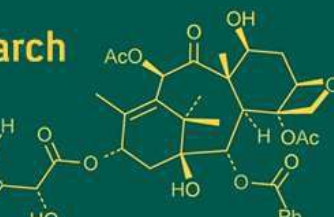
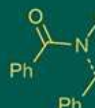
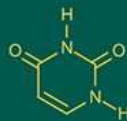


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Effect of supplementary diets on *Apis mellifera* colonies

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Abstract

The research was conducted at the apiary of Instructional farm, Krishi Vigyan Kendra, ADT Baramati during the period of October, 2023 to February, 2024. This study evaluates the effects of supplementary feeding on the performance of *Apis mellifera* colonies in terms of colony growth, brood area and honey yield. The experiment compared five dietary treatments soybean, chickpea, pea flour, BSF larva powder with sugar syrup and a control. Results showed that colonies fed with soybean flour + sugar syrup exhibited the best outcomes, with a higher number of frames covered by bees (6.93), larger brood areas (1429.30 cm²) and the highest honey yield (2.46 kg/hive). Chickpea flour + sugar syrup ranked second in performance. All supplementary diets significantly outperformed the control. These findings emphasize the importance of protein-rich diets in maintaining healthy bee colonies, especially during periods of natural forage scarcity.

Keywords: *Apis mellifera*, sugar syrup, supplementary diet

1. Introduction

Honeybees are known as producer of honey, royal jelly, propolis and bees wax as well as bee venom. They are primarily instrumental in increasing the productivity of a number of agricultural crops produced through cross pollination (McGregor, 1976; Sihag, 1986; Free, 1993) [1-3]. Apart from increasing the yield of different crops, they have been found to significantly improve the quality of seeds and fruits. Beekeeping has been acknowledged as crucial inputs in agriculture (Sihag, 2001) [4].

In the beekeeping sector supplementary feeding with honey are essential to prevent hunger and encourage brood formation in autumn and early winter. This practice helps to develop a stronger worker bee population as well as healthier queens and drones. It also supports colony growth and mitigates the adverse effects of agricultural chemicals used in plant production reducing bee losses (Wheeler and Robinson, 2010) [5]. Especially, the composition and ratio of nutrients affect the lifespan of honey bees (Schulz *et al.*, 2019, Amro *et al.*, 2016) [6, 7]. In India, many beekeepers either do not provide any external food to their bee colonies or rely solely on sugar syrup. However, bee scientists frequently stress that providing pollen supplements or substitutes can help to preserve weaker colonies and sustain a sufficient bee population, enabling them to take full advantage of future non-dearth periods (Kumar and Agrawal, 2014) [8]. The fundamental concept behind an artificial diet lies in its incorporation of all elements ingredients, texture and consistency that are palatable to honey bees. Additionally, it should possess nutritional value while being devoid of anti-nutritional factors (Saffari *et al.*, 2010) [9]. Additionally, there could be a scarcity of pollen prompting bees to decrease the amount of brood they rear (Day *et al.*, 1990) [10].

2. Materials and Methods

Field experiment was conducted at the apiary of Instructional farm, Krishi Vigyan Kendra, ADT Baramati during the period of October, 2023 to February, 2024. The trial used a randomized block design with five treatments and four replications. Feed materials, including soybean flour, pea flour, chickpea flour and BSF larvae powder were sieved to a fine consistency. Sugar syrup was added and the mixture was prepared according to requirements.

Using the top bar method diets were fed as patties in petri dishes placed on top of the honeybee colonies. T₁, T₂ and T₃ were based on Tadle's (2022) [11] diets for *Apis mellifera* in Ethiopia and T₄ was based on BSF larvae's nutritional content with 42% protein. Each diet, high in protein, carbs, minerals and fats was freshly prepared by mixing 100 g of each ingredient with 100 ml of sugar syrup. A total of 200 g of each combination was fed to the colonies every seven days, while control colonies received no supplemental diet.

2.1 Hive frames covered by bees

The number of hive frames covered by bees were recorded by counting the number of fully covered bee frames from each colony fed with different supplementary diets after a seven days interval (Burgett *et al.*, 1984) [12]. This process involved inspecting each colony and carefully observing the frames to determine the extent of coverage by bees.

