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THE PRODUCTIVE AND ECONOMIC EFFICIENCY OF BEEKEEPING PROJECTS IN EGYPT

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ABSTRACT

The study aims to evaluate the production efficiency of honeybee-keeping projects in Egypt, to identify the key factors affecting honey production, and to determine both the optimal production level and the cost-minimizing and profit-maximizing levels of output. The sample was collected from Fayoum Governorate and divided into three categories: less than 50 hives, 50–100 hives, and more than 100 hives. The results revealed that the most influential factors affecting honey production varied by category. For the first category, the most significant variables were the cost of bee disease control (EGP) (Xi4) and the beekeeper's experience in years (Xi5), with production elasticities of 0.696 and 0.173, respectively. For the second category, the most influential variables were the quantity of feeding sugar (Xi2), the amount of labor (Xi3), and the beekeeper's experience (Xi5), with production elasticities of 0.438, 0.250, and 0.234, respectively. In the third category, the number of hives (Xi1), the amount of labor (Xi3), and the cost of disease control (Xi4) were the main determinants of honey production, with corresponding production elasticities of 0.188, 0.288, and 0.947. Moreover, the findings indicated that the second category achieved superior economic efficiency indicators among all groups. The average honey yield per hive was 11.36, 11.62, and 10.23 kilograms for the first, second, and third categories, respectively. The unit cost reached approximately 68.28, 59.43, and 64.14 EGP/kg for the three categories, while the return per invested pound was about 0.83, 1.08, and 0.95 EGP, respectively.

KEYWORDS: Honeybee Keeping, Production Functions, Cost Functions, Economic Efficiency Indicators.

1. INTRODUCTION

Beekeeping is one of the oldest agricultural and economic activities. It is considered a relatively simple agricultural enterprise whose skills can be easily acquired alongside other farming operations. Beekeeping can also be integrated with various agricultural or non-agricultural activities, making it an important source of income for both farmers and non-farmers. Moreover, it serves as one of the means of increasing farmers' income (Temesgen & Desalegn, 2022). It is also classified among small rural projects characterized by low capital requirements, a rapid turnover of capital, and simple production techniques and tools, which help reduce potential risks and losses in case the project encounters difficulties (Jones et al., 2020). Therefore, it is particularly suitable for young graduates at the beginning of their professional careers (FAO, 2018).

Honey is a vital and beneficial food for humans, known for its high nutritional value due to its richness in essential vitamins such as A, B1, and B6. It also contains glucose, fructose, enzymes, minerals, organic and amino acids, and proteins (Bogdanov et al., 2008). Hence, honey represents a key source of energy, along with other valuable bee products such as royal jelly, which is highly nutritious and energy-dense, and beeswax, which is used in certain medical and cosmetic industries. Additionally, bee venom is employed in some pharmaceutical applications, particularly in the treatment of rheumatic pain (Park et al., 2011).

Egypt enjoys favorable conditions for beekeeping due to its moderate climate and the abundance of successive flowering crops that support continuous honeybee activity. This environment facilitates beekeeping with less effort compared to many other regions, such as Europe, which imports most of its honey requirements. Consequently, Egypt's beekeepers have greater potential to increase production and export volumes. During the period 2019–2023, Egypt's honey production reached approximately 4.9 thousand tons, with exports of about 2.52 thousand tons, representing 56.02% of total production and valued at nearly 7.26 million USD (Central Agency for Public Mobilization and Statistics, 2022). Overall, beekeeping can significantly contribute to agricultural output and, consequently, to national income. It also creates diverse employment opportunities, from the production of wooden hives to the marketing of various bee products (Shaker, 2021).

1.1. Research Problem

Despite the noticeable decline in the number of honeybee colonies and the relative decrease in domestic honey production, recent data indicate an upward trend in Egyptian honey exports over the past few years. This paradox between declining production and rising exports raises important questions about the production and economic efficiency of beekeeping projects in Egypt, the extent to which available resources are utilized, and the sector's capacity to remain a stable source of income and exports. The research problem, therefore, lies in the lack of quantitative analytical studies that assess the actual economic performance of these projects amid market fluctuations and the structural challenges facing the agricultural sector.

1.2. Research Objectives

This study aims to evaluate the production and economic efficiency of honeybee-keeping projects in Egypt through the following specific objectives

1. To identify the current production status of honey in Egypt.
2. To analyze the factors influencing production volume using field data collected from a representative sample of producers through the estimation of the production function.
3. To estimate cost functions and determine the optimal production scale for different categories of producers.
4. To examine selected measures of production and economic efficiency among the sampled producers in order to classify them according to their levels of economic efficiency.
5. To identify the key production challenges facing honey producers and propose practical recommendations to enhance resource utilization and maximize returns within the framework of sustainable agricultural development.

