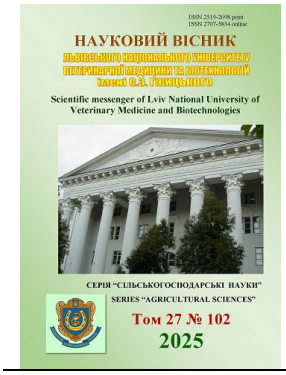

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The efficiency of feed paste consumption affects wintering success and subsequent colony development in honey bees

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Efficient winter-feeding strategies play a critical role in ensuring the survival and productivity of honey bee (Apis mellifera) colonies. One of the most commonly used supplementary feeds in beekeeping is "Kandy" paste, a sugar-based formulation designed to sustain bee colonies during periods of food scarcity. However, inconsistencies in colony wintering success, despite the use of similar feeding protocols, have raised concerns regarding the quality and physical properties of commercial feed pastes. This study aimed to evaluate the impact of feed paste composition, particularly sugar particle size, on winter survival and subsequent colony development. The experiment was conducted during the winter of 2023–2024 at the agricultural service cooperative "Dnipro Beekeeper" (Ukraine). Three groups of bee colonies (n = 10 per group) were studied: the first group received self-produced "Kandy" feed paste containing 70 % finely ground powdered sugar and 30 % fructose-glucose syrup, the second group received a commercially available "Kandy" paste, and the third group served as a control, overwintering solely on honey reserves. The colonies were monitored for feed consumption, winter survival rates, and spring brood development. The results showed that sugar particle size significantly influenced feed consumption efficiency. Colonies in the first group consumed 5.29 ± 0.14 kg of feed paste during winter, while those in the second group consumed only 4.83 ± 0.12 kg, with a higher proportion of undissolved sugar crystals found in hive debris ($P < 0.05$). The second group exhibited a greater colony weakening rate (21.28 ± 3.21 %) compared to the first (17.71 ± 2.31 %) and control (17.52 ± 3.45 %) groups, indicating poorer feed digestibility in the commercial paste. Furthermore, spring brood development was slower in the second group, with statistically significant differences observed in the second and third monitoring periods ($P < 0.05$). These findings confirm that the physical characteristics of feed paste, particularly sugar particle size, directly affect its accessibility and digestibility for bees. The use of finely ground sugar improved feed utilisation, resulting in better colony survival and accelerated post-winter development. The study underscores the necessity of stricter quality control for feed formulations, ensuring optimal particle refinement to enhance the efficiency of supplemental feeding. Future research should explore the effects of additional dietary components, such as proteins and organic acids, on honey bee metabolism and resilience under varying environmental conditions

Key words: *Apis mellifera, wintering of honey bees, colony survival, brood development, supplemental feeding, Kandy paste, beekeeping management.*

Introduction

Beekeeping plays a crucial role in agriculture, providing essential products such as honey, wax, and other valuable substances. Honey is not only a nutritional product but also a key ingredient in the pharmaceutical and cosmetic industries (Kumari et al., 2023; Kucher et al., 2024a). Optimal bee nutrition is critical for maintaining colony productivity and survival, particularly during the winter period (Mischenko et al., 2021; Tsuruda et al., 2021). Studies indicate that feed quality directly affects the physiological state of bees, their metabolic rate, and overall winter resilience (Abdella et al., 2024).

Wintering is a critical phase in the life cycle of bee colonies, as the risk of mortality increases due to insufficient feed supply, poor feed quality, or other stress fac-

tors. It is well established that supplementary feeding can significantly improve colony survival rates; however, its effectiveness depends on both the composition and availability of feed for bees (Lazarov et al., 2025). The use of alternative feed additives, such as protein components or specialised feed pastes, has been reported to enhance bee survival, increase resilience to adverse conditions, and even influence the quality of future bee generations (Přidal et al., 2023; Kucher et al., 2024b).

In practice, beekeepers frequently use "Kandy" feed paste, which contains powdered sugar and syrups, as a supplementary winter feed. However, field observations suggest that even under identical conditions, the outcomes of wintering and subsequent spring colony development can be inconsistent. Notably, in certain batches of "Kandy" paste, significant amounts of large sugar crystals were found in hive debris after wintering, indicating inadequate refinement of powdered sugar. High-quality powdered sugar for feed preparation must meet specific moisture (≤0.14 %) and particle size (≤0.1 mm) standards to ensure optimal consumption by bees (DSTU 7005:2009).

Research on the efficiency of different feeding strategies has shown that the composition of sugar pastes for bees can significantly impact their ability to utilise the feed. The presence of large sugar crystals in the paste, for instance, can hinder consumption and result in an insufficient intake of essential nutrients (Matovic et al., 2024). Analyses of winter bee losses have revealed that, in certain cases, substantial amounts of undissolved sugar crystals remained in the hives, indicating inadequate refinement of powdered sugar (Falcão et al., 2024). This issue may contribute to underfeeding and lead to weakened colonies in the spring season (Sultana et al., 2024).