A frame was considered fully covered if the bees had populated the entire surface area of the frame. This method ensured an accurate assessment of the bees utilization of the supplementary diets over the seven days time period.

2.2 Brood area (cm²)

Brood area was estimated by measuring the areas (in square centimeter) of the worker's sealed brood at intervals of seven days. Observation on brood area development was recorded from November to February. The brood area was measured by using a grid placed over each side of a comb and the number of squares containing brood was counted. This method provided an estimation of the brood area present in the colony at different time points, allowing for the monitoring of brood development over time (De Grandi Hoffman *et al.*, 2008 and Saffari *et al.*, 2010) [13, 9].

2.3 Honey production (kg/hive)

Honey was harvested after the experiment using a manually operated honey harvester from the super chamber and the honey yield of supplementary diet fed colonies were compared. The harvested honey from each fed colonies were collected and worked out to determine the yield in kg.

3. Results and Discussion

3.1 Number of frames

The Table investigates the number of frames covered by bees across different treatments over the period of November, 2023 to February, 2024. The results highlight the substantial influence of feeding supplementary diets on the number of frames covered by bees. The most superior treatment was soybean flour + sugar syrup recorded maximum mean number of frames i.e. 6.93 frames covered by bees was at par with diet chickpea flour + sugar syrup with 6.70 frames covered. The next effective treatments were pea flour + sugar syrup and BSF larva powder + sugar syrup recorded 6.21 and 5.06 mean number of frames covered by the bees respectively. All the diet treatments were outperformed the control recorded 4.34 mean number of frames covered.

These findings align with Sihag and Gupta (2011) [15] they utilized four types of pulses soybean (*Glycine max* L.), mung bean (*Vigna radiata* L.), chickpea (*Cicer arietinum* L.) and pigeon pea (*Cajanus cajan* L.) to formulate artificial diets for feeding honeybee (*Apis mellifera* L.) colonies during periods of forage scarcity. Soybean diet formulation found to better than other in all desired aspects increased in

number of frames from 5 to 8. Mahfouz (2016) [16] studied different pollen sources namely defeated soybeans flour, whey protein for the formulation of pollen supplement diets and concluded both the diets of honeybee's colonies increased number of frames from 5 frames to 6 frames on soybean flour and 4 frames to 6 frames on whey protein during winter season. Tadle (2022) [11] tested three pollen supplements of soybeans, chickpea and pea and demonstrated that colonies that received soybean feed showed the highest number of frames covered by bees 9.4. Colonies provided with a diet chickpea and pea had 7.3 and 6.4 number of frames covered by bees respectively. Tesfaye (2019) [17] explored the impact of supplementary pollen feeding during a dearth period. Three treatments were administered to bee colonies, namely chickpea (*Cicer arietinum*), mung bean (*Vigna radiata*), and soybean (*Glycine max*). The results led to the conclusion that the maximum frame with bees was counted by soybean 6.66 frames followed by mung bean 5.81 frames and chickpea with 5.75 frames.

3.2 Brood area (cm²)

The data displayed in Table 2 and Fig. reflects the brood area measurements per week across different treatments from November, 2023 to February, 2024. The data in the table revealed that the largest brood area i.e. 1429.30 cm² observed in bee colonies fed with soybean flour + sugar syrup followed by T₃ chickpea flour + sugar syrup with 1377.86 cm² mean brood area and these were at par with each other. The next effective treatment was pea flour + sugar syrup with maximum mean brood area 1247.74 cm² followed by BSF larva powder + sugar syrup 1211.24 cm² were at par with each other. Each of these diets was significant over control recorded 1023.87 cm² mean brood area.

