THE SIGNIFICANCE OF FOWLS' BATHING IN DUST

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Abstract

Dustbathing in fowls (eg chickens, Gallus gallus) consists of tossing the litter onto and between the fluffed feathers and subsequently enclosing it by flattening the feathers. The proximal contact between litters like sand and peat, and the integument is intensified by rubbing the body. This is not the case in wood-shavings which adhere to the distal plumage after tossing; rubbings in wood-shavings are frequently interrupted by reinitiated tossings. Lipids accumulate on the feathers and become stale during dust deprivation. Only baths in sand and peat are effective in removing excessive lipids from the proximal downy feather parts. Fluffiness of the down is highest in hens on peat, intermediate on sand and lowest on wood-shavings, while the reverse is true for the plumage surface temperature of the back. Hens monitor the integumental lipid condition which becomes causally connected with bathing in the course of experiencing litter bathing effects. It is shown from the author's experimental study that hens naive of bathing in litter, and hens experienced with wood-shavings initially shifted bathing litters but finally preferred peat or sand (in that order) when peat, sand and wood-shavings were simultaneously presented. Most of the hens experienced with bathing in sand did not shift to another substrate when presented with one. Recommendations are given concerning adequate dustbathing litter. A chronic deprivation of adequate litter leads to an uncontrollable condition of the lipids on the integument and an abnormal development of dustbathing. Such a deprivation therefore reduces animal welfare. Moreover, it is suggested to be costly.

Key words: *animal welfare, dustbath, feather, fowl, lipid, litter*

Animal welfare implications

Dustbathing in fowls is behaviourally organized to promote contact between litter particles and the proximal integument. The types of litter which are preferred for dustbathing remove excessive stale lipids from proximal, ie downy feather parts. Dustbathing is stimulated by stale feather lipids. Chronic deprivation of adequate litter reduces the control of the integumental condition and therefore reduces fowls' welfare.

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Introduction

Dustbathing is a maintenance behaviour which has significant adaptive value, as it is found in numerous species of birds, as well as mammals. As far as birds are concerned, galliformes are 'specialized' to bathe in dust only, whereas many other species may bathe in water as well (Heinroth 1955, Simmons 1964). During dustbathing the fowl lies down and tosses litter onto and between the feathers. Subsequently, it lies on its side for some time and mostly ends the bathing sequence by body/wing shaking, which removes the dust from the plumage (in Bobwhite quail, *Colinus virginianus* and Japanese quail, *Coturnix coturnix*: Borchelt 1975, 1977 and in chickens: Vestergaard 1981); these sequences are illustrated in Figure 1.

Chickens kept in laboratory or farming conditions may take baths of about 20 minutes once every two days, but the duration is variable within as well as between individuals (Huber 1987, Liere & Bokma 1987, Liere *et al* 1990, Vestergaard 1982, Vestergaard *et al* 1990).

Given the fowl's adaptation to bathe in dust, it is of ethical and scientific interest that hens, lacking litter long-term, keep up sham-dustbathing behaviour (Bessei & Klinger 1982, Black & Hughes 1974, Martin 1975, Vestergaard 1980, Vestergaard *et al* 1990). Such a deprivation is not likely to occur in nature, but is a reality for millions of hens kept in intensive systems such as battery cages. An international assembly of ethologists ranked dustbathing behaviour in fowl among the ten most urgent subjects for research in the applied field (Wiepkema *et al* 1983). Fowl may not be able to adapt their maintenance strategy to a dustless environment, as they depend entirely on dust for this purpose. Without litter the behavioural measures would not be effective and a discrepancy between the actual and the expected stimulus value (expected as described by Baerends 1976) might remain. In man such uncontrollable circumstances would be experienced as chronic stress. In fowl it could be the case too, if their mental constitution is regarded homologous to man in the same way as are, eg anatomic, physiologic or neurologic traits (Griffin 1976, Wiepkema & Koolhaas 1992). Thus, the fowls' welfare can be at stake when these animals are deprived of dust for a long period of time.

The link between the appropriate facilities for fowl to dustbathe and the main interests of modern poultry husbandry, ie low mortality, growth and egg production, has not been clarified. Despite this unclarity, dustbathing behaviour is not superfluous if an energy saving mechanism has guided the fowl's evolution of dustbathing. Resource savings also characterize commercialism, therefore it is in the interest both of animal welfare and modern poultry farming to know in what way dustbathing behaviour is functional.

Recent findings concerning the organization, effects and causality of dustbathing in relation to litter quality advance the understanding of dustbathing behaviour. These features are reviewed in this paper, together with a report of the author's study on the impact of litter experiences on preference for dustbathing substrate.

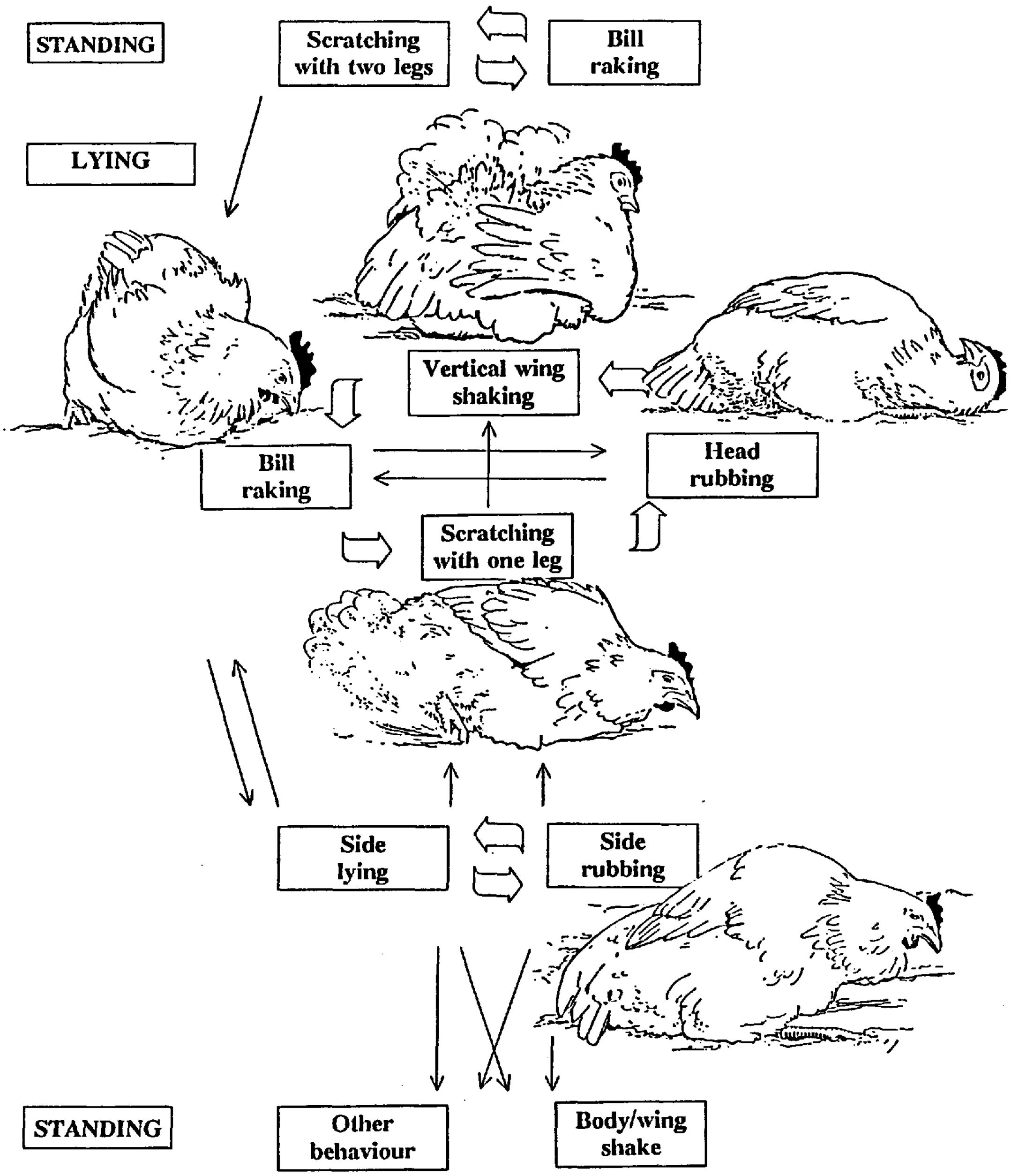

Figure 1 **Sequence of complete dustbathing behaviour in hens. The width of the arrows is arbitrarily chosen and corresponds to a low or a high transition probability.**
(Liere 1991, Vestergaard 1981, for incomplete dustbaths: Liere et al 1990)

The organization of bathing behaviour in dust

The main characteristic of the preparatory behaviour in a dustbath is the fluffing of the plumage (Figure 1). This is called tossing and consists of sequences of bill raking, scratching with one leg, head rubbing and vertical wing shaking (cf for Bobwhite and Japanese quail: Borchelt 1975, 1977). For instance, during vertical wing shaking the hen lies on its breast and scratches both legs through the soil backwards and upwards between the trunk and the outwardly held wings. This results in sweeps of litter dropping onto the fluffed feathers. The posture of the feathers during tossing clearly assists the dust particles to sift through the feathers to the skin, but it depends on the nature of the litter whether this is achieved. It is in the case of sand and peat, but not in wood-shavings, which adhere to the distal feather parts and only contact the skin in featherless tracts (Liere 1991, Liere *et al* 1990, Petherick pers comm).

The 'inviting' posture of the fluffed feathers discriminates tossing behaviour from rubbing behaviour. Rubbing is characterized by flattened feathers and wings pressed against the body (Figure 1). It consists of side lying and side rubbing and brings about an enclosure of the litter which has reached between the feathers. The contact between this litter and the proximal integument is intensified during side rubbing. This occurs when the bird lies on its side and stretches its leg. It causes the animal to rotate to some extent along the longitudinal axis and to push itself against the rim of its dustbathing hole. Rubbing is always preceded by tossing behaviour (in Bobwhite quail: Borchelt 1975 and in hens: Liere 1992, Liere *et al* 1990, Vestergaard *et al* 1990). It is followed by the removal of litter by body/wing shaking (Vestergaard *et al* 1990). Rubbing is therefore central in executing the final contact between the dust and the proximal integument, ie the down and the skin.

Hens which are kept on wood-shavings perform more incomplete dustbaths, consisting of tossing behaviour only, than hens on sand (Liere *et al* 1990). This indicates that hens on wood-shavings start dustbathing repeatedly and have difficulty in realizing a state that stimulates rubbing.

After one week of litter deprivation complete dustbaths in sand or in wood-shavings are performed with comparable amounts of tossing until the first rubbing (Figure 2). However, the rubbings in the sand baths are performed in long bouts, while those in the wood-shavings baths are short and frequently interrupted by tossings. Moreover, these tossings last longer than in the sand baths, resulting in an extension of the wood-shavings baths (Liere *et al* 1990).

In peat, bathing hens accumulate litter on their skin and rub in an uninterrupted way just like the hens on sand (Liere 1991, Petherick pers comm). Thus the bathing quality of the substrate is determined by the presence of litter at the proximal level of the integument and its ability to elicit and maintain the rubbing part of a dustbath.