Thus, we hypothesised that the effectiveness of "Kandy" feed paste consumption depends not only on its chemical composition but also on its physical properties, particularly the size of sugar particles. To test this hypothesis, a comparative study was conducted on the overwintering success of bee colonies using a self-produced feed paste containing 70 % powdered sugar and 30% fructose-glucose syrup, compared with commercially available "Kandy" paste.

The objective of this study was to assess the efficiency of feed paste consumption during overwintering, determine its impact on colony survival, evaluate the degree of post-winter weakening, and analyse the speed of spring colony development.

Materials and Methods

The study was conducted during the winter period of 2023–2024 at the apiary of the agricultural service cooperative "Dnipro Beekeeper" (Solonianskyi district, Dnipropetrovsk region, Ukraine). The research followed the standard methodology for beekeeping studies (Brovarskyi et al., 2017). The bee colonies met the requirements of the Ukrainian Steppe breed standard based on exterior evaluation results (Pokhyl et al., 2023). The study complied with the European Convention for the Protection of Animals Used for Experimental and Other Scientific Purposes (1986).

To assess the efficiency of feed consumption and its impact on overwintering and spring development, two types of bee feed paste ("Kandy") were used: a self-produced variant and a commercially available product from an external manufacturer. Both feed types met microbiological, organoleptic, and physicochemical requirements according to DSTU 7005:2009. The self-produced "Kandy" feed paste from the "Dnipro Beekeeper" cooperative was officially certified for quality and safety by the State Research Institute for Laboratory Diagnostics and Veterinary-Sanitary Expertise.

The experiment began on January 1st. Three groups of bee colonies were formed, each consisting of 10 analogous families. At the beginning of the experiment, all colonies had an average of 9.57 ± 0.52 frames, sufficient pollen reserves, second-year queens, two frames with capped brood, and two frames with open brood. In the experimental groups, honey stores were removed, while pollen reserves were left intact. The first group received self-produced "Kandy" feed paste, while the second group was fed a commercially available "Kandy" feed paste. The third group served as the control and overwintered without additional feeding, relying solely on their honey reserves. Feeding was carried out by placing a feed paste block directly on the frames under the hive ceiling (Fig. 1).

Several key parameters were assessed to evaluate the condition of the bee colonies. Queen laying performance was measured by counting capped brood using a 5×5 cm grid frame method. Colony strength was assessed based on the number of frames occupied by bees, converting this into biomass by assuming that bees covering a standard frame (435×300 mm) weigh 300 g. The extent of feed utilisation was estimated by analysing the residual undissolved sugar crystals found in hives after wintering.

Statistical analysis of the obtained data was performed using Statistica 12 software. One-way analysis of variance (ANOVA) was used to compare the mean values between groups. The Shapiro-Wilk test was applied to check the normality of data distribution. Data are presented as the mean (M) ± standard error (SE). Differences were considered statistically significant at $P < 0.05$.

Results and discussion

Wintering of bee colonies and feed consumption

One of the key factors ensuring the successful wintering of honeybee colonies is providing them with a sufficient quantity of high-quality feed. Proper nutrition during the preparation period for wintering plays a crucial role in colony survival, as confirmed by numerous studies (Rodney & Purdy, 2020; Pastushok et al., 2024). It has been established that the quality and composition of supplemental feeding directly affect the physiological condition of bees, their metabolic rate, and overall winter resilience (Tsuruda et al., 2021; Hrechka & Senchylo, 2022; Abdella et al., 2024).

Analysis of winter hive debris revealed a significant amount of undissolved sugar crystals in the second experimental group, which may indicate an insufficient level of sugar powder refinement in the commercial feed paste. It is known that the optimal sugar particle size in bee feed

should not exceed 0.1 mm to ensure uniform feed consumption by bees (Falcão et al., 2024; Matovic et al., 2024). In contrast, the first group, which received self-produced feed paste containing finely ground sugar powder, exhibited significantly fewer residual sugar crystals.

Feed consumption during the winter period differed between the groups. The total consumption of supplemental feed in the first group was 5.29 ± 0.14 kg, while in the second group, it was 4.83 ± 0.12 kg (see table 1). The proportion of feed residues unsuitable for use was 3.82% in the first group and 12.18 % in the second group, with the difference being statistically significant ($P < 0.05$). This confirms that the physical properties of the feed directly influence its consumption and assimilation by bees. A detailed analysis of the feeding process revealed a substantially higher presence of sugar crystals in the commercial feed paste used in the second group (Fig. 2).

A B

Fig. 1. Use of paste for feeding bees of the "Kandy" type, which was placed on frames under the hive ceiling (A – first group; B – second group)

A B

Fig. 2. Uniform structure of self-produced "Kandy" bee feed paste (A – first group) and commercial bee feed paste (B – second group), in which sugar crystals are visibly present.