These findings align with Sihag and Gupta (2011) [15] utilized four types of pulses soybean (*Glycine max* L.), mung bean (*Vigna radiata* L.), chickpea (*Cicer arietinum* L.) and pigeon pea (*Cajanus cajan* L.) to formulate artificial diets for feeding honeybee (*Apis mellifera* L.) colonies during periods of forage scarcity. Supplement diet formulation increased in brood area from 325 cm² /colony to 490 cm² /colony. Mahfouz (2016) [16] studied different pollen sources namely defeated soybeans flour, whey protein for the formulation of pollen supplement diets and concluded both the diets of honey bees colonies during winter season proved very effective and increased in brood area 1204 cm² /colony to 1384 cm² /colony from defeated soybeans flour and 1156 cm² /colony to 1356 cm² /colony from whey protein. Tadle (2022) [11] tested three pollen supplements of soybeans, chickpea and pea and the results clearly demonstrated that colonies fed soybean diet produced the largest sealed brood area averaging 300.66±15.14 cm² per colony, followed by the chickpea and pea diets with average sealed brood areas of 266.93±12.63 cm² and 243.63±10.69 cm² per colony, respectively. Tesfaye (2019) [17] explored the impact of supplementary pollen feeding during a dearth period. Three treatments were administered to bee colonies, namely chickpea (*Cicer arietinum*), mung bean (*Vigna radiata*) and soybean (*Glycine max*). The results led to the conclusion that the maximum mean of brood area on frame was recorded by soybean 740 cm² followed by chickpea with 600 cm².

3.3 Honey yield

The Table 1 and Fig. provides data on honey yield resulting from different dietary treatments given to bee colonies from

the fourth week of November, 2023 to the second week of February, 2024. The highest honey yield was observed in diet soybean flour + sugar syrup with 2.46 kg/hive. The next superior diet chickpea flour + sugar syrup with 2.07 kg/hive. The next effective with 1.67 kg/hive pea flour + sugar syrup and BSF larva powder + sugar syrup with 1.33 kg/hive. The control colony produced the lowest honey yield of 0.97 kg/hive. Tesfaye (2019) [17] explored the impact of supplementary pollen feeding during a dearth period. Three treatments were administered to bee colonies, namely

chickpea (*Cicer arietinum*), mung bean (*Vigna radiata*) and soybean (*Glycine max*). The results led to the conclusion that soybean flour supplementation resulted in enhanced honey area 2096 cm² followed by mung bean with honey store 2058 cm² and chickpea with 1408 cm². Tadde (2022) [11] tested three pollen supplements of soybeans, chickpea and pea and demonstrated that colonies given a soybean diet achieved the highest honey yield averaging 11.5 kg per colony with chickpea and pea diets following at 8.4 kg and 6.9 kg per colony, respectively.

Table 1: Impact of feeding supplementary diets on the strength of *Apis mellifera* colonies from November, 2023 to February, 2024

Treatment	Treatment Details		No. of frames cover by bees per week											Mean
		November, 2023	December, 2023				January, 2024					February, 2024		
		IV Week	I Week	II Week	III Week	IV Week	I Week	II Week	III Week	IV Week	V Week	I Week	II Week	
T ₁	Soybean flour + sugar syrup (200 g)	5.00	5.26 (2.40)*	5.67 (2.48)	6.07 (2.56)	6.26 (2.60)	6.51 (2.65)	7.12 (2.76)	7.89 (2.89)	7.12 (2.76)	7.90 (2.90)	8.39 (2.98)	8.36 (2.98)	6.80 (2.70)
T ₂	Pea flour + sugar syrup (200 g)	5.00	5.09 (2.36)	4.96 (2.34)	5.52 (2.46)	5.67 (2.48)	6.02 (2.55)	6.21 (2.59)	6.63 (2.67)	6.21 (2.59)	7.39 (2.81)	7.16 (2.77)	7.51 (2.83)	6.12 (2.57)
T ₃	Chickpea flour + sugar syrup (200 g)	5.00	4.97 (2.34)	5.37 (2.42)	5.89 (2.53)	6.13 (2.58)	6.45 (2.64)	6.75 (2.69)	7.63 (2.85)	6.75 (2.69)	7.63 (2.85)	7.89 (2.89)	8.26 (2.96)	6.56 (2.65)
T ₄	BSF larve powder + sugar syrup (200 g)	5.00	4.80 (2.30)	4.75 (2.28)	4.79 (2.30)	4.14 (2.15)	4.75 (2.29)	5.00 (2.34)	5.14 (2.37)	5.01 (2.34)	5.50 (2.45)	5.60 (2.47)	5.90 (2.53)	5.04 (2.35)
T ₅	Control	5.00	4.79 (2.30)	5.35 (2.42)	4.80 (2.30)	4.25 (2.18)	4.16 (2.16)	4.04 (2.13)	4.14 (2.15)	4.00 (2.12)	4.37 (2.21)	3.90 (2.10)	3.90 (2.10)	4.40 (2.21)
Sem±		N.S.	0.04	0.04	0.04	0.04	0.04	0.02	0.04	0.04	0.04	0.04	0.04	0.02
CD 5%		N.S.	0.12	0.13	0.14	0.13	0.13	0.08	0.12	0.14	0.12	0.13	0.13	0.07
CV		N.S.	7.25	7.33	7.89	8.04	7.27	7.82	6.78	7.60	6.86	7.45	6.53	3.72

