IJAFLS
e-ISSN: 2602-4381
International Journal of Agriculture, Forestry and Life Sciences
Original Article Open access Int J Agric For Life Sci (2023) 7(2): 25-29

Technical Efficiency of Honey and Beeswax Production in Kaduna State, Nigeria: Implications for Climate and Food Security Sustainability

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Citation
Alabi, O.O, Anekwe, C.E, (2023). Technical Efficiency of Honey and Beeswax Production in Kaduna State, Nigeria: Implications for Climate and Food Security Sustainability. Int J Agric For Life Sci (2023) 7(2): 25-29.
Received :6 April 2023
Accepted :29 September 2023
Published Online :22 December 2023
Year: :2023
Volume :7
Issue :2 (December)
Pages :25-29

Available online https://dergipark.org.tr/ijafls

Abstract
This study evaluated the technical efficiency of honey and beeswax production in Kaduna State, Nigeria. Multi-stage sampling technique was adopted. A total sample size of 120 honey and beeswax producers was used. Primary data were collected with the aid of a structured and well-designed questionnaire. The gross margin and net farm income of honey and beeswax production per cycle were calculated at 924, 235.00 Naira and 891, 850.00 Naira respectively. This shows that honey and beeswax production was profitable in the study area. The significant predictors influencing the technical efficiency of honey and beeswax production were labour input, bee feed and sugar syrup, land size, number of beehives, quantities of antibiotics and vaccines, and cost incurred in honeybee pest, diseases, and predators control. The socio-economic predictors influencing negatively the technical inefficiency of honey and beeswax production were age, gender, household size, educational level, experience in beekeeping, and membership of cooperatives. The average technical efficiency score for honey and beeswax producers was 56.3% leaving a gap of 43.7% for improvement. The constraints faced by honey and beeswax producers were a lack of modern equipment, lack of credit facilities, inadequate extension services, inadequate training and capacity building, transportation problems, and disease, pest and predator attacks. The study recommended that modern beekeeping equipment should be provided for honey and beeswax producers for increased productivity, training and capacity building should be organized for honey and beeswax producers for increased efficiency and productivity

Key words
Technical Efficiency, Honey and Beeswax Production, Climate and Food Security, Sustainability, Nigeria.

Introduction
Beekeeping or Apiculture or Apiary is the act, business or science of managing honey bees to produce honey, beeswax, bee pollen, propolis, royal jelly, apitoxin, and other bee products for personal consumption and industrial use (Masuku, 2013). Apiary offers an enormous opportunity to ameliorate poverty and meet nutritional requirements. The demand for bees' products is expanding in both international and local markets in Nigeria. Honey production in Nigeria is still at its developmental stage, this can be attributed to inefficient use of available resources, and inadequate information on the beekeeping enterprise. Beekeeping is an activity (business) that requires little land, the quality of land is less important (Tijani et al., 2011), and it serves as a means of empowering smallholder farmers who have low capital investments (Farinde et al., 2005). Beekeeping for honey production has been identified as one the lucrative business in many parts of the world (Ahmad et al., 2016). Beekeeping is an activity (business) that provide benefits in terms of pollination of crops, employment, and conservation of biodiversity (Didas 2005). Beekeeping is an economically sustainable occupation that offers attractive opportunity for self-employment with multiple benefits. Beekeeping requires a shorter duration, and promise high returns compared to other income generating activities (Sadia et al., 2021). Beekeeping is an activity (business) with lower risk and the skills required can be acquired more easily than any other agricultural activity (Alropy et al., 2019). The beekeeping value chain is rich in employment opportunities from equipment manufacture, processing, value addition, packaging, and marketing has vast opportunities. Employment offered by beekeeping enterprise enhances household income thereby improving food security for the household.

Beekeeping practice needs to be adapted to the changing climate situations, the impact of disappearing natural habitats, dwindling floral biodiversity, emergent pests and diseases on bee populations is unprecedented. There is therefore the need for a concerted effort toward the conservation of the bee colonies and the establishment of a healthy environment with abundant bee floral resources. The use of technology in climate smart beekeeping also makes it possible to exploit all the primary bee products, this approach therefore yields ecosystem benefits and enhances farmers' income. Honeybees are pollinators and their activities in pollination promotes production in forestry, agriculture, and keep the natural resources and biodiversity stable. Nigeria consumes about 440,000 tonnes of honey annually and we produce just 10%. The global demand for honey was projected to exceed 2.8 million tonnes by 2024. Nigeria produces about 15,000 tonnes of honey annually, this is less than 3% of its potential of about 800,000 tonnes (FMARD, 2017). In the United States of America, about 109, 799, 366.60 Kg of honey worth $ 24,200,000.00 is produced each year. In 2021, the United States imported 651 million USD in honey, becoming the 1st largest importer of honey in the world. At the same year was the 45th most imported product in the United States, the United States import honey primarily from: Argentina (141 million USD), Brazil (115 million USD), India (114 million USD), New Zealand (95.3 million USD), and Vietnam (85.8 million USD). Australia produces 18, 375,000.51 Kg of honey, and Tanzania about 750, 000 pounds' worth of honey is produced annually (Canadian Statistics, 2003). Ethiopia which is the largest producer of honey in Africa and 10th largest producer in the world produces about 45,000 tonnes which accounted for about 27% and 3% of African and world honey production respectively (FAOSTAT, 2015). Honey which is one the products of honeybee contain plant sugars, fat, protein, carbohydrates, ash, phosphorous, calcