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Original article

Comparison of the effects of two kinds of commercially available pollen on colony development and queen production in the bumble bee *Bombus terrestris* L (Hymenoptera, Apidae)

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Summary — The effects of two kinds of stored pollen (fresh and dried, kept in the freezer) on individuals and colonies of *Bombus terrestris* were investigated. The pattern of colony development, and the number and biomass of workers and males were similar for colonies fed on fresh-frozen pollen (FFP) and dried-frozen pollen (DFP). However, queens reared on DFP were smaller, had lower biomass, higher mortality and produced smaller colonies than queens reared on FFP.

***Bombus terrestris* / bumble bee / pollen / nutritive value / queen production**

INTRODUCTION

In extensive commercial rearing, bumble bee colonies are normally fed on fresh pollen collected from pollen traps at honey bee hives. However, because fresh pollen is not easy to obtain all the year round, dried-frozen pollen (DFP) is a possible alternative. DFP has advantages over fresh pollen in the sense that it is cheaper and is less likely to become contaminated by fungi and other microorganisms. On the other hand, it is unattractive to queens probably because of its unpalatability (Pomeroy and Plowright, 1980). In fact, many authors have advocated the use of fresh pollen to initiate colonies in captivity (Hasselrot, 1952; Free and Butler, 1959; Plowright and Jay, 1966; Röseler, 1985).

Pollen and nectar are essential food sources for bees. Being rich in proteins, pollen affects their growth, longevity, ability to rear brood as well as the development of their ovaries, fat bodies and hypopharyngeal glands (Maurizio, 1950, 1951; Standifer, 1967; Knox et al, 1971; Duchateau and Velthuis, 1989).

However, not all kinds of pollen have the same nutritive value. One of the main reasons is that the chemical composition (ie,

amount of amino acids, lipids, sugars, minerals and vitamins) varies considerably from one plant species to another (Todd and Bretherick, 1942; Vivino and Palmer, 1944; Standifer, 1966; for reviews see Haydak, 1970; Herbert, 1992).

In general, pollen that has a low starch content (and high oil or sugar levels) is considered to be a valuable food source for bees. In contrast, pollen containing abundant starch (and only a small amount of lipids) is of little value (Baker and Baker, 1979). Trees and plants that produce high quality pollen for honey bees include *Crocus, Papaver, Salix, Erica,* fruit trees (plum, apple, pear, chestnut), and clovers. Poor quality pollen comes from coniferous trees (*Pinus*, *Cedrus*, etc) (Vivino and Palmer, 1944; Maurizio, 1950; Stanley and Linskens, 1974).

The nutritive value of pollen may also be influenced by factors such as drying, ageing or storage conditions. Dried old pollen may have very negative effects on bee growth (reduced dry weight of heads, thoraces and abdomens), on the development of hypopharyngeal glands and on brood rearing (Levin and Haydak, 1957; Haydak, 1961, 1963; Hagendorn and Moeller, 1968). But the degree of impairment depends mainly on the drying methods (Groot, 1953; Maurizio, 1958, 1960). For this reason, it is recommended that the temperature during the drying process should not exceed 45 °C, and the moisture should be removed gradually (Chambers, 1990).

So far, however, we have hardly any information about the nutritional value of pollen to bumble bees, although Regali and Rasmont (1995) wrote a paper recently on the subject. Since bumble bees are becoming increasingly important as greenhouse pollinators, investigations into this matter are urgently needed.

In this work our aim was to compare the effects of two kinds of pollen available commercially on *Bombus terrestris* L at the individual and colony level.

MATERIALS AND METHODS

We have used two kinds of pollen in our study, one fresh and the other dried. The fresh pollen was collected from pollen traps at honey bee colonies kept at Utrecht University. The dried pollen was bought from a commercial company. Although both kinds of pollen differed in composition (table I), and time of storage in the freezer (1 year for the fresh pollen and 2 years for the dried pollen), they could be considered of good quality (ie, many of them were starchless and/or had a high protein content, table I). Moreover, we decided to compare them because both are available commercially and there is a great interest in obtaining more information about the most adequate pollen diet to rear bumble bees.

The pollen pellets were ground and supplied liberally to the colonies throughout the experiment. The colonies were also given a sugar/water solution at a concentration of 50%, in separate containers.

