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Categorical Evaluation of Consumption Preferences for Dry Pollen Substitute Candidates in Honey Bees

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Abstract

Honey bees are essential pollinators, and pollen is their main nutritional source. When pollen becomes scarce, dry substitutes are required. In this study, 27 materials were tested: bee pollen, beetroot, spinach, pumpkin seeds; red and green lentil, corn, soybean, oat, buckwheat, wheat germ, breadcrumbs, psyllium husk; chia, sesame, roasted chickpea, black cumin, oleaster; whey protein, BCAAs, creatine; cumin, red pepper, black pepper, thyme, turmeric, and ginger. These were evaluated for consumption preferences. Red lentil flour, consumed even more than natural pollen, was the strongest candidate. Green lentil, corn, oat, soybean, and wheat germ flours received moderate interest, while breadcrumbs and buckwheat flour showed low consumption. Most ground vegetables, seeds, mixtures, sports supplements, and spices were minimally preferred or rejected. Whey protein's ultra-fine particles created excessive dust during wing fanning, discouraging bees from interacting with it. Overall, the results show that physical traits such as particle size and dustiness, in addition to nutritional composition, strongly influence product acceptance, and that lentil-based materials hold high potential for developing dry pollen substitutes.

Keywords: *Autumn, bees, foraging, dry feeding, dearth period*

Bal Arılarında Kuru Polen İkamesi Adaylarının Tüketim Tercihlerinin Kategorik Olarak Değerlendirilmesi

Özet

Bal arıları, ekosistemlerin devamlılığı açısından kritik öneme sahip tozlayıcılardır ve polen, koloni sağlığı için temel besin kaynağıdır; ancak mevsimsel polen kıtlığı dönemlerinde kuru polen ikamesine ihtiyaç duyulmaktadır. Bu çalışmada, arılara sunulan 27 kuru materyalden öğütülmüş ürünler (arı poleni, pancar, ıspanak, kabak çekirdeği), unlar (kırmızı ve yeşil mercimek, mısır, soya, yulaf, karabuğday, buğday rüşeymi, galeta, Psyllium husk), öğütülmüş tohumlar (chia, susam, leblebi, çörek otu, iğde), sporcu ürünleri/protein kaynakları (whey protein, BCAA, kreatin) ve baharatlar (kimyon, kırmızı biber, kara biber, kekik, zerdeçal, zencefil) olarak sınıflandırılarak tüketim tercihleri değerlendirilmiştir. Bulgular, özellikle kırmızı mercimek ununun doğal polenden dahi yüksek oranda tüketilerek en güçlü aday olduğunu, yeşil mercimek, mısır, yulaf, soya ve buğday rüşeymi unlarının orta düzeyde ilgi gördüğünü, galeta ve karabuğday ununun ise düşük düzeyde tüketildiğini göstermiştir. Öğütülmüş sebze, tohum ve karışımların büyük kısmı ile sporcu ürünleri ve baharatlar arılar tarafından ya çok az tercih edilmiş ya da tamamen reddedilmiştir; özellikle whey proteinin ultra ince partikül yapısı, kanat çırpışıyla aşırı toz kalkmasına yol açarak arıları üründen uzaklaştırmıştır. Sonuçlar, besinsel içeriğin yanı sıra partikül boyutu ve tozuma gibi fiziksel özelliklerin arı kabulünde belirleyici olduğunu ve özellikle mercimek türevlerinin kuru polen ikamesi formülasyonları için yüksek potansiyele sahip olduğunu ortaya koymaktadır.

Anahtar Kelimeler: *Sonbahar, arılar, tarlacılık, kuru besleme, kuru periyot*

Introduction

Protein nutrition is crucial for the growth, development, and productivity of honey bee colonies. Of all the nutritional resources collected by worker bees, pollen is the primary source of proteins, lipids, vitamins, minerals, and other essential nutrients required for brood rearing and physiological maintenance. Adequate pollen intake is directly linked to colony population growth, improved foraging performance, enhanced disease resistance, and increased honey production. However, the availability of natural pollen is often affected by seasonal fluctuations, climatic conditions, and habitat characteristics, resulting in periods when colonies experience nutritional stress (Skubida et al., 2008; Zahra and Talal, 2008).