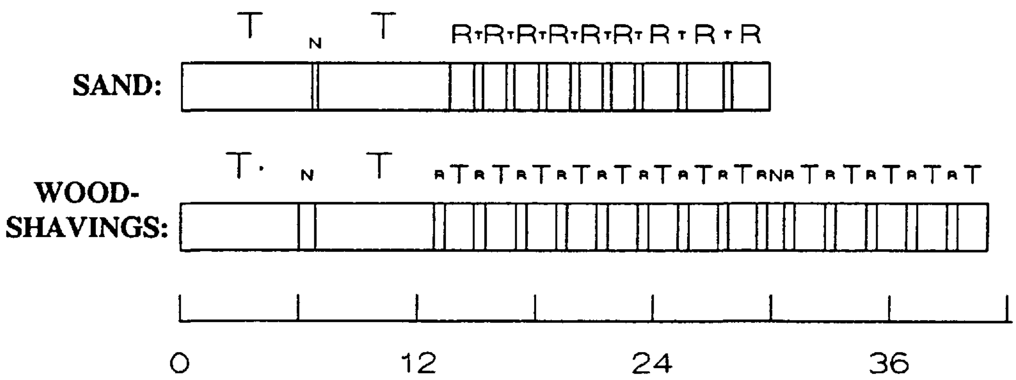

Figure 2 **Schematic representation of the organization of tossings, (T) rubbings (R) and non-dustbathing events (N) in the first dustbath after one week deprivation of sand or wood-shavings; n=11.**
(after Liere 1992, by kind permission of Elsevier Science Publishers B.V.)

The effects of bathing in dust

The dust used in a bath would serve to dislodge the fowl's ectoparasites (Heinroth 1955, Simmons 1964). Borchelt *et al* (1973) presumed that the dust desiccated or suffocated them or scraped the ectoparasites from the plumage. In addition, they presumed that ectoparasites feed on feather lipids and that dustbathing might reduce their numbers by reducing the level of feather lipids. A control of ectoparasite numbers has, however, never been demonstrated for dustbathing.

Uropygial gland lipids oiled to the feathers, and lipids produced during epidermal keratinization adhere to the feathers (Borchelt *et al* 1979, Hodges 1974, Ishida *et al* 1973, Jacob & Ziswiler 1982, Liere *et al* 1991, Lucas & Stettenheim 1972). These lipids accumulate when fowl are deprived of dust (in quail: Borchelt & Duncan 1974, Healy & Thomas 1973), while subsequent dustbathing removes excessive feather lipids (in hens: Liere & Bokma 1987). Healy and Thomas (1973) presumed that the particles which are tossed onto and rubbed between the feathers adsorb lipids during their feather contact.

The reduction of feather lipids which is accomplished by bathing in sand, also promotes an increase in the fluffiness of the feathers. Downy feather barbs might adhere less to each other and appear more fluffy when excessive lipids are removed from them (Healy & Thomas 1973, Liere 1992, Liere & Bokma 1987). Laying hens that bathed in wood-shavings, however, were not able to remove excessive lipids from proximal downy feather parts (Liere 1992). Likewise the lipid level of the down of hens that were kept on wood-shavings for a long time (5 months) was high compared to hens on sand or peat (Figure 3). This lipid level was lowest in hens on peat. In turn, the feathers of the hens on wood-shavings were the least fluffy, those of the birds on peat were the most fluffy, while feather fluffiness on sand was intermediate. Since fluffy down is a good thermo-insulator (Cena *et al* 1986), plumage surface temperature of the back was also measured. The plumage surface temperature was highest for the birds on wood-shavings, intermediate for the birds on sand and lowest for the birds on peat (Figure 3). These findings suggest that birds bathing in peat lose less energy than birds bathing in sand or in wood-shavings. The ability to remove excessive feather lipids from distal as well as proximal integumental parts is therefore the third factor in determining the bathing quality of the litter.