* Figures in parenthesis are $\sqrt{X} + 0.5$ transformation

Table 2: Impact of supplementary diets on the brood area in *Apis mellifera* colony during November, 2023 to February, 2024

Treatment	Treatment details	Brood area per week (cm ²)												Mean
		November, 2023	December, 2023				January, 2024					February, 2024		
		IV week	I Week	II Week	III Week	IV Week	I Week	II Week	III Week	IV Week	V Week	I Week	II Week	
T ₁	Soybean flour + sugar syrup (200 g)	1295.09 (4.11)*	1362.14 (4.13)	1407.38 (4.14)	1434.46 (4.15)	1497.75 (4.17)	1460.74 (4.16)	1431.68 (4.16)	1439.86 (4.16)	1380.09 (4.14)	1436.78 (4.16)	1484.73 (4.17)	1520.90 (4.18)	1429.30 (4.15)
T ₂	Pea flour + sugar syrup (200 g)	1115.50 (4.05)	1268.10 (4.10)	1297.52 (4.11)	1319.20 (4.12)	1267.08 (4.10)	1313.36 (4.12)	1234.84 (4.09)	1243.23 (4.09)	1153.02 (4.06)	1210.94 (4.08)	1244.34 (4.09)	1305.74 (4.11)	1247.74 (4.10)
T ₃	Chickpea flour + sugar syrup (200 g)	1294.42 (4.11)	1340.12 (4.13)	1378.94 (4.14)	1408.45 (4.15)	1453.79 (4.16)	1445.28 (4.16)	1366.58 (4.13)	1351.35 (4.13)	1285.82 (4.11)	1350.28 (4.13)	1391.81 (4.14)	1467.45 (4.17)	1377.86 (4.14)
T ₄	BSF larvae powder + sugar syrup (200 g)	1176.84 (4.07)	1178.78 (4.07)	1227.53 (4.09)	1309.14 (4.11)	1247.95 (4.10)	1293.94 (4.11)	1205.39 (4.08)	1249.43 (4.10)	1192.45 (4.07)	1157.76 (4.06)	1136.55 (4.05)	1159.16 (4.06)	1211.24 (4.08)
T ₅	Control	1193.45 (4.08)	1165.14 (4.07)	1140.76 (4.06)	1120.88 (4.05)	1041.57 (4.02)	1131.93 (4.05)	1001.60 (4.0)	942.26 (3.97)	829.77 (3.92)	872.39 (3.94)	912.08 (3.96)	934.66 (3.97)	1023.87 (4.01)
Sem ±		N.S.	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01
CD 5%		N.S.	0.05	0.06	0.06	0.05	0.05	0.04	0.04	0.05	0.05	0.06	0.06	0.03
CV		N.S.	7.74	8.34	9.58	6.91	6.71	5.76	6.23	6.80	7.80	8.38	8.53	5.23

