



Synergistic Effects of Protein Diets and Management Practices on Health and Productivity of *Apis mellifera* Colonies



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INTRODUCTION

Bees are key pollinators essential to ecological balance and global agriculture (Grozinger & Flenniken, 2019). Their primary energy source is carbohydrates from floral nectar, stored as honey, while nutrient deficiencies impair colony development, increase stress, and reduce productivity (Brys & Strachecka, 2024). In tropical regions such as Brazil, seasonal fluctuations and drought frequently induce nutritional stress, particularly in Africanized populations. Under these conditions, artificial protein supplementation enhances colony performance and brood production, mitigating field losses and improving individual health (Morais et al., 2013; Paiva et al., 2019a; Kim et al., 2024). Colony health and nutrition also depend on management practices, with measures such as replacing old combs and requeening contributing to improved welfare (Goulson et al., 2015).

METHODS

The study was conducted in the city of Bambuí (20° 00' 21" S, 45° 58' 37" O), located in the state of Minas Gerais (Fig 1), within the Cerrado biome in Southeast Brazil.

The three experimental apiaries were located approximately 6 kilometers apart in a straight line, ensuring similar climatic exposure while maintaining spatial independence. The artificial food supplements artificial supplementation consisted of a protein diet (Table 1) developed from mixtures of low-cost ingredients easily accessible to beekeepers. All ingredients were subjected to nutritional analysis before being used in the formulations. The diet was formulated so that the final crude protein percentage was 25%, a value established based on our previous experience (Morais, Turcatto, Franco, et al., 2013; Morais, Turcatto, Pereira, et al., 2013) and similar studies conducted by international research groups (Li et al., 2012).

Table 1:	Composition of the protein feed used.
Control (C-)	Treatment (T)
Sugar Syrup 50%	10% Egg powder 34% Wet grain 36% Sugarcane yeast 20% Sugar Enough 70% syrup to give a pasty consistency

RESULTS

The results demonstrated that the combination of protein supplementation and proper management practices significantly improved colony performance, particularly in apiaries with recommended conditions.

In Apiary 2, which included queen replacement and comb renewal, brood production increased significantly, reaching 70% of frames occupied in September, reflecting a stronger potential workforce. Apiaries under intermediate management also showed benefits, albeit less pronounced. In contrast, Apiary 1, under poor management, exhibited only modest improvements even with protein supplementation, underscoring the necessity of integrating nutritional interventions with management practices to achieve optimal results. The protein diet was highly accepted, with over 90% consumed by all treated colonies, corroborating previous studies that emphasize the efficacy of nutritional supplements in supporting colonies during resource scarcity. Management practices, such as comb and queen replacement, were critical in improving key indicators, including food storage and reducing empty cells, mitigating the impact of stressors like parasites and diseases.

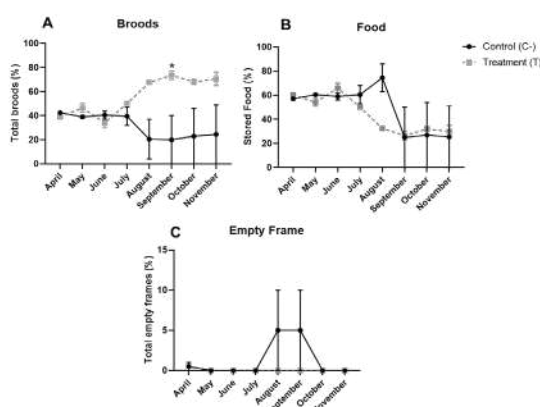


Figure 1 - A: Percentage of total brood; B: Percentage of stored food; C: Total number of empty frames in Apiary 2, from April to November. Results are shown as mean $\pm$ SEM. $p < 0.05$ is indicated by ***. The comparison between the control (C-) and treatment group (T), carried out using the Sidak test.

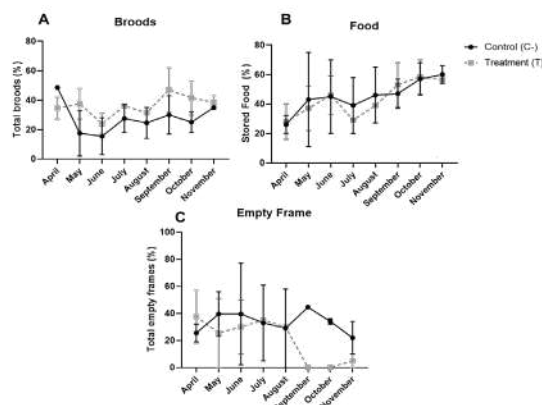


Figure 2 - A: Percentage of total brood; B: Percentage of stored food; C: Total number of empty frames in Apiary 1, from April to November. Results are shown as mean $\pm$ SEM. $p < 0.05$ is indicated by ***. The comparison between the control (C-) and treatment group (T), carried out using the Sidak test.

CONCLUSIONS

The study concludes that combining protein supplementation with proper colony management significantly strengthens colony resilience and productivity during critical periods of resource scarcity. These findings emphasize the importance of integrated approaches to promote bee colony health and resilience, essential for pollinator conservation and global food security. Moreover, they underscore the need to train beekeepers in sustainable practices to ensure effective implementation and foster the sustainable development of apiculture in ecologically and economically vulnerable contexts.

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Bees play a crucial ecological role as pollinators, yet various environmental stressors, including habitat loss and nutritional deficiencies, significantly impact their populations. This study aimed to evaluate the impact of protein supplementation and best management practices on the development of *Apis mellifera* colonies in three apiaries located in southwestern Brazil over an eight-month experimental period, spanning critical resource-scarcity seasons. The apiaries were categorized based on their management conditions: poor, recommended, and intermediate. In each apiary, colonies were divided into control and treatment groups. In addition to standard carbohydrate supplementation, treatment colonies received a newly developed protein diet, and management practices included queen replacement and comb renewal. Parameters such as brood area, food storage, and empty spaces in frames were assessed monthly. The results demonstrated that the combination of protein supplementation and proper management practices significantly improved colony performance, particularly in apiaries with recommended conditions. In Apiary 2, which included queen replacement and comb renewal, brood production increased significantly, reaching 70% of frames occupied in September, reflecting a stronger potential workforce. Apiaries under intermediate management also showed benefits, albeit less pronounced. In contrast, Apiary 1, under poor management, exhibited only modest improvements even with protein supplementation, underscoring the necessity of integrating nutritional interventions with management practices to achieve optimal results. The protein diet was highly accepted, with over 90% consumed by all treated colonies, corroborating previous studies that emphasize the efficacy of nutritional supplements in supporting colonies during resource scarcity. Management practices, such as comb and queen replacement, were critical in improving key indicators, including food storage and reducing empty cells, mitigating the impact of stressors like parasites and diseases. The study concludes that combining protein supplementation with proper colony management significantly strengthens colony resilience and productivity during critical periods of resource scarcity. These findings emphasize the importance of integrated approaches to promote bee colony health and resilience, essential for pollinator conservation and global food security. Moreover, they underscore the need to train beekeepers in sustainable practices to ensure effective implementation and foster the sustainable development of apiculture in ecologically and economically vulnerable contexts.