2. METHODOLOGY

The study employed both descriptive and quantitative analytical methods to achieve its objectives. A set of statistical techniques was applied, including simple linear regression and stepwise regression, using both linear and double-log functional forms to determine the model that best fits the economic and statistical logic. The research relied on both secondary and primary data. Secondary data were obtained from published and unpublished sources issued by the Ministry of Agriculture and Land Reclamation and the Central Agency for Public Mobilization and Statistics (CAPMAS). Primary data were collected through a field survey conducted among honey producers in Fayoum Governorate.

2.1. Study Sample

Fayoum Governorate is considered one of the major honey-producing regions in Egypt due to its suitable desert hinterland, which supports the expansion of beekeeping projects. A stratified random sample was selected from the governorate. Two villages, Beni Saleh and Seila, were chosen from Fayoum District; together they contain 165 apiaries, representing approximately 32.87% of the total number of apiaries in the governorate. Additionally, two villages, El-Minya and Tatoun, were selected from Itsa District; they include 95 apiaries, representing about 18.92% of the total 502 apiaries in the governorate.

A random sample of 71 apiaries was ultimately selected and distributed as follows:

- Category I (less than 50 hives): 33 apiaries.
- Category II (50–100 hives): 23 apiaries.
- Category III (more than 100 hives): 15 apiaries.

3. LITERATURE REVIEW

Ferenczi et al. (2024) conducted a survey of 632 Hungarian beekeepers and found that income generation was the main objective for most producers. The study revealed that the major challenges facing beekeepers include Varroa mites, pesticide poisoning, Nosema infection, inadequate nutrient availability, and market-related problems. Consequently, the authors recommended highlighting both the biological and economic constraints affecting honey production.

Mohamed Refaat (2024), in his study entitled "Competitiveness of Egyptian Honey Exports," identified several reasons why honey production and export represent a promising sector:

1. Rising global demand: There is an increasing global demand for honeybee products, including honey, live Egyptian bee colonies, pollen, royal jelly, and beeswax. Consumers have become more aware of the nutritional and health benefits of these products. Egypt currently enjoys strong demand for its live bees due to their adaptability to diverse climatic conditions, making Egypt the leading global exporter of live bees with a market share exceeding 25% of total world exports.
2. Favorable climatic conditions: Egypt's climate supports continuous honeybee reproduction and year-round nectar availability.
3. Agricultural pollination: Honeybees contribute to the pollination of crops, accounting for about 35% of global food production.
4. Employment generation: Beekeeping projects provide stable year-round employment opportunities.

Ahlam Hassan and Dalia El-Batran (2023) examined the economics of honeybee-keeping projects and found that, despite their multiple benefits, such ventures have received limited advisory and economic attention from investors and policymakers. The study aimed to enhance the economic efficiency of existing agricultural investment projects in Qalyubia Governorate through financial and economic evaluation, including sensitivity analysis under specific assumptions to achieve the highest possible efficiency. The results indicated that, at a 15% discount rate, the project generated a positive net present value (NPV) of approximately 140,541 EGP per year. Moreover, the ratio of discounted cash inflows to discounted costs exceeded one, with a discounted profitability index of 1.44. This implies that each invested pound yielded a profit of about 0.44 EGP, surpassing the opportunity cost of capital.

Saeed (2023) investigated the causes of rising production costs and estimated the actual production expenses to assess project profitability using both financial and performance evaluations. The results of the multiple-log model showed that the key factors positively affecting honey production were the number of hives (x1), the surrounding cultivated area (x2), the quantity of feeding sugar (x3), and the value of biological control (x4). The production elasticities for these variables were 12.1, 241.2, 242.2, and 20.2, respectively, indicating potential for future production growth.

Iman Hassan and Zeinab Mahgoub (2022) sought to examine the current status of honey production variables, economic benefit indicators, cost-minimizing and optimal production levels, and the key problems facing honey producers. The results revealed that the most influential production factors were the number of hives, the amount of feeding sugar, years of experience, and the number of seasonal transfers. The cost-minimizing production level was estimated at 18.29 kg per hive annually. The study also found that the most critical issues confronting producers were disease prevalence and palm wasp infestations, representing about 29.17% of the identified challenges. While Temesgen and Desalegn (2022) demonstrated that inefficient agricultural marketing systems and traditional production methods prevent beekeepers from realizing the full potential of their honey supplies.

Uysal (2021) analyzed the factors influencing honey production in Mersin Province, Turkey, through a cost and profitability assessment of 81

apiaries. The results underscored the importance of variable costs and marketing efficiency, particularly in small-scale operations, identifying three main determinants of honey output.

The CREA PB Honey Cost Project established a comprehensive methodology for data collection and evaluation of the beekeeping sector through a survey of 434 apiaries. Costs were calculated at three levels: operating expenses, overheads, and family labor costs. The findings indicated that packaging and marketing represented the largest variable costs, with an average total production cost of about €9 per kilogram, often exceeding market prices.