* Figures in parenthesis are $\log x + 1$ transformation

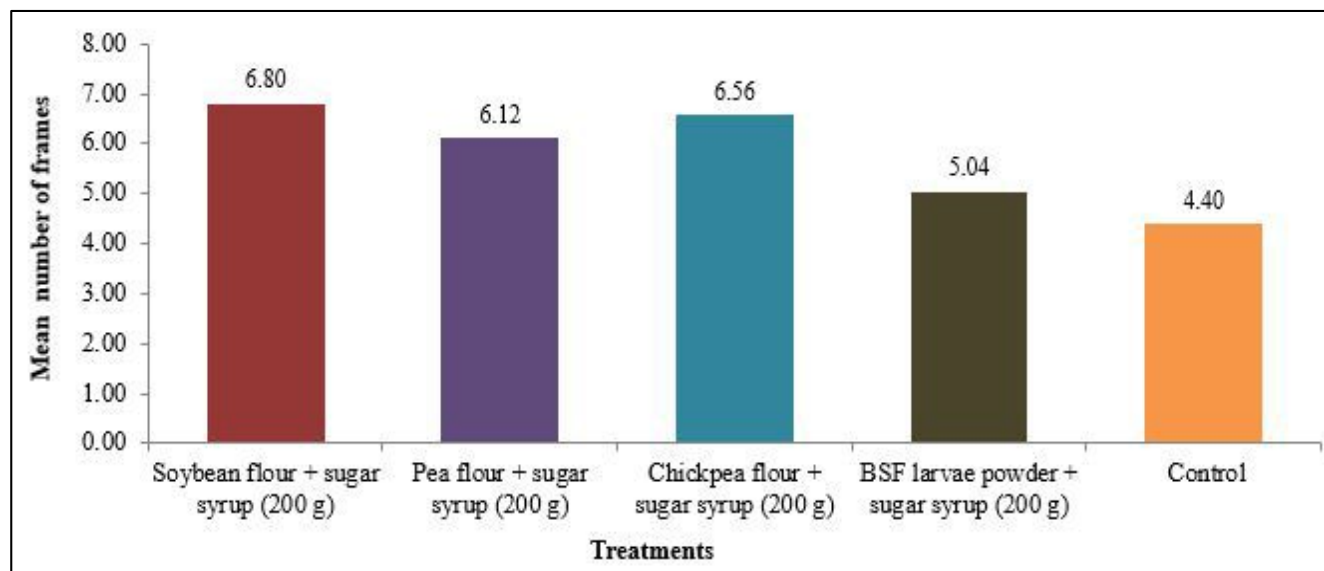


Fig 1: Mean impact of feeding supplementary diets on the strength of *Apis mellifera* colonies from December, 2023 to February, 2024

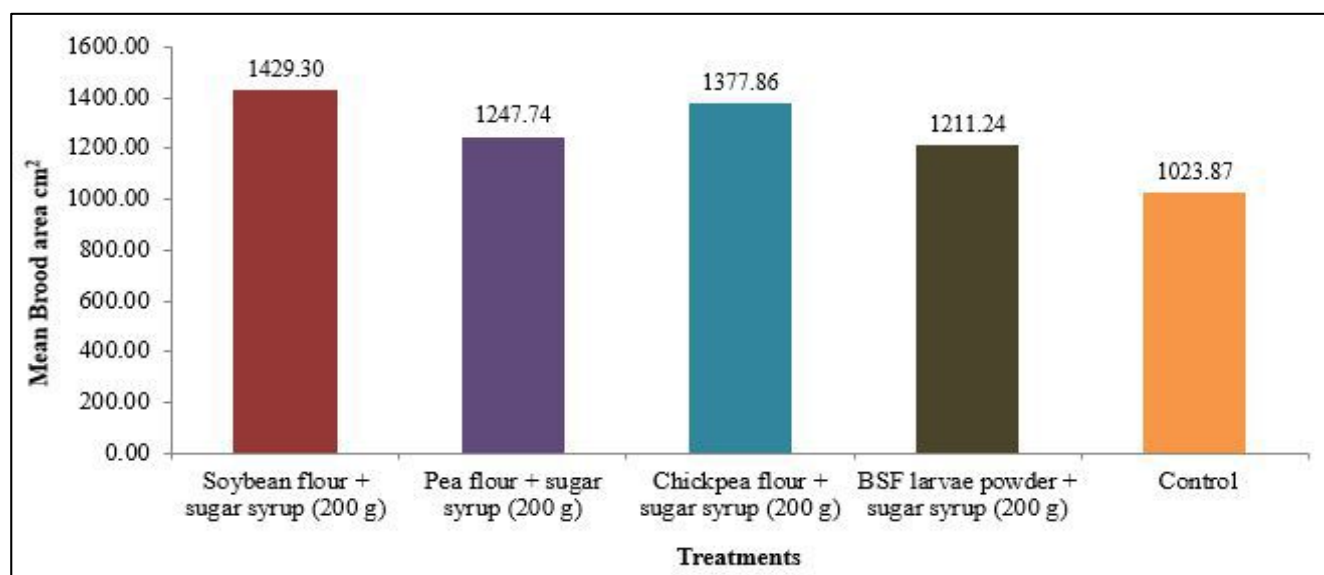


Fig 2: Mean impact of supplementary diets on the brood area in *Apis mellifera* colony during November, 2023 to February, 2024