B terrestris queens were collected in early spring 1990 in the Gimborn Arboretum and in the Botanical Gardens of Utrecht University, The Netherlands. Colonies were reared in the laboratory following the method of Duchateau (1985) and Duchateau and Velthuis (1988). Their development was monitored daily.

Initially, all colonies received fresh-frozen pollen (FFP). However, when the queen began to lay the eggs of the second brood, the colonies were divided into two groups, in such a way that both groups had a similar number of egg cells. The first group continued to receive FFP ($n = 8$) while the second started to receive DFP ($n = 7$). From this moment the quantity of pollen consumed was measured by weighing the amount provided and the amount left unconsumed after 24 h. Because there was an obvious difference in moisture, specific amounts of the two kinds of pollen were kept in an oven at 60 °C, for 24 h, and then measured again. The differences between the final and the initial weights were used to correct for the water content. Since the length of the experiment varied according to the colony (see below), the pollen consumption per day was also calculated. No correction was made for the number or biomass of individuals because the amount of food eaten by workers, males and queens, either in the larval or adult stages, was not measured separately.

Because we were interested only in the offspring produced by the queen the colonies were

Table I. Composition of FFP and DFP used to feed *B terrestris* colonies.

FFP	*DFP*
41% Rosaceae [a] (21% fruit trees [c]; 12% *Fragaria*; 8% others)	99% Cruciferae [a] (*Brassica* [c])
11% Cruciferae [a] (*Brassica* [c])	1% Papilionaceae [b]
11% Caprifoliaceae *(Sambucus)*	
10% Compositae [ac] *(Carduus, Chrysanthemum)*	
4% Rhamnaceae [a]	
4% Oleaceae [a]	
4% Plantaginaceae (*Plantago* [c])	
3% Primulaceae [a]	
12% ? (malformed grains)	

[a] Plant families have starchless or predominantly starchless pollen (unmarked families have starchy or predominantly starchy pollen); [b] not classified (Baker and Baker, 1979); [c] pollen with a high protein content (20% or more) (Todd and Bretherick, 1942; Standifer, 1967; Regali and Rasmont, 1995).

killed no later than 25 days after the workers started to lay eggs.

Several parameters were recorded for the colonies, namely the number of egg cells, the number and biomass (dry weight) of workers, males and queens produced, the day on which the queen switched to laying haploid eggs (switch point) and the day of the first workers' oviposition (competition point; both moments were calculated in relation to the emergence of the first worker; for details see Duchateau and Velthuis, 1988).

The young queens produced were given opportunities to mate and hibernate. Queens that did not mate after several attempts were left outside or killed. A few queens did not enter the hibernation phase and showed the typical behaviour that indicated they were ready to lay eggs. They were put directly into small cages to see if they would find colonies. The number of queens was corrected in the light of these factors when necessary (for instance, to calculate the percentages of survivors).

Hibernation occurred in a cold room (5 °C) and lasted 3 or 6 months (for details see Duchateau, 1985). After that, the queens were placed in flight cages for 10 days and then in wooden boxes kept in a room at 28 °C and 60% of relative humidity. The rearing method used for these queens was the same as that used for their mothers. The pollen provided during the entire colony development was fresh-frozen and composed of 88% Cruciferae *(Brassica)*, 9% Aceraceae *(Acer)*, 2% Compositae *(Taraxacum)*, 1% Rosaceae (fruit tree).

A minimum of ten workers was the criterion used to define a colony. Queens that produced fewer than ten workers were not considered to be colony-producers.

Data on the queens' mortality were recorded so that we could calculate the percentage of survivors. The size of the queens was determined by measurements of their biomass (dry weight) and length of their wing's radial cell (Owen, 1988). The radial cells of the mother-queens were also measured.

The statistical tests used were Mann–Whitney U, Chi-Square, ANOVA and ANOVA nested (Sokal and Rohlf, 1981). In some cases, both mean and median are included in the figures to give a more complete picture of the data.