Mohamed El-Zeer (2019) examined the economic and social effects of small projects in Dakahlia Governorate during 2016–2017, focusing on investment and operational costs in honey production ventures. The results showed that the most significant positive factors influencing honey yield were the number of hives (x1) and the surrounding cultivated area (x2), with marginal productivities of 1.19 and 7.57, respectively, highlighting their importance in increasing total output. Conversely, the quantity of feeding sugar (x3) and the amount of medicine used (x4) had negative effects, with marginal productivities of –0.012 and –31.46, respectively, indicating overuse of these inputs.

Bett (2017) analyzed the main factors affecting honey quality in East Trans Nzoia, Kenya, using a sample of 90 beekeepers. The study identified hive management, environmental conditions, and beekeeper training as key determinants of honey quality and emphasized the need for targeted training and modern equipment to improve production standards and market competitiveness.

Tosun (2021) evaluated the economic and social performance of 94 beekeeping projects supported by the Agricultural and Rural Development Program in Van, Turkey, using stratified samples. The findings showed an average net profit of USD 20,684, with a production cost of USD 4.16 per kilogram of honey and a return of USD 1.82 for each dollar spent.

4. RESULTS and DISCUSSION

4.1. First: Current Production, Consumption, and Export Status of Honey in Egypt

1. **Time Trend of Honeybee Colonies in Egypt**
   Table (1) indicates that the number of honeybee colonies in Egypt showed a declining trend during the period 2010–2023, with an overall decrease estimated at about 27.9 thousand hives. As presented in Table (2), the annual rate of decline was approximately 3.1% of the average number of colonies during the study period, which amounted to about 886.8 thousand hives. The coefficient of determination (R^2) reached 0.87, meaning that 87% of the variation in the number of colonies could be explained by the time factor, while the coefficient of variation was estimated at 14.1%.

Table 1: Produced, Consumed, and Exported Quantities of Honey and Its Products in Egypt during (2010–2023).

Year	Number of Bee Hives (Thousands)	Honey Production (tons)	Honey Consumption (tons)	Beeswax Production (tons)	Honey Exports (tons)	Live Bee Exports (tons)
2010	1138.53	6029	7340	160.1	675	374
2011	1075.52	5680.2	5000	150.8	655	391
2012	983.04	5065.9	5000	131.2	1182	587
2013	965.26	5405.3	4000	140.9	1159	1082
2014	929.63	5443.3	3000	114.9	1202	2264
2015	879.98	4942.6	5000	94	1534	2151
2016	837.44	4375.9	4000	90	1487	2964
2017	828.94	4196.3	3000	105	1770	2513
2018	934.52	5491.2	4000	101	1207	2731
2019	819.56	4495.04	2000	107	1725	2617
2020	788.01	4566.83	4000	129	2471	2808
2021	793.71	4358.44	4000	119	3080	2764
2022	729.19	4439.84	3253	100	2315	1629
2023	711.5	4603.5	4538	65	2681	2970
Average	886.8	4935.2	4152.2	114.9	1653	1988.9
Standard Deviation	124.9	583.9	1261.2	25.7	738	983.9
Coefficient of Variation (%)	14.6%	11.8%	30.4%	22.4%	44.6%	49.5%

Source: Ministry of Agriculture – Agricultural Economics Bulletins – Various Issues. Central Agency for Public Mobilization and Statistics (CAPMAS) – Foreign Trade Bulletins – Various Issues.

2. **Time Trend of Honey and Beeswax Production in Egypt** As a result of the reduction in the number of honeybee colonies, the total honey output in Egypt has also declined. Table (1) shows that honey production followed a decreasing trend of about 104.8 tons, representing approximately 2.1% of the average production volume during 2010–2023, which amounted to around 4,935.2 tons. The coefficient of determination (R^2) was approximately 0.56, and the coefficient of variation reached 11.8%.

Similarly, beeswax production exhibited a downward trend estimated at about 4.38 tons, equivalent to roughly 3.8% of the average beeswax production during the same period, which was around 114.9 tons. The R^2 value was about 0.51, with a variation rate of approximately 22.4%.

Table 2: General Time Trend Equations for Production, Consumption, and Export Quantities of Honey and Its Products in Egypt (2010–2023).

Variable	Equation	F-value	R^2	Annual Relative Change (%)
Number of Bee Hives	$\hat{Y} = 1096.3 - 27.93 \times$ (41.9)** (–9.7)**	82.9	0.87	–3.1
Honey Production	$\hat{Y} = 5721.37 - 104.8 \times$ (25.2)** (–3.9)**	15.5	0.56	–2.1
Honey Consumption	$\hat{Y} = 5366.1 - 161.9 \times$ (8.6)** (–2.2)*	4.9	0.29	–3.9
Beeswax Production	$\hat{Y} = 147.9 - 4.48 \times$ (13.9)** (–3.3)*	12.3	0.51	–3.8
Honey Exports	$\hat{Y} = 457.6 + 159.4 \times$ (2.5)* (7.3)**	53.3	0.81	9.6
Live Bee Exports	$\hat{Y} = 635.7 + 180.4 \times$ (1.75)- (4.1)**	17.2	0.59	9.1

Source: Calculated based on data from Table (2).