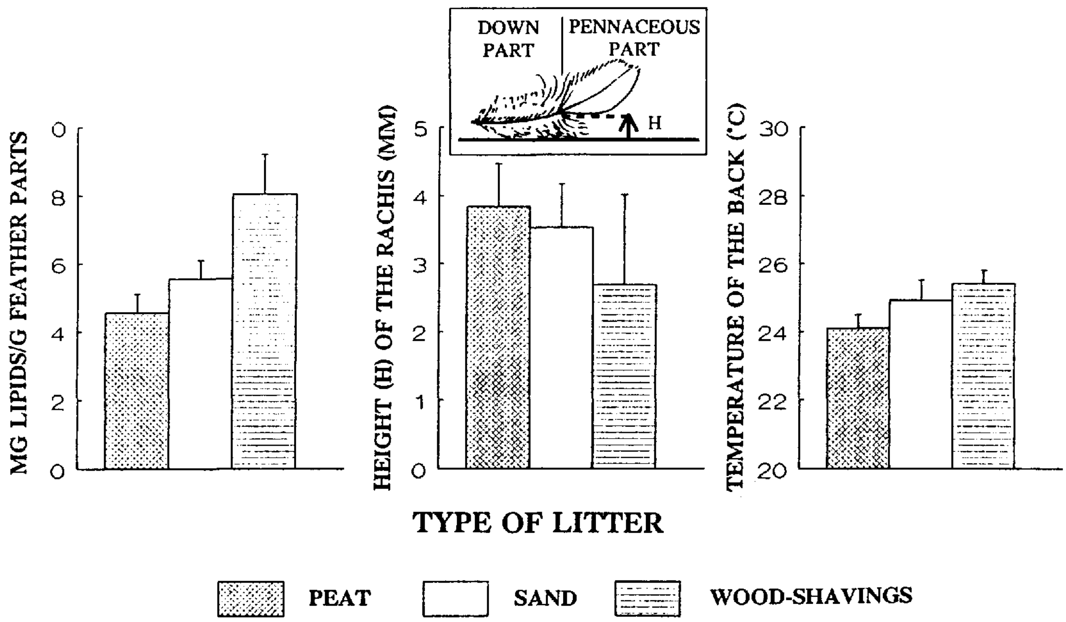

Figure 3 **Median quantity of lipids on down parts of back feathers; median height (H) of the rachis carried on a horizontal plane (see inserted drawing) as a measure of fluffiness of the down of back feathers (with third quartile deviations), and average temperature of the surface of the back plumage (with SD) in hens that were housed at 20°C ambient on either peat, sand or wood-shavings; n=1 group of 16.**

(after Liere 1991, Liere & Siard 1991)

Lipids, which accumulate on the fowl's feathers and skin, change in quality due to oxidation (Simmons 1964) or lipase activities by the microflora of the integument (Jacob & Ziswiler 1982). This links to the earlier mentioned effect of dustbathing on ectoparasite numbers, because hydrophobic metabolites produced by the vertebrate's skin or by the microflora of its skin can attract ectoparasites. Several Diptera (Emmens 1983, Roessler 1961, Warnes 1990) and Trematode cercariae (Haas *et al* 1987, Salafsky *et al* 1984, Zibulewsky *et al* 1982,) are known to sense and move towards such lipoid metabolites. Accordingly, isolated cholesterol, which is one of the many components of the duck preen gland, strongly attracts *Trichobilharzia ocellata* cercaria, whereas the excretion of this gland itself does so poorly (Feiler & Haas 1988). Diesters of fatty acids on the skin and the plumage of chickens are attractive to *Dermanyssus gallinae*, the red poultry mite (Zeman 1988), while species-specific free fatty acids and alcohols from the preen gland have antibacterial and antimycotic properties (Jacob & Ziswiler 1982).

In conclusion, the composition of the integumental excretions is complex but functionally balanced in such a way that regular maintenance activities are necessary. Dustbathing is a means to remove excessive, and stale lipids from the integument and may thwart parasite host finding, if stale feather lipids attract parasites. In this case, parasite attraction is expected to differ between birds on wood-shavings and, for instance, on sand, as the removal of excessive lipids is less well accomplished in wood-shaving baths.

The causal significance of feather lipids

The causal significance of lipids on the feathers for dustbathing was originally hypothesized by Borchelt (1975) and Borchelt *et al* (1973). A lipid regulation model was put forward which predicted that dustbathing was progressively stimulated whenever the feather lipid quantity increased over a certain critical value (Borchelt *et al* 1973, Levine *et al* 1974). This hypothesis could not be affirmed, however, because an increase in feather lipids by applying donor feather lipids did not affect the amount of dustbathing in Japanese quail (Borchelt *et al* 1979). In addition, extirpation of the uropygial gland did not influence the occurrence of dustbathing in Japanese quail (Borchelt *et al* 1979) and chickens (Nørgaard-Nielsen & Vestergaard 1981). Nevertheless, the change in the level of lipids on chickens' feathers due to a week of sand deprivation positively correlated with the amount of rubbing in the first bath after this deprivation (Liere 1992). This finding suggested that the quality of the lipids could be critical as feather lipids (and probably skin lipids too) not only accumulate but become stale as well. Indeed treating hens with stale feather lipids did enhance their tendency to dustbathe and in particular their tendency to rub (Liere *et al* 1991). An increased proportion of stale lipids is therefore one of the factors which stimulates dustbathing behaviour.