Colony strength reduction after wintering

The results of the winter survival assessment of bee colonies are presented in Table 1.

The results indicate that the greatest colony weakening was observed in the second group (21.28 ± 3.21 %), which was statistically higher than in the first (17.71 ± 2.31 %) and third (17.52 ± 3.45 %) groups ($P < 0.05$). The higher weakening rate in the second group may be associated with poorer digestibility of commercial "Kandy" due to the presence of undissolved sugar crystals, as supported by previous research (Sultana et al., 2024).

The control group, which relied exclusively on its honey reserves, exhibited the highest feed consumption (8.5 ± 0.13 kg of honey per colony), consistent with reports on the energetic demands of bees in the absence of additional supplemental feeding (Přidal et al., 2023).

Table 1
Colony survival and feed consumption during wintering in experimental groups

Parameter	Group 1	Group 2	Group 3
Colony strength, streets: autumn	9.6 ± 0.41	9.4 ± 0.52	9.7 ± 0.61
Colony strength, streets: spring	7.9 ± 0.25	7.4 ± 0.23	8.0 ± 0.32
Colony weakening rate, %	17.71 ± 2.31	21.28 ± 3.21	17.52 ± 3.45
Honey stock, kg: autumn	15.2 ± 0.28	14.8 ± 0.25	15.0 ± 0.38
Honey stock, kg: spring	-	-	6.5 ± 0.32
Feed paste provided per hive, kg	5.5 ± 0.00	5.5 ± 0.00	-
Residual feed paste removed from hives, kg	0.21 ± 0.02	0.67 ± 0.05	-
Feed paste consumed during winter, kg	5.29 ± 0.14	4.83 ± 0.12	-
Honey consumed during winter, kg	-	-	8.5 ± 0.13

Spring development of bee colonies

Significant differences among groups were observed in the rate of spring brood development (Table 2).

Observational measurements of colony development demonstrated a minor difference at the first control measurement, followed by a statistically significant lag in brood growth in the second and third control periods in the second group ($P < 0.05$). The absence of a significant difference in the first measurement suggests that the quality of queens and their genetic equivalence likely did not influence the results. A comparison among groups indicates close similarities between the first and third groups across all three measurements. The differences between the second group and the first and third groups were 11.5 % and 14.6 % in the second observation and 11.9 % and 13.2 % in the third observation, respectively. The difference between the first and second groups was statistically significant in the second ($P < 0.05$) and third ($P < 0.05$) observation periods. These findings confirm that poorer feed digestibility during winter had a long-term effect on colony development.

Table 2
Spring brood development dynamics in experimental bee colonies (hundreds of cells)

Group	First observation	Second observation	Third observation
Group 1	64.2 ± 0.17	227.5 ± 0.22	452.1 ± 0.42
Group 2	60.2 ± 0.12	201.3 ± 0.34	398.2 ± 0.37
Group 3	65.4 ± 0.14	230.7 ± 0.36	450.8 ± 0.36

Previous studies have shown that winter diet quality directly influences early spring colony development, as bees receiving adequate nutrition exhibit better physiological conditions and a greater number of actively developing brood cells (Paray et al., 2021; Lata et al., 2023; Pastushok et al., 2024). Our findings align with these conclusions.

Correlation between feed consumption and colony strength

The obtained results suggest that the efficiency of feed consumption is determined not only by its chemical composition but also by its physical characteristics. The use of "Kandy" paste with finely ground sugar particles (first group) contributed to better winter resilience and faster spring development. In contrast, feed with coarser sugar particles (second group) exhibited poorer digestibility, resulting in higher winter losses and slower colony development. The difference in brood development rates between the first and second groups was statistically significant, indicating that suboptimal feed structure negatively impacts colony growth beyond the wintering period. These findings confirm the hypothesis that sugar particle size in feed is a critical factor in ensuring effective feed consumption and maintaining the physiological condition of bees. Future research should focus on evaluating the effects of additional feed components, such as protein additives and organic acids, on metabolism and bee survival.

Conclusions

The study confirmed the necessity of additional quality control for "Kandy" feed paste, with particular attention to the absence of whole sugar crystals in the final mixture. The presence of undissolved sugar crystals negatively impacted feed accessibility for bees, leading to lower feed consumption efficiency. This, in turn, resulted in higher colony weakening rates during winter and a subsequent delay in spring colony development.

Our findings indicate that the physical properties of feed paste, particularly sugar particle size, play a crucial role in ensuring its effective consumption by honey bee colonies. The use of finely ground sugar significantly improved feed utilisation, contributing to better winter survival and faster spring brood development.

These results highlight the importance of refining feed formulation standards for beekeeping, emphasising not only the chemical composition but also the physical characteristics of supplementary feeds. Further research should focus on evaluating the effects of additional feed components, such as protein supplements and organic acids, on honey bee metabolism and colony resilience under varying environmental conditions.

Conflict of interest

The authors declare that there is no conflict of interest.

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