3. **Time Trend of Honey and Live Bee Exports in Egypt** Table (1) reveals that the quantity of exported honey followed an upward trend, increasing by approximately 159.4 tons, which represents about 9.6% of the average exported volume (1,653 tons) during the period 2010–2023. The coefficient of determination (R^2) was estimated at 0.81, while the coefficient of variation reached approximately 44.6%.

Similarly, the quantity of exported live bees showed an increasing trend of about 180.4 tons, representing roughly 9.1% of the average export volume of 1,988.9 tons during the same period. The coefficient of determination (R^2) was about 0.59, and the coefficient of variation was estimated at 49.5%.

4.2. Second: Estimation of Honey Production Functions for the Sample in Fayoum Governorate

The relationships among variables were first examined using a correlation matrix to ensure the absence of multicollinearity problems. The production function was then estimated using several econometric models, including both the linear and double-log functional forms, applying multiple regression and stepwise regression techniques to identify the most influential variables affecting honey production.

The results indicated that the double-log functional form provided the best fit from both economic and statistical perspectives.

The production factors included the following variables:

($\hat{Y}_i$): the quantity of the production (Kg).

(X_{i1}): the number of hives in the apiary (hive).

(X_{i2}): the quantity of sugar solution feeding (Kg).

(X_{i3}): the quantity of labor (man/day).

(X_{i4}): the value of combating bee diseases (pounds).

(X_{i5}): the number of years of experience for the beekeeper.

1. **Honey Production Function for Category I (Fewer than 50 Hives)**

Table (3) shows that the most influential factors affecting honey production in this category are the cost of bee disease control (EGP) (Xi4) and the beekeeper's experience in years (Xi5). The estimated production elasticities for these variables were approximately 0.696 and 0.173, respectively. Both variables exhibited a positive relationship with production, indicating that a 1% increase in either factor would lead to an increase in output by about 0.696% and 0.173%, respectively.

The total elasticity was 0.869, suggesting that producers in this category operate within the rational (economic) stage of production. The coefficient of determination (R^2) was 0.94, meaning that 94% of the variations in honey production are explained by these factors, which confirms their significance.

2. **Honey Production Function for Category II (50–100 Hives)**

According to Equation (2) in Table (3), the double-log functional form provided the best fit from both economic and statistical perspectives for this group. The key factors influencing honey production were the amount of feeding sugar (Xi2), labor quantity (Xi3), and beekeeper's experience (Xi5), with production elasticities of 0.438, 0.250, and 0.234, respectively.

The relationships between these factors and production were positive, indicating that a 1% increase in each of these variables would result in an increase in honey output of approximately 0.438%, 0.250%, and 0.234%, respectively. The total elasticity was estimated at 0.922, confirming that producers in this category operate within the economic stage of production. The R^2 value was 0.82, implying that 82% of the variation in honey production could be attributed to these variables, emphasizing their importance.

3. **Honey Production Function for Category III (More than 100 Hives)**

Equation (3) in Table (3) indicates that the number of hives (Xi1), labor quantity (Xi3), and cost of bee disease control (Xi4) were the most influential variables affecting honey production in this category. Their respective production elasticities were 0.188, 0.288, and 0.947.

All variables had a positive relationship with production, meaning that a 1% increase in these factors would lead to increases in honey output by 0.188%, 0.288%, and 0.947%, respectively. The total elasticity was 1.43, suggesting that producers in this group operate beyond the economic stage of production. The coefficient of determination (R^2) was 0.95, confirming that 95% of the variation in production is explained by these variables.

4. **Honey Production Function for the Total Sample**

Equation (4) in Table (3) summarizes the results for the total sample, showing that the quantity of feeding sugar (Xi2), labor quantity (Xi3), and beekeeper's experience (Xi5) were the main factors influencing honey production. Their respective production elasticities were 0.23, 0.34, and 0.35. Each of these variables showed a direct positive relationship with production, indicating that a 1% increase in these factors would raise output by approximately 0.23%, 0.34%, and 0.35%, respectively. The total elasticity was 0.92, implying that the producers, overall, operate within the rational (economic) stage of production.

4.3. Third: Cost Functions of Honey Production in the Study Sample

The cost function refers to the relationship between two variables: the dependent variable, which is production costs, and the independent variable, which is the quantity of honey produced. Several attempts were made to estimate the cost functions of the studied apiaries using both the quadratic and cubic forms. Some economic derivatives, such as average and marginal costs, were also calculated. In addition, both the cost-minimizing production level and the profit-maximizing production level were determined.

1. **The Relative Importance of Fixed Cost Items in Honey Production Projects**

The costs of honey production can be classified into fixed and variable costs, with differences according to scale.

Fixed costs: These costs remain relatively constant regardless of the level of production.