Insufficient pollen availability can adversely affect colony performance by reducing brood production, shortening worker longevity, and weakening overall colony strength. Such nutritional deficiencies may also increase colony susceptibility to pathogens, parasites, pesticide exposure, and other environmental stressors. As a result, the development of alternative protein sources capable of supporting colony requirements during periods of pollen shortage has attracted considerable attention from researchers and beekeepers alike (Wilson et al., 2005; Macdonald et al., 2002).

Although natural pollen remains the most suitable protein source for honey bees, its collection, storage, and commercial use present several challenges. Large-scale pollen harvesting is labour-intensive and costly, and collected pollen may contain pesticide residues, environmental contaminants, or disease-causing microorganisms. These limitations have encouraged efforts to formulate artificial diets that can partially or completely replace natural pollen when floral resources are inadequate (Pande and Karnatak, 2014; Kumar and Agrawal, 2014). Various ingredients, including soybean flour, brewer's yeast, skimmed milk powder, spirulina, cereal products, and legume-derived flours, have been incorporated into pollen substitute formulations with varying degrees of success (Herbert et al., 1980; Saffari et al., 2010).

The practical value of a pollen substitute depends not only on its nutritional composition but also on its acceptance by bees. A diet containing balanced nutrients may fail to provide benefits if worker bees do not readily consume it. Therefore, feed palatability and consumption preference are among the most important criteria in evaluating the suitability of pollen substitute formulations (Baumont, 1995; Provenza, 1995). Understanding dietary preferences can help identify ingredients that are more attractive to honey bees and improve the effectiveness of supplemental feeding programmes.

In modern beekeeping, supplemental feeding has become an essential management practice, particularly during periods of nectar and pollen scarcity. While migratory beekeeping is often used to alleviate forage shortages, transportation costs, colony stress, and environmental uncertainties frequently limit its effectiveness. Consequently, artificial diets have become a practical and economical approach to maintaining colony development and productivity throughout the year (Saffari et al., 2006; Sharma and Gupta, 2006). Previous studies have mainly focused on evaluating the nutritional performance of individual or a limited number of pollen substitute formulations. However, comprehensive comparisons involving a wide range of candidate ingredients remain relatively rare.

Therefore, the present study aimed to systematically evaluate the consumption preferences of honey bees for 27 different dry pollen substitute candidates and to identify the most acceptable formulations that may serve as promising alternatives for supplemental protein feeding in apicultural practices.

Materials and Methods

Study Area and Experimental Period

The study was conducted in 2025 at the Beekeeping Research and Application Unit of the Department of Animal Science, Muş province/Türkiye. Experimental observations took place during the pollen dearth period (October-November) under natural environmental conditions. Honey bee colonies (*Apis mellifera* L.) maintained in the research apiary were used to evaluate the consumption preferences for candidate dry pollen substitute materials.

Experimental Colonies

A total of 100 colonies with comparable population strength, brood area, queen age, and general health status were selected for the experiment. Before the study, all colonies were inspected to ensure the absence of major disease symptoms and abnormal conditions. Standard colony management practices were applied throughout the experimental period.

Test Materials

Twenty-seven dry pollen substitute candidates representing various plant-derived and protein-rich ingredients were evaluated. The tested materials included bee pollen (control), sugar beet, spinach, pumpkin seed, red lentil flour, green lentil flour, corn flour, soybean flour, oat flour, buckwheat flour, wheat germ, breadcrumbs, plantago ovata powder, chia seed, sesame seed, roasted chickpea flour, black cumin seed, whey protein, branched-chain amino acids (BCAA), creatine monohydrate, cumin, red pepper, and other candidate ingredients. The nutritional characteristics of the tested materials are presented in Table 1.

Feeding and Preference Assessment

All test materials were offered to colonies in dry form under identical field conditions. Equal quantities of each candidate ingredient were simultaneously presented to the colonies in separate feeding containers placed within the apiary. To minimise positional bias, the locations of the feeding containers were periodically rotated during the experiment. Consumption preference was assessed by visually monitoring bee visitation intensity and

measuring the amount of material removed from each feeding container. Observations were conducted at regular intervals throughout the experimental period.