Table 3: Effect of different supplementary diets on honey yield (kg/hive) during November 2023 to February 2024

Treatment	Treatment detail	Honey yield kg/hive
T ₁	Soybean flour + sugar syrup (200 gram)	2.46
T ₂	Pea flour + sugar syrup (200 gram)	1.67
T ₃	Chickpea flour + sugar syrup (200 gram)	2.07
T ₄	BSF larve powder + sugar syrup (200 gram)	1.33
T ₅	Control	0.97
Sem ±		0.07
CD 5%		0.23
CV		8.75

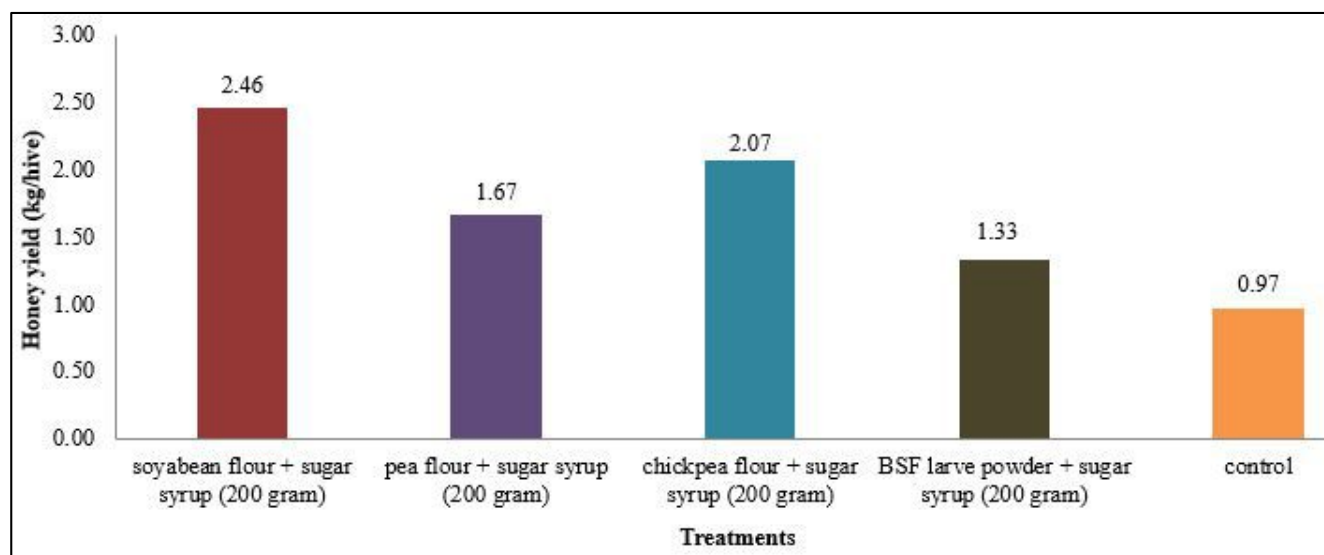


Fig 3: Effect of different supplementary diets on honey yield (kg/hive) during November, 2023 to February, 2024

4. Conclusion

The study's findings concluded the critical role of supplementary diets in the health and productivity of *Apis mellifera* colonies. Supplementary feeding, particularly with soybean and chickpea flour with sugar syrup, significantly improved colony parameters including Number of frames, brood area and honey yield, especially during periods of natural forage scarcity. The strong preference for these diets highlights their nutritional value in supporting bee colonies. these findings underscore the necessity of strategic supplemental feeding to maintain robust and productive bee colonies which are essential for sustainable agriculture.

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