Table 4 shows the relative importance of fixed cost items for the study sample categories. For the first category (fewer than 50 hives), the total annual fixed costs amounted to about 5,233 EGP per year. The cost of hives ranked first, representing 66.5% of fixed costs, followed by the honey extractor (15.29%), rent (3.82%), frames (3.33%), scale and windbreaks (2.87%), beekeeper suit (2.29%), queen cages (1.26%), smoker (0.67%), feeders (0.50%), wasp traps (0.46%), and finally, royal jelly containers, which accounted for about 0.15% of total fixed costs.

For the second category (50–100 hives), the annual fixed costs were about 11,446 EGP per year. The cost of hives ranked first at about 80.73%, followed by the honey extractor (6.64%), frames (3.83%), rent (1.75%), scale and windbreaks (1.31%), beekeeper suit (1.05%), feeders (0.65%), royal jelly containers (0.28%), and smoker and wasp traps together representing 0.26% of total fixed costs.

Finally, for the third category (more than 100 hives), the annual fixed costs amounted to about 18,923 EGP per year.

The cost of hives ranked first at about 85.61%, followed by the honey extractor (3.96%), frames (3.42%), queen cages (2.22%), rent (1.06%), windbreaks (0.95%), scale (0.79%), feeders (0.71%), beekeeper suit (0.63%), wasp traps (0.21%), and finally, the smoker, which represented about 0.16% of total fixed costs.

Table 3: Honey Production Functions for Different Producer Categories in the Fayoum Governorate Sample, 2024

Category	Production Function (log-linear form)	F-value	R^2
First Category	$\log \hat{Y}_i = 0.267 + 0.696 \log X_{4i} + 0.173 \log X_{5i}$ (0.46) (7.2) ** (3.1)**	142.9	0.94
Second Category	$\log \hat{Y}_i = 0.666 + 0.438 \log X_{2i} + 0.250 \log X_{3i} + 0.234 \log X_{5i}$ (1.4) (2.1) * (4.3) ** (2.9)**	97.5	0.82
Third Category	$\log \hat{Y}_i = 3.9 + 0.188 \log X_{1i} + 0.288 \log X_{3i} + 0.947 \log X_{4i}$ (4.3) ** (2.6) ** (2.8) ** (6)**	121.8	0.95
Total Sample	$\log \hat{Y}_i = 2.8 + 0.23 \log X_{1i} + 0.34 \log X_{3i} + 0.35 \log X_{5i}$ (2.9)** (2.1)* (2.8) ** (2.6)**	68.3	0.92

*Significant at 5% level ($p < 0.05$) ** Significant at 1% level ($p < 0.01$)

Table 4: The Relative Importance of Fixed Cost Items for a Honey Project.

Items	First Category			Second Category			Third Category		
	Less than 50 beehive		% of T.C	(50-100) beehive		% of T.C	more than 50 beehive		% of T.C
	quantity	value	%	quantity	value	%	quantity	value	%
Hives	29	17400	66.50	74	46200	80.73	135	81000	85.61
Hive tools(Frames)	58	870	3.33	148	2200	3.84	270	3240	3.42
Honey Extractors	1	4000	15.29	1	3800	6.64	1	3750	3.96
Feeders	29	130	0.50	74	370	0.65	135	675	0.71
Smokers	1	175	0.67	1	150	0.26	1	150	0.16
Wasp Traps	2	120	0.46	3	150	0.26	4	200	0.21
Queen House	29	330	1.26	74	1100	1.92	140	2100	2.22
royal jelly containers	1	40	0.15	8	160	0.28	15	250	0.26
Bee Suits	1	600	2.29	1	600	1.05	1	600	0.63
Weighing Scales	1	750	2.87	1	750	1.31	1	750	0.79
Windbreakers		750	2.87		750	1.31		900	0.95
Total		25165	96.18		56230	98.25		93615	98.94
Rent		1000	3.82		1000	1.75		1000	1.06
Total fixed cost		26165	100		57230	100		94615	100.00
Fixed Costs per year		5233			11446			18923	

Source: Field Data 2024

4.4. The Relative Importance of Variable Cost Items in Honey Production

Variable costs represent the expenses that change in proportion to the level of production.

Table 5 presents the variable cost items for honey production. For the first category (fewer than 50 hives), the total variable costs amounted to about 17,265 EGP. The relative importance of these items shows that labor costs ranked first, accounting for about 40.54%, followed by sugar costs (21.03%), jar costs (10.14%), candy feed (9.85%), foundation wax (8.69%), medicine (2.99%), burlap covers (2.51%), transportation (1.79%), repairs (1.49%), gloves (0.7%), scraping knife (0.32%), and finally the cleaning brush (0.24%) of the total variable costs. For the second category (50–100 hives), the total variable costs amounted to about 39,660 EGP. Sugar costs ranked first, representing about 37.82%, followed by labor costs (22.69%), jars (12.61%), candy feed (12.1%), foundation wax (8.32%), burlap covers (2.06%), transportation (1.8%), medicine (1.54%), repairs (0.64%), gloves (0.3%), scraping knife (0.13%), and cleaning brush (0.1%) of the total variable costs.