This conclusion is based on findings in birds which were experienced with bathing in litter. The condition of feather lipids does not relate to sham-dustbathing in birds, which are reared and kept without litter (Hogan *et al* 1991, Vestergaard *et al* 1990). It is therefore presumed that the lipid condition becomes causally connected with dustbathing behaviour in the course of effective bathing experiences. Similar causal changes resulting from functional experiences have been suggested for several other behavioural systems (Hogan 1988). If this is the case for dustbathing, then the monitoring of changes in the feather lipid condition is a crucial developmental factor in litter deprived fowl. It implies that litter deprived fowl, when given access to different litters, will develop a preference for litter which adequately reduces feather lipids.

The selection of bathing substrates

The selection of a bathing substrate depends (amongst other things) on the interaction between naive preferences, social factors and experiences gained in the course of bathing. Young fowl do not seem to perform their first bathing movements in one specific environment, as chicks not only bathe in soil but perform baths on fully bare hard ground as well (Kruijt 1964). Nevertheless, naive chicks prefer to peck at and manipulate particles of certain colours, sizes and shapes (Hogan 1973) and may peck more often into loose soil than on fully bare hard ground. Pecking experiences relate to dustbathing behaviour, as pecking into loose soil facilitates the development of dustbathing behaviour (at least in Bobwhite quail: Borchelt & Overmann 1975). Klinger (1985) showed that battery caged laying hens which pecked into particulate food sham-dustbathed more than hens given porridge-like food. Thus the environments in which chicks are attracted to peck may simultaneously be the ones that promote dustbathing.

Social bonding to other pen-mates or to the mother hen can guide the young animal to bathing sites where it may dustbathe too (Borchelt & Overmann 1974, Vestergaard *et al* 1990, Wood-Gush 1971). In this way the bonding to other animals more or less biases what environment will be selected for bathing. In addition the bathing effects themselves strongly influence the orientation of the bird when it is motivated to dustbathe again (Liere 1991, Liere & Wiepkema 1992, Vestergaard *et al* 1990).

Author's observations

In a study carried out by Liere and Siard (1991) the impact of bathing litter experience on preferences for dustbathing substrates was observed in hens which were reared and kept without the possibility of bathing in litter (or in litter-like food) for 19 weeks. The hens were divided into three treatment groups. Each treatment group consisted of four groups of four birds. For four weeks, from week 19 until week 22, one treatment group remained without litter (this was the no-experience, NE treatment). Another treatment consisted of access to wood-shavings (the wood-shavings experience, WE treatment). The third consisted of access to sand (the sand experience, SE treatment). Subsequently all hens were kept without litter during week 23. Dustbathing of all hens was recorded from week 24 on for 26 days when all hens had daily and simultaneous access to peat, sand and wood-shavings.

The NE hens bathed more in sand than in the other litters on the first day of access, but shifted bathing litters thereafter until the seventh day (Figure 4). From day 7 onwards 13 hens preferred peat, while the remaining 3 consistently chose sand. Wood-shavings were only chosen twice in the latter period and the dustbaths were short and incomplete.

The WE hens bathed more in wood-shavings than in the other litters on the first day. However within 90min on this day and until day 7 they ambiguously selected bathing substrates. From day 7 onwards 14 hens preferred peat, while the remaining 2 consistently chose sand. One short, incomplete bath was performed in wood-shavings during the latter period.

The SE hens mostly continued to bathe in sand during the entire observation period. Six out of the 16 SE hens shifted from sand to peat on day 7 or later and continued to bathe in peat afterwards. One individual showed an aberrant pattern, because it shifted between sand, peat and wood-shavings following day 7.

In sum, both the NE and the WE treated hens ambiguously responded at access to different litters and preferred peat following the seventh day of access. Similar findings have been reported by Petherick and Duncan (1989). However, the SE treated hens preferred sand at access to different litters and the majority continued to do so throughout the experiment. The presence in the different litters did not explain these results. They indicate that hens, which formerly have been naive of bathing in dust, develop a preference for a litter such as peat or sand, which efficiently removes excessive lipids from the feathers. This supports the earlier mentioned hypothesis that the monitoring of changes in the feather lipid condition is crucial in fowl.

