forest soil as a control contained only 0.30 g/kg measured by atomic absorption spectrometry. The root system of *Acer* plants yielded a content of 0.92% Zn, in leaves only 0.02% Zn was found. In contrast control plants grown on forest soil yielded 0.01% Zn in the root and 0.004% of the metal in the leaf tissue (all data on dry weight basis). The root system of the *Acer* plants was subsequently assayed for phytochelatins using our established method of analysis[1,2]. The figure shows the HPLC-profile of the root extract of the *Acer* collected from the mining refuse. Besides cysteine and glutathione the typical peaks of phytochelatins with two, three and four (γ-Glu-Cys) units are visible. The roots of *Acer* plants grown in uncontaminated forest soil were devoid of phytochelatins. The roots of *Silene* from zinc-rich soil showed basically the same phytochelatin pattern as the *Acer* plant. Again, in control plants no heavy metal chelating peptides were detected.



Assay for phytochelatin in extracts of roots of *Acer pseudoplatanus* grown (*A*) in a zinc-enriched mine dump, and (*B*) in a soil, located nearby, of low heavy metal content. The analysis was performed as described[2, 8]. Briefly, roots were frozen in liquid nitrogen and ground with a mortar and pestle. The plant material was suspended in alkaline borohydride solution and homogenized by sonification. After centrifugation the supernatant was deproteinized by acid precipitation. The cleared extract was separated by HPLC with sulfhydryl-specific detection by means of post column derivatization with Ellman reagent[9]. The first peaks represent cysteine (Cys) and glutathione (GSH), not fully resolved, followed by the individual phytochelatins. Phytochelatins are marked by shaded peaks and signified by the index number n of the primary structure $(\gamma\text{-Glu-Cys})_n\text{-Gly}$.