For the third category (more than 100 hives), the results indicate that sugar costs ranked first, accounting for 46.11% of the total variable costs, followed by candy feed (16.07%), labor (14.35%), jars (10.05%), foundation wax (7.75%), transportation (1.65%), protective equipment (1.1%), repairs (0.69%), gloves (0.17%), cleaning brush (0.11%), and scraping knife (0.07%). The total variable costs for this category amounted to about 69,680 EGP.

4.5. Cost Functions of Honey Production in the Study Sample

The cost function refers to the relationship between two variables: the dependent variable, which is production costs, and the independent variable, which is the quantity of honey produced.

Table 5: The Relative Importance of Variable Cost Items for Honey Production.

Items	First Category			Second Category			Third Category		
	Less than 50 beehive		% OF V.C	(50-100) beehive		% of V.C	more than 50 beehive		% of V.C
	quantity	value	%	quantity	value	%	quantity	value	%
Sugar cost	110	3630	21.03	500	15000	37.82	1170	32130	46.11
Honeycomb cost	5	1500	8.69	11	3300	8.32	18	5400	7.75
Canady food	20	1700	9.85	60	4800	12.10	140	11200	16.07
Labor	70	7000	40.54	90	9000	22.69	100	10000	14.35
Jar-tin cost	350	1750	10.14	1000	5000	12.61	1400	7000	10.05
Gloves	1	120	0.70	1	120	0.30	1	120	0.17
Scraping knife	1	55	0.32	1	50	0.13	2	50	0.07
Cleaning brush	1	40	0.24	1	40	0.10	2	80	0.11
Burlap covers	30	420	2.51	77	800	2.06	140	1400	1.93
Drug cost		500	2.99		600	1.54		800	1.10
transportation		300	1.79		700	1.80		1000	1.65
Repair and maintenance cost		250	1.49		250	0.64		500	0.69
Total variable costs		17265	100		39660	100		69680	100
Total Cost		22498			51106			88603	

Source: Collected and calculated from the questionnaire data in Fayoum governorate 2024.

The method for deriving the average cost and marginal cost from the cost equation of the apiaries in the study sample in Fayoum Governorate can be expressed as follows:

$$TC = a + b_1 X + b_2 X^2$$

$$AC = \frac{a}{x} + b_1 + b_2 X$$

$$MC = b_1 + 2 b_2 X$$

Whereas TC= Total cost of onions per pound / feddan

X = Feddan yield kg / feddan

AC= average costs per pound / feddan

MC= Marginal costs per pound / feddan

1. Cost Function for the First Category of Apiaries in the Study Sample By examining the relationship between production costs and the quantity of honey produced for the first category (fewer than 50 hives), using both quadratic and cubic forms to select the best from an economic and statistical standpoint, it is evident from the first equation in Table 6 that the quadratic form is the most appropriate for representing the relationship between total costs and honey output. The equation indicates a statistically significant positive relationship between the two variables. The value of the coefficient of determination (R^2) was approximately 0.67, suggesting that about 67% of the variation in total costs is explained by changes in production.

To determine the cost-minimizing production level, average cost was set equal to marginal cost, which yielded an optimal production level of approximately 331.7 kilograms. The average honey yield for this category was 343.5 kilograms, and results showed that 80% of the producers achieved this level. To identify the profit-maximizing output, marginal cost was equated to the market price, estimated at 125 EGP per kilogram, resulting in a profit-maximizing production level of about 362.32 kilograms. Approximately 62% of the producers reached this level.

This indicates that producers in the first category still have room to increase production and maximize profits through vertical expansion in honey production. The cost elasticity was estimated at 1.13, which indicates that production is within the economic stage, meaning that productivity can increase by about 10% with an 11.3% increase in costs under the current production conditions.

2. Cost Function for the Second Category of Apiaries in the Study Sample The second equation in Table 6 shows the relationship between total costs and the quantity of honey produced (in kilograms). The results indicated that the quadratic form provided the best representation of the relationship.The equation revealed a statistically significant positive relationship between total production costs and honey output. The coefficient of determination (R^2) was 0.59, indicating that about 59% of the variations in total costs are due to changes in production.

The cost-minimizing production level was estimated at approximately 882.96 kilograms, while the average honey production in this category was about 860 kilograms. The results showed that 76% of producers in this category achieved this level. The profit-maximizing production level was estimated at

about 1,122.86 kilograms; however, no producers in this category reached this output level. This suggests that producers in the second category still have the potential to increase production to maximize profits through expanded honey production. The cost elasticity was approximately 1.06, indicating that production remains within the economic stage, where productivity can increase by about 10% with a 10.6% increase in costs at the current production level.

3. Cost Function for the Third Category of Apiaries in the Study Sample The third equation in Table (6) shows the relationship between total costs and the quantity of honey produced (in kilograms) for the third category in the study sample. The results indicated that the quadratic form was the best representation of the relationship. The equation revealed a statistically significant positive relationship between total production costs and honey output. The coefficient of determination (R^2) was 0.53, indicating that about 53% of the variation in total costs is due to changes in production.