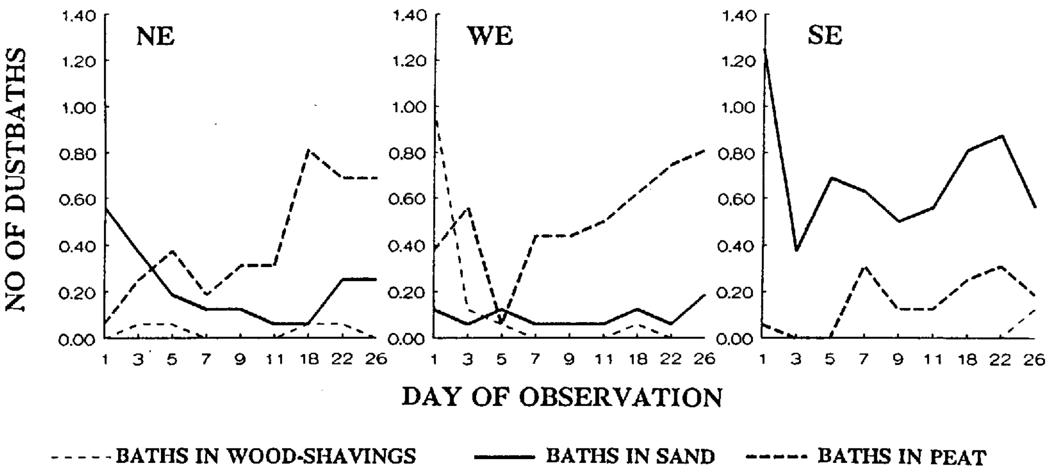

Figure 4 **Average numbers of dustbaths per hen per day in peat, sand and wood-shavings during a 26 day period following no litter experience (NE), wood-shavings experience (WE) or sand experience (SE), respectively; n=4 groups of 4.**

(after Liere 1991, Liere & Siard 1991)

Similar results were found in the WE hens, as the experience with wood-shavings did not substantially influence these hens to select wood-shavings for dustbathing. The assimilated experience with sand or with peat significantly reinforced the hens in this experiment to select sand or peat, respectively. The reinforcing properties of wood-shavings on the one hand and of sand or peat on the other, relate to the differences between these substrates in their bathing effects, ie their penetration into the plumage and their reduction of proximal feather lipids. Therefore a preference, which is maintained for the familiar litter to other unfamiliar litters for several days, is considered a fourth significant indicator of bathing litter quality.

Despite the fact that the majority of the NE and the WE hens preferred peat (Figure 4), some hens consistently used sand which appears to be optimally reinforcing for some and suboptimally reinforcing for other hens. These systematic differences between individuals, however, are not well understood and may relate to differences in the detailed sequences of bathing components (cf in Bobwhite quail: Borchelt 1975), in other maintenance activities such as oiling or preening (Liere *et al* 1991) or in the condition of the integument, eg skin keratinization, feather formation or oil gland physiology (Abalain *et al* 1984, Kar 1947, Lucas & Stettenheim 1972). Some variability in the selection of bathing substrates was maintained, as some short incomplete baths were 'tried' in wood-shavings. A low level of trying out bathing substrates is functional, as the dustbathing facilities in nature or the demands of the animal may fluctuate (cf fowl in winter: Aschenbrenner 1985, Klaus *et al* 1990 or moulting birds: Dow 1988). Therefore, it would be of high interest to study bathing litter selection in fowl during maturation and over a longer period.

Conclusions and discussion

The organization of dustbathing evidently indicates that it promotes the penetration of litter into the plumage and the contact of litter with the proximal integument. Deep penetration is essential for uninterrupted rubbing, in which the proximal contact is intensified. An important effect of the accumulated litter onto and between the feathers is that the level of feather lipids is reduced. As a result of lipid reduction by bathing litter, which reaches the proximal integument, the fluffiness of the down increases and, probably in turn, thermo-insulation is enhanced. Moreover the fowl's attractiveness to parasites is likely to be reduced.

Pecking experiences and social bonding guide young birds to a limited range of bathing substrates. Here, fowl assimilate experience about the effects of bathing and develop a bathing substrate preference. Hens monitor the integumental lipid condition and effective bathing experiences reinforce causal connections between this condition and dustbathing behaviour. As a result, experienced hens respond to an enhanced level of stale lipids on their feathers by dustbathing more. Moreover, most hens prefer the litter which is best in reducing proximal feather lipids.

The findings so far suggest that bathing litter is adequate, if:

- during bathing the particles penetrate the plumage up to the skin;
- rubbings are rarely interrupted by tossings;
- excessive feather lipids are removed at the distal as well as at the proximal level;
- preferences remain stable for several days when fowl have simultaneous access to unfamiliar litters.

Whether or not fowl are reared on litter, they are likely to monitor changes in feather lipid condition, otherwise feather lipid condition would not become causally connected with bathing in litter. Moreover, the preferred substrate would not necessarily be one which efficiently reduces feather lipids. Fowl have no other behavioural means than to use dust for the purpose of integumental lipid maintenance. Therefore changes in integumental lipid condition become chronically uncontrollable during long-term deprivation of litter. The uncontrollable condition of the lipids on the integument is the first factor which indicates that fowl's welfare is reduced during chronic deprivation of litter. The second factor is the abnormal development of dustbathing behaviour. The deprivation of its functional consequences leaves dustbathing to be intrinsically controlled (Liere & Wiepkema 1992, cf for a comparable prefunctional control of dustbathing: Hogan *et al* 1991). The main feature of this type of control is that sham-dustbathing is regulated in a closed-loop way. On a chronic basis this results in:

- abnormally organized sham-dustbaths; these are dominated by sham-rubbing behaviour or consist of sham-rubbing behaviour only (Liere & Wiepkema 1992);
- an abnormally high motivational level; the motivation cannot be reduced due to the lack of functional consequences (Hughes & Duncan 1988, Liere 1991, Toates & Jensen 1990).

When fowl are housed on litter that chronically does not meet the criteria given above, integumental lipid condition becomes out of control and may result in reduced welfare. Fresh wood-shavings, as used in this study, are an example of inadequate litter. However, wood-shavings in deep litter housing systems decompose while being fouled by manure. The deep litter bathing quality should therefore be evaluated on the basis of different samples in time. The litter quality is important to enable fowl to efficiently enhance the condition of their integument. In addition, it has been found that the quality of the litter for foraging (Blokhuis 1989) or for dustbathing (Vestergaard 1989, Vestergaard *et al* 1990) modulates the stimulation of pecking behaviour. Attractive beddings serve to reduce the occurrence of pecking at and pulling out feathers of pen-mates and, as a consequence, to limit cannibalism. Feather pecking as well as dustbathing affects the condition of the feather cover of the body. This is essential for the maintenance of body temperature and reduction of food consumption (Herremans 1987, Luiting 1991). Social bonding is likely to affect the occurrence of litter related behaviour, while experience with litter in its turn, affects the appraisal of the social environment: hens that are reared and kept without litter peck at pen-mates more, and more severely, than hens reared and kept on sand (Vestergaard 1989).

These different aspects largely coincide with the commercial intent of poultry farming, but problems concerning the use of litter in poultry husbandry have also been described in the literature, eg the production of ammonia (Weaver & Meijerhof 1991) and disease incidences such as coccidiosis (Braunius 1987). On the other hand, the behavioural activity is a major source of variation in energy losses, in particular in battery caged hens (Luiting 1991), while sham-activities in a restricted and monotonous environment can reach abnormally high levels. Moreover there is a growing body of literature demonstrating that a psychological factor, such as controllability, can affect the animal's endocrinological and immunological status (Ader *et al* 1991, Brush & Levine 1989).

A substrate which does not stimulate fowls in conformity with their evolutionary shaped specializations, reduces their welfare, moulds their behavioural development in an abnormal way and is likely to result in an increase of integumental damages and energy losses.

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