RESULTS

The water content of the FFP was 17.5% and that of the DFP was 5%. The results for the corrected consumption of pollen (total and consumption/day) are presented in figure 1. Colonies which received DFP consumed less pollen than the ones which received FFP (almost 1.5 times less), but the difference was not significant. The productivity (number of egg cells in the third brood and number of individuals per egg cell) was similar for the two groups of

colonies (table II). No significant difference was found in the number of workers, males and queens produced (fig 2). The switch and competition points were similar, too. The averages for the switch point were 17.0 ± 6.5 days and 16.7 ± 8.8 days for colonies fed on FFP and DFP, respectively. For the competition point the average values were 32.2 ± 9.7 days (FFP) and 31.3 ± 8.9 days (DFP). The biomass of workers, males and queens was lower for colonies fed on DFP colonies than for colonies which received FFP, but only for queens was the difference highly significant ($P \leq 0.001$, table III).

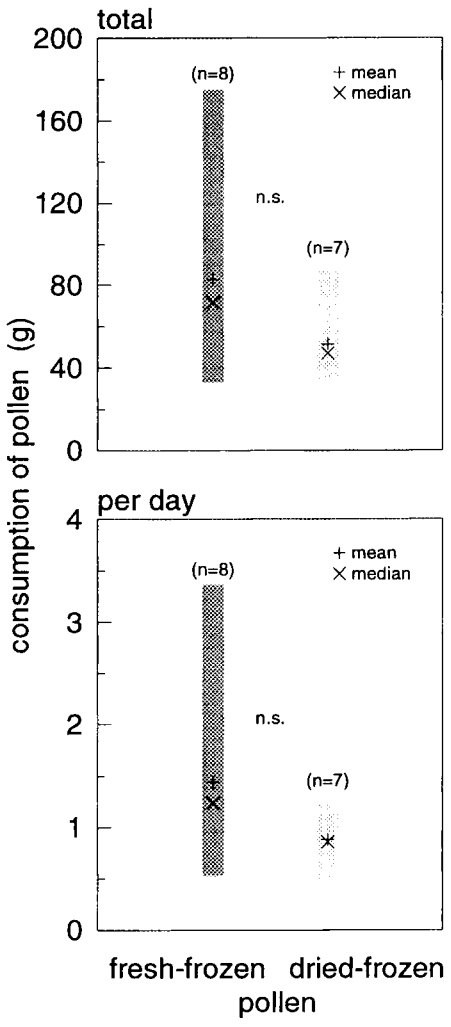

Fig 1. Consumption (maximum and minimum) of pollen (g), total and per day, of *B terrestris* colonies fed on FFP and DFP. Data were corrected for water content, see text for explanation. ns = not significant ($P > 0.05$, Mann–Whitney test); n = number of colonies.

Queens produced by colonies fed on DFP were much smaller than those produced by colonies fed on FFP. The length of the radial cell was highly significantly different ($P < 0.001$; fig 3). The radial cells of the mother-queens were of similar length and averaged 4.25 ± 0.06 mm ($n = 4$; colonies fed on FFP) and 4.28 ± 0.10 mm ($n = 6$; colonies fed on DFP).

Young queens reared on FFP and DFP had a moderate mating success; for both groups the success was above 60% (no significant difference; table IV).

The percentage of survivors before hibernation was much lower in the colonies which received DFP than in the colonies which received FFP (highly significant difference, $P = 0.0001$; table IV). After hibernation the survival was also lower, however, the difference was not significant (table IV). When we consider the total mortality of the young queens at colony level, we find that although there was a general high mortality, the colonies which received DFP presented larger percentages; four colonies even had a mortality of 100%! Among the colonies that received FFP, however, only two colonies had a high mortality: around 68% (fig 4).

Queens that did not go into hibernation behaved in different ways. The two queens reared on FFP produced small colonies. The five queens reared on DFP did not produce any colony at all.