The cost-minimizing production level was estimated at approximately 1,366.78 kilograms, while the average honey production in this category was about 1,381.5 kilograms. The results showed that 83% of producers in this group achieved this level. The profit-maximizing production level was estimated at about 1,903.3 kilograms, which no producer reached. This suggests that producers in the third category still have the potential to increase production to maximize profits through expanding honey production. The cost elasticity was about 0.81, indicating that production is in the uneconomic stage, meaning that productivity can increase by 10% with an 8.1% increase in costs at the current production level.

4. Cost Function for the Total Sample of Apiaries

The fourth equation in Table (6) shows the relationship between total costs and the quantity of honey produced (in kilograms) for the total study sample. The results indicated that the quadratic form provided the best fit. The equation revealed a statistically significant positive relationship between total production costs and honey output.

The coefficient of determination (R^2) was 0.65, meaning that about 65% of the variation in total costs is explained by production changes.

The cost-minimizing production level was estimated at about 897.68 kilograms, while the average production for the total sample was about 861.67 kilograms. The results showed that 76% of the producers achieved this level.

Table 6: Cost Functions for Honey Bee Hives in the Study Sample in Fayoum Governorate.

Category	Equation	R^2	F	Cost elasticity
First category	TC i = -188324+1359.9 X i -1.7 X i ^{2} (4.1)** (3.2)** (2.2)* AC = - 188324.9X^{-1}+1356..9 +1.7 X MC =1356.9 – 3.4X	0.67	15.4	1.13
Second category	TC i =-155144.7+571.9 X i -0.199 X i ^{2} (5.1)** (3.8)** (2.4)* AC = -155144.7. X^{-1}+ 571.9 -0. 199 X MC = 571.9 - 0.398X	0.59	8.4	1.06
Third category	TC i = 254061 –392.7 X i +0.136 X i ^{2} (3.6)** (3.2)** (2.2)* AC = 254061X^{-1}-392.7 + 0.136X MC = -392.7. + 0.272 X	0.76	28.8	0.81
Total sample	TC i = 32233–39.4 X i +0.04 X i ^{2} (4.1)** (3)** (2.7)** AC = - 39.4 + 0.04 X + 32233X^{-1} MC = - 39.4 + 0.08X	0.65	19.5	0.95

Where:
Tc_i= Total cost of honey production
X_{i1} = the quantity of honey production estimated per kg
AC= average costs per poundn
MC= Marginal costs per pound
i= 1, 2, 3, number of farmers in the area.
** Significant at the level of 0.01 * significant at the level of 0.05

Source: Collected and calculated from the questionnaire data 2024.

The profit-maximizing production level was about 1,992.5 kilograms, which no producer attained. This indicates that producers in the sample still have the opportunity to expand production to maximize profits. The cost elasticity was approximately 0.88, showing that production is in the uneconomic stage, meaning that productivity can increase by 10% with an 8.8% increase in costs under the current

production level.

Fourth: Measures of Productive and Economic Efficiency for the Apiaries in the Study Sample

There are many indicators of productive and economic efficiency used to assess the performance and profitability of the apiaries. This study relied on the most important of these indicators, which include the following:

1. **Efficiency Measure of Input Use (Average Honey Yield per Hive)**

The productivity of the honeybee hive represents the final outcome of the technical and technological recommendations within the framework of agricultural policy. Table 7 shows that the average honey yield per hive reached 11.36 kilograms for the first category, 11.62 kilograms for the second category, and 10.23 kilograms for the third category, indicating a relatively high level of honey productivity in Fayoum Governorate.

Table 7: Economic Efficiency Indicators for Honey Production Beehive Categories as Studied in Fayoum Governorate in 2024.

Item	First category	second category	Third category
Average of hives number	29	74	135
Average of production	329.5	860	1381.5
Hive productivity (Kg)	11.36	11.62	10.23
Total costs in pounds	22498	51106	88603
Unit cost (pound/kg)	68.28	59.43	64.14
Total revenue (pounds)	41187.5	106250	172687.5
Net profit (pound)	18689.5	55144	84084.5
Invested pound profit	0.83	1.08	0.95

Source: Collected and calculated from the questionnaire data 2024.

2. Unit Cost Measure (Kilogram of Honey/EGP)

Table 7 shows the total production costs of honey for the sample categories, estimated at about 22,498 EGP, 51,060 EGP, and 88,603 EGP for the first, second, and third categories, respectively. The unit cost of production was calculated to be approximately 68.28, 59.43, and 64.14 EGP/kg for the same categories, respectively.

3. Total Revenue Measure

Total revenue represents the monetary value of both the main product (honey) and the by-products (royal jelly, wax, and swarms). As shown in Table (7), total revenue increased (as the sum of the values of all products from the hive), reaching about 41,187.5 EGP for the first category, 106,250 EGP for the second category, and 172,687.5 EGP for the third category.