Data Collection and Evaluation

The findings were used to identify dry pollen substitute candidates most readily accepted by honey bees and therefore potentially suitable for use in supplemental feeding programmes.

Table 1. Nutritional composition of bee pollen and candidate dry pollen substitute ingredients used in the study

Product	*Crude Protein (%)*	*Crude Fat (%)*	*Carbohydrate (%)*	*Fiber (%)*
Bee pollen	22.0	7.5	44.0	13.0
Beetroot powder	20.7	<1.0	70.0	23.0
Spinach	32.0	4.5	40.0	24.0
Pumpkin seed	21.0	51.0	20.0	–
Red lentil flour	24.5	0.91	47.7	15.6
Green lentil flour	23.4	0.96	38.7	24.0
Corn flour	7.8	2.6	76.9	3.7
Soybean flour	52.0	0.96	36.0	3.32
Oat flour	12.6	5.5	60.9	6.7
Buckwheat flour	12.65	3.15	70.98	9.72
Wheat germ	31.0	10.0	49.0	10.0
Breadcrumbs	11.12	1.67	70.90	2.96
Plantago ovata powder	11.8	0.3	62.8	25.5
Chia seed	22.1	33.3	3.5	32.8
Sesame seed	2.55	8.06	3.18	1.4
Roasted chickpea flour	20.0	7.0	56.0	17.0
Turmeric	48.0	7.0	20.0	22.0
Whey protein	72.7	5.5	8.8	–
BCAA (Leucine, Isoleucine, Valine)	4:1:1	–	–	–
Creatine monohydrate	5000 mg per serving (Creatine: 793.65 mg)			
Cumin	20.0	16.9	46.9	1.1
Red pepper	14.8	1.1	51.5	2.6

Results and Discussion

Marked differences in consumption preferences were observed among the 27 dry substitute candidates tested. Overall, honey bees showed clear selectivity depending on material type and physical characteristics.

Of all the materials tested, red lentil flour had the highest level of acceptance and consumption, exceeding even that of natural bee pollen. This result indicates a strong preference for red lentil-based formulations compared to other substitutes. Green lentil, corn, oat, soybean, and wheat germ flours showed moderate consumption and were consistently accepted by the colonies, although at lower rates than red lentil flour.

In contrast, buckwheat flour and breadcrumbs were less accepted, with noticeably reduced consumption compared to the more favourable flours. Most ground vegetable materials (beetroot and spinach), ground seeds (chia, sesame, roasted chickpea, black cumin, oleaster), sports supplements (whey protein, BCAAs, creatine), and spice-based materials (cumin, red pepper, black pepper, thyme, turmeric, ginger) were either minimally consumed or completely rejected by the honey bees.

A notable behavioural response was observed in the whey protein treatment, where its ultra-fine particle structure caused significant dust dispersion during bee wing fanning activity. This appeared to reduce direct contact and feeding activity, further contributing to its low acceptance.

Bee density across the experimental colonies is presented in Table 2, which shows that colony-level bee distribution remained consistent during the feeding period, supporting the conclusion that observed differences in consumption were primarily related to material preference rather than variations in colony strength.

Similar findings have been reported in previous studies (Güneşdoğdu, 2025a). Güneşdoğdu and Buluş (2025b) also highlighted comparable outcomes regarding dry feeding systems and bee acceptance patterns. In addition, Pal and Mall (2026) reported that soybean-based flour and pollen-enriched dry diets were among the most preferred formulations by honey bees, supporting the present findings on the importance of plant-based protein sources in dry diet acceptance.

Table 2. Honey bee density under dry substitute feeding conditions

Conclusion

This study showed that honey bee acceptance of dry pollen substitute materials varies considerably among different sources. Red lentil flour was the most preferred material, followed by moderate acceptance of green lentil, corn, oat, soybean, and wheat germ flours, while most other plant-based powders, seeds, sports supplements, and spices were poorly accepted or rejected. Further studies conducted in different geographic locations and under varying environmental conditions are recommended to validate these findings. In addition, testing different formulations and combinations of the most promising materials, particularly lentil-based products, may contribute to the development of more effective dry pollen substitute diets for honey bee colonies.

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