As regards the founding of colonies by queens that went into hibernation, the queens from colonies fed on FFP were again more successful than those from

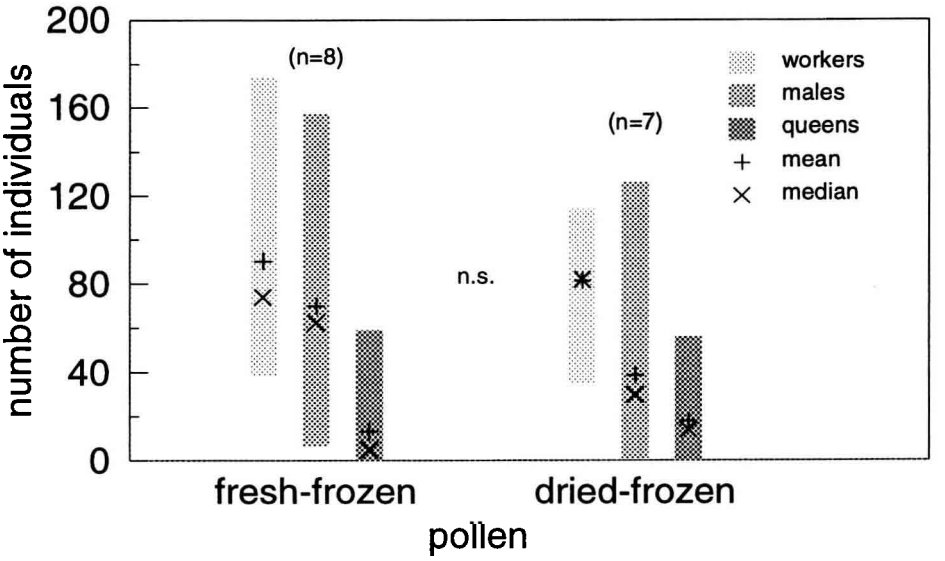

Fig 2. Number of individuals (workers, males and queens) produced by *B terrestris* colonies fed on FFP and DFP. ns = not significant ($P > 0.05$, Mann–Whitney test); n = number of colonies.

colonies fed on DFP, but the difference was not significant (table IV). However, the colonies produced by queens reared on DFP were much smaller than the colonies produced by queens reared on FFP (averages 49 ± 35.55 and 112 ± 65.06 workers, respectively); the difference was significant ($P < 0.05$, Mann–Whitney test).

Furthermore, both groups of queens differed tremendously with regard to the number of days that elapsed before they started to lay eggs; the queens reared on FFP began to lay eggs much sooner than the queens reared on DFP ($P = 0.0001$; fig 5).

Table II. Average productivity in the third brood of *B terrestris* colonies fed on FFP and DFP.

	Colonies fed on		
	FFP (n = 8) mean ± sd	*DFP (n = 7) mean ± sd*	
Number of egg cells in the third brood	22.62 ± 11.03	24.57 ± 8.40	ns
Number of individuals per egg cell in the third brood	5.70 ± 2.01	3.92 ± 1.49	ns

n = number of colonies; ns = not significant ($P > 0.05$; Mann–Whitney test).

DISCUSSION

The quantity of DFP consumed was lower than the quantity of FFP pollen consumed. A possible reason for the difference is that the drying process modified some of the substances that act as phagostimulants (a free fatty acid and/or a neutral lipid; Lepage and Boch, 1968; Robinson and Nation, 1968; Schmidt, 1985). Another possible explanation is that the palatability of DFP was reduced (Robinson and Nation, 1968) because there was an accumulation of phospholipids due to the loss of membrane integrity of the pollen grains.

DFP did not have a negative effect on colony development and on workers and males (number and biomass). Most of the values for colonies fed on DFP tended to be smaller than those for colonies fed on FFP, but the differences were not significant.

The young queens, however, were drastically affected by DFP. They were much smaller than the queens reared on FFP. This result was confirmed when the same kind of pollen *(Brassica)* was compared in

Table III. Incidence table of ANOVA two-factor analysis of variance for the biomass (mg) of the individuals produced by *B terrestris* colonies fed on FFP and DFP.

	Colonies fed on		
	FFP	*DFP*	
Workers	59.75 ($n = 8$)	53.57 ($n = 7$)	ns
Males	91.12 ($n = 8$)	78.43 ($n = 7$)	ns
Queens	345.00 ($n = 3$)	173.60 ($n = 5$)	*

n = number of colonies; ns = not significant: $P > 0.05$; * highly significant: $P << 0.001$.

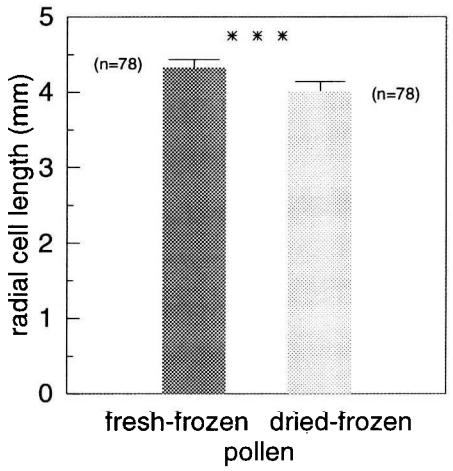

Fig 3. Average length (mm) of wing's radial cell in young queens produced by *B terrestris* colonies fed on FFP and DFP. *** = Highly significant ($P < 0.001$, ANOVA nested); n = number of individuals.

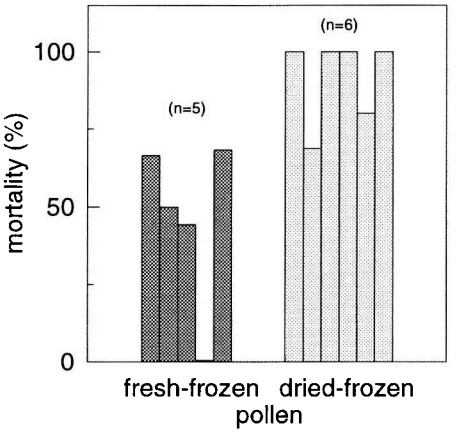

Fig 4. Total mortality (%) of young queens produced by *B terrestris* colonies fed on FFP and DFP. n = number of colonies. This number of colonies is different from the initial because these are only the queen-producing colonies.

Table IV. Percentages of mating success, survival before and after hibernation and colony production of young queens of *B terrestris* colonies fed on FFP and DFP.

	Colonies fed on		
	FFP (%)	*DFP (%)*	
Mating success	61.90 (n = 105)	69.09 (n = 110)	ns
Survival before hibernation	90.57 (n = 106)	62.20 (n = 127)	***
Survival after hibernation	46.77 (n = 62)	41.67 (n = 48)	ns
Colony production	58.62 (n = 29)	38.89 (n = 18)	ns

n = number of individuals; ns = not significant: $P > 0.05$; *** highly significant: $P << 0.001$, Chi-square test. The number of individuals differs for each variable because the number was corrected for the number of queens that were killed or escaped, or did not go into hibernation, etc (see text for explanation).

fresh-frozen and dried-frozen conditions: significantly smaller queens were produced by the DFP in comparison to the FFP (Duchateau, unpublished data).

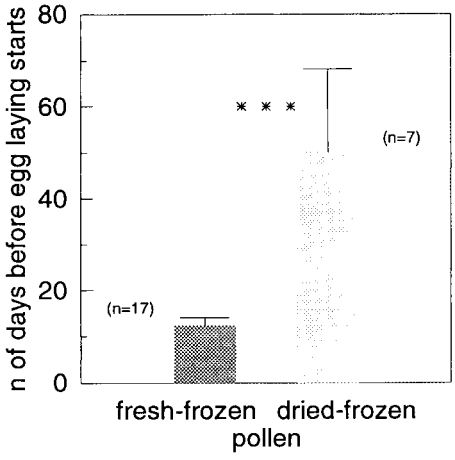

Fig 5. Average number of days before egg laying by young queens produced by *B terrestris* colonies fed on FFP and DFP. *** = Highly significant (P = 0.0001, Mann–Whitney test); n = number of individuals.

Although we did not calculate heritability (Falconer, 1981), our results indicate that the size of the young queens was a result of environmental (pollen) rather than genetic forces, because mother-queens were of similar size.

The fact that colonies reared on DFP produced smaller queens may be related to a lower amount of proteins in this pollen. DFP was composed almost only of *Brassica* which is considered to be a very good quality pollen, probably because of the high protein content (around 22%, Regali and Rasmont, 1995). Indeed, as already mentioned, fresh-frozen *Brassica* pollen produced larger queens (Duchateau, unpublished data). This could be an indication that the drying process affected the proteins of the pollen. In fact, loss of protein in dried (old) pollen was detected by Svoboda (1940) and Haydak (1963). Of the ten amino acids found to be essential for honey bees (Groot, 1953), half of them (methionine, lysine, arginine, tryptophan and cystine) are particularly sensitive to heating

(Liener, 1958). These amino acids are often found in pollen collected by honey bees (Auclair and Jamieson, 1948; Bieberdorf et al, 1961), and could be affected by the drying process. Stored pollen was also found to contain fewer amino acids (Dietz and Haydak, 1965). Besides destroying some amino acids, heating may also lead to changes in the molecular structure of the protein. The latter then becomes more resistant to enzymatic digestion (Liener, 1958). Since the final pollen digestion occurs through the action of enzymes (Stanley and Linskens, 1974), this could have serious consequences for the absorption and use of such substances by the bees.

Other nutrients such as vitamins might also be damaged or destroyed by drying, and storage (predominantly the vitamins that are water-soluble, eg, carotene and ascorbic acid; Liener, 1958). Ascorbic and panthotenic acids (essential nutrients) in fact were found to be very unstable under storage conditions (Nielsen, 1956; Haydak 1963; Hagedorn and Burger, 1968).

Finally, the lipid content of the DFP may also have been affected during the drying process. Polyunsaturated fatty acids, such as linoleic and linolenic acids (present in many plant species; Stanley and Linskens, 1974) are essential nutrients for most insects and may not be synthesized by them (Dadd, 1973). The membrane of pollen grains loses its integrity during the drying–ageing process. As a consequence, lipids are de-esterified and lysophospholipids and free fatty acids accumulate. An excessive leakage of the internal contents occurs with rehydration (Crowe et al, 1989; Bilsen and Hoekstra, 1993; Bilsen et al, 1994a,b). (It has been observed that bumble bees moisten the pollen before ingesting it, or when preparing it to feed the larvae. For obvious reasons the amount of moisture was always larger in the containers of DFP than in the FFP. Sometimes even a change in the colour of the pollen was observed. This could indicate a reaction between amino acids and reducing sugars (Leiner, 1958).) Therefore, as a result of leakage and loss and/or damage of substances, the bees may have less nutrients available for digestion and absorption. It seems that the queen larvae are especially sensitive to reduced amounts of nutrients.

Our results also indicate that DFP provoked higher mortality (especially before hibernation) in the young queens produced. Larger queens do indeed have a higher survival rate (Holm, 1972; Owen, 1988).

In our experiment the survivors also had less success in producing colonies. Holm (1966) suggested that a queen's ability to start and develop a colony depends on her previous nutritional condition.

Probably the lower survival rate and less success in producing colonies were also associated with the lower biomass of these queens. Body mass is related to several factors including fat content (Alford, 1969a; Holm, 1972). During hibernation queens use most of the reserves (fat and glycogen) they have accumulated previously in the fat body. Alford (1969a,b) found that the amount of fat in young *B terrestris* queens about to go into hibernation was on average 34% of their dry weight. Considering that pollen is important for the development of the fat body (Maurizio, 1950; Duchateau, unpublished data), it is possible that DFP caused an underdevelopment of the fat body of young queens in our experiment.

In conclusion, fairly good colonies may be reared with DFP (if the temperature during the drying process is not too high). But to ensure that young queens are of high quality (adequate size, biomass, survival and capability to produce good colonies) it is essential that the pollen used to feed the colonies during the queens larval development is fresh (or FFP).

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Zusammenfassung — Vergleich der Auswirkung von zwei handelsüblichen Pollensorten auf Kolonieentwicklung und Königinnenproduktion bei der Hummel *Bombus terrestris* (L) (Hymenoptera, Apidae). Verschiedene Pollen haben unterschiedlichen Nährwert für Bienen. Hierfür gibt es zwei Gründe: 1. Die chemische Zusammensetzung des Pollens ist je nach Pflanzenart unterschiedlich. 2. Faktoren wie Trocknung, Alterung und Lagerungsbedingungen beeinflussen den Nährwert. Es existieren in der Literatur keine Angaben über den Effekt von getrocknetem Pollen auf die Entwicklung des Hummelvolkes und die Produktion von Hummelköniginnen. Zwei im Handel erhältliche Pollensorten wurden in diesem Experiment verwendet. Die Pollensorten stammten von unterschiedlichen Pflanzen (Tabelle I) und wurden vor Versuchsbeginn unterschiedlich gelagert. Der Pollen wurde entweder frisch oder getrocknet verwendet. Getrockneter oder frischer Pollen wurde sofort verwendet oder tiefgefroren. Beide Pollensorten waren auf Grund ihres hohen Proteingehaltes und ihres geringen Stärkegehaltes als qualitativ hochwertig anzusehen (Tabelle I). Wir Kontrollierten die Völker täglich, um Daten über die Entwicklung der Individuen und der Völker zu gewinnen. Den geschlüpften Königinnen wurde Gelegenheit zur Paarung und Überwinterung geboten. Die ersten 10 Tage nach der Überwinterung verbrachten die überlebenden Königinnen in einem Flugkäfig. Danach wurden sie, um neue Völker zu starten, bei 28 °C und 60% relativer Luftfeuchtigkeit in Holzkisten gehalten. Zur Bestimmung der Größe der Königinnen wurde ihre Biomasse (Trockengewicht) sowie die Länge der radialen Fügelzelle bestimmt. Getrockneter Pollen wurde weniger konsumiert als frischer Pollen (nicht signifikant, Abb 1). Eine mögliche Ursache hierfür könnte die durch den Trocknungsprozeß bedingte Veränderung einiger Substanzen sein, die vor dem Trocknungsprozeß den Pollen attraktiver für Hummeln machen. Eine andere Ursache könnte sein, daß getrockneter Pollen weniger schmackhaft für Hummeln ist. Die Entwicklung der Kolonie sowie die Anzahl und Biomasse der Arbeiterinnen und Drohnen wurde durch den getrockneten Pollen nicht beeinflußt (Tabelle II und III; Abb 2). Königinnen, die mit getrocknetem Pollen aufgezogen wurden, waren jedoch kleiner und hatten eine geringere Biomasse und eine höhere Sterblichkeit vor der Überwinterung als mit frischem Pollen aufgezogene Königinnen. Sie begannen später mit der Eiablage und produzierten eine geringere Anzahl Individuen (Tabelle III und IV; Abb 3, 4 und 5). Mit getrocknetem *Brassica* Pollen gefütterte Völker produzierten ebenfalls signifikant kleinere Königinnen als mit frischem *Brassica* Pollen gefütterte Völker. Dies kann möglicherweise durch eine geringere Menge an Proteinen in getrocknetem Pollen bedingt sein. Der getrocknete Pollen bestand hauptsächlich aus proteinreichem *Brassica*pollen. Der Trocknungsprozeß könnte jedoch die Proteine beeinflussen. Viele wichtige Aminosäuren reagieren besonders empfindlich auf Erwärmung. Erwärmung könnte die Molekularstruktur eines Proteins und damit seine Verdaubarkeit durch Enzyme verändern. Während des Trocknungsprozesses und der Lagerung könnten auch Vitamine oder Fettsäuren (wichtige Nährstoffe für einen Großteil der Insekten)

geschädigt werden. Durch den Verlust und/oder die Schädigung wichtiger Substanzen steht den Hummeln bei der Fütterung mit getrocknetem Pollen möglicherweise eine geringere Menge an Nährstoffen zur Verfügung. Königinnenlarven scheinen besonders empfindlich auf die geringere Qualität des getrockneten Pollens zu reagieren. Die geringere Biomasse der Königinnen steht möglicherweise im Zusammenhang mit der Größe ihres Fettkörpers. Während der Überwinterung benötigen Königinnen ihre im Fettkörper zuvor angereicherten Reserven (Fett und Glykogen). Pollen hat eine wichtige Funktion bei der Entwicklung dieses Fettkörpers. Die Fütterung mit getrocknetem Pollen könnte zur Unterentwicklung des Fettkörpers führen. Aus den Ergebnissen unserer Untersuchung folgern wir, daß Durchschnittsvölker mit getrocknetem und eingefrorenem Pollen aufgezogen werden können. Zur Zucht qualitativ hochwertiger junger Königinnen sollte jedoch frischer (oder eingefrorener frischer) Pollen verwendet werden.

***Bombus terrestris* / Pollen / Nährwert / Königinnenzucht**

Résumé — Étude comparative de l'action de deux types de pollen du commerce sur le développement de la colonie et sur la production de reines chez le bourdon *Bombus terrestris* (L) (Hymenoptera, Apidae). La valeur nutritive des pollens pour les insectes varie d'un pollen à l'autre, d'abord parce que leur composition chimique est fonction de l'espèce botanique, ensuite du fait de l'action de divers facteurs tels que le séchage, le vieillissement et/ou les conditions de conservation. Il n'existe pas dans la littérature d'information sur les conséquences de l'utilisation de pollen séché sur le développement de la colonie et sur la production de reines chez les bourdons. Deux types de pollen disponibles dans le commerce ont été utilisés dans cette expérience. Leur composition différait (tableau I), ainsi que leur mode de conservation : à l'état frais + un an au congélateur pour le premier, séché + deux ans au congélateur pour le second. Néanmoins, en raison de leur qualité probablement bonne (pas d'amidon et/ou forte teneur en protéines) et de la nécessité d'obtenir des informations sur les régimes de pollen convenant aux bourdons, nous les avons utilisés pour nourrir des colonies et comparer leurs effets éventuels sur les insectes. Des données sur les individus et le développement des colonies ont été relevées journellement. Les jeunes reines produites ont été libres de s'accoupler et d'hiberner. Après l'hibernation les survivantes ont été placées dans des cages de vol pendant 10 jours, puis dans des boîtes en bois en conditions contrôlées de température (28 °C) et d'humidité relative (60 %) pour la fondation des colonies. La taille des reines a été déterminée en mesurant leur biomasse (poids sec) et la longueur de la cellule radiale alaire. Le pollen séché a été moins consommé que le pollen frais, mais la différence n'est pas significative (fig 1). La raison pourrait en être que le processus de séchage a modifié certaines des substances phagostimulantes et/ou une réduction de l'appétibilité du pollen. Le développement de la colonie (tableau II), le nombre d'ouvrières et de mâles (tableau III, fig 2) et leur biomasse (tableau III) n'ont pas été affectés par la consommation de pollen séché. Pourtant les reines élevées avec du pollen séché étaient plus petites (fig 3), avaient une biomasse inférieure (tableau III) et une mortalité avant l'hibernation plus élevée (fig 4, tableau IV), commençaient à pondre plus tardivement (fig 5) et produisaient de plus petites colonies (tableau IV). Le pollen séché de *Brassica* a également donné des reines significativement plus petites que celles élevées avec du pollen de *Brassica* frais (Duchâteau, comm pers). Cela peut être mis en relation avec la quantité de protéines peut-être plus réduite dans le pollen séché.

Bien que le pollen séché ait été constitué principalement de pollen de *Brassica*, riche en protéines, il est possible que le séchage ait affecté les protéines. De nombreux acides aminés essentiels sont sensibles à la chaleur. Des températures élevées peuvent modifier la structure moléculaire des protéines et augmenter la résistance aux enzymes digestifs. Les vitamines également peuvent être abimées ou détruites par le séchage et la conservation. Certains lipides (nutriments essentiels pour la plupart des insectes) peuvent avoir subi une dégradation au cours du séchage. En conséquence, suite à la perte et/ou la détérioration de substances, les nutriments disponibles pour la digestion et l'absorption peuvent être disponibles en moins grande quantité. Il semble que les larves de reines soient particulièrement sensibles à la réduction des nutriments. La biomasse plus faible des reines est liée à la teneur en graisse. Au cours de l'hibernation les reines utilisent la majeure partie de leurs réserves (graisse et glycogène) accumulées auparavant dans le corps gras. Le pollen ayant un rôle important dans le développement du corps gras, il se peut que le pollen séché donné en nourrissement entraîne un sous-développement du corps gras. En conclusion, il est possible d'élever de belles colonies de bourdons avec du pollen séché, mais pour s'assurer de la bonne qualité des jeunes reines, il est essentiel que le pollen utilisé pour nourrir les colonies pendant le développement des larves de reines soit frais ou congelé à l'état frais.

***Bombus terrestris* / pollen / valeur nutritive / élevage reines**

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