4. Apiary Profitability Measure (Net Return per Apiary)

The net return of the apiaries depends on the prices of production inputs, the prices of the main and secondary products, and the average productivity of the apiary, as shown in the following equation:

Net Return per Apiary = Total Revenue – Total Costs

Table 7 shows that the net profit for the first category was about 18,689.5 EGP, for the second category about 55,144 EGP, and for the third category about 84,084.5 EGP.

5. Profitability of the Invested Pound

This measure indicates the economic efficiency of the variable production inputs and shows the return generated from the use of variable assets in the production process. The higher the value of this measure, the greater the return relative to costs. According to Table 7, the benefit–cost ratio was high, amounting to about 0.83 EGP for the first category, meaning that each pound invested generated a return of approximately 0.83 EGP. For the second category, it reached about 1.08 EGP, and for the third category, about 0.95 EGP. From the above, it is clear that the production and economic efficiency indicators of honeybee colonies show that the second category (50–100 hives) is the most efficient in both production and economic terms, given that there are no significant price differences among the categories and, therefore, no scale economies.

Fifth: Major Problems Facing Honey Production in the Study Sample

Table (8) indicates that one of the main problems facing honey production in Fayoum Governorate is the high production costs due to the prices of production inputs (feeding sugar, wooden hives, and transportation), reported by 56 producers, representing about 80.28% of the total sample. Around 53 producers, or 74.65% of beekeepers, reported serious bee diseases such as Varroa, Nosema, and wax moth infestations, particularly in the absence of specialized veterinary expertise. In addition, 51 producers (71.83% of the total) stated that adverse environmental conditions especially high temperature and relative humidity—are among

the major challenges facing beekeepers. Furthermore, about 50 beekeepers (70.42% of the sample) indicated that the difficulty in obtaining pure queen bee strains is a major problem they face. Around 40 beekeepers (56.34%) pointed out that the lack of beekeeping experience is one of the key issues affecting honey production. Finally, 38 beekeepers noted the limited marketing outlets for honey and the widespread presence of adulterated honey in the market.

Table (8). The production problems that faced beekeepers.

The problem	frequency	%
The rising production costs	**56**	**80.28**
Infestations and serious diseases	**53**	**74.65**
Environmental conditions	**51**	**71.83**
The difficulty in obtaining pure queen bee strains	**50**	**70.42**
Lack of experience of beekeepers	**40**	**56.38**
Lack of marketing outlets	**38**	**53.5**

Source: Collected and calculated from the questionnaire data 2024.

5. CONCLUSION

Beekeeping is one of the oldest agricultural and economic activities. It is also considered one of the means of increasing the farmer's income, also its one of the small rural projects that do not require large investment capital compared to other productive projects. The main research problem lies in the lack of quantitative analytical studies that evaluate the apiculture sector's actual economic performance of the apiculture sector. The study aims to evaluate the production efficiency of honey beekeeping projects in Egypt, also identify the most important factor affecting honey production. The sample was calculated from Fayoum governorate, it was concluding three categories which are: (less than 50 hives), (50-100 hives), and (more than 100 hives). The results showed that the most influential factors on the honey production are the value of combating bee diseases (pounds) (Xi4), and the beekeeper's experience in years (Xi5) for the first category, the quantity of feeding sugar (Xi2), the quantity of labor (Xi3), and the beekeeper's experience years (Xi5) the production elasticity of the factor reached about 0.438, 0.250, and 0.234, respectively for the second category, while there were the number of hives in the apiary (Xi1), the amount of labor (Xi3), and the value of combating bee diseases (Xi4) while the production elasticity of these factors reached about 0.188, 0.288, 0.947, respectively for the third category. The result also showed that the optimal volume of the production, which minimizes costs were 331.7, 882.96, 1366.7, and 897.68 Kg for the three categories and total sample respectively, while the Averages production were 343.5, 860, 1381.5 Kg for the three categories and total sample respectively. The result also found that the volume of production which maximizes profit was about 362.32, 1122.86, 1903.3, and 1992.5 kg respectively. By studying the productive and economic efficiency indicators of the beehive categories, it was found that the second category (50-100) hives is the most productive and economically efficient category.

6. RECOMMENDATIONS

After examining the most important problems facing producers the study concluded a set of recommendations which can be summarized as follows:

1. The study showed the high costs of production. Therefore, the study recommends providing direct financial and technical support, establishing marketing channels, and activating the role of beekeeper cooperatives in regulating supply and demand.
2. Developing awareness and training programs for beekeepers, providing specialized veterinary support, encouraging selective breeding of resistant strains, and providing pure queen bee strains.
3. Supporting the cultivation of nectar-producing plants, restricting the use of pesticides harmful to bees, and expanding the establishment of suitable bee pastures.
4. Supporting the introduction of modern breeding techniques, improving local strains, and training beekeepers in seasonal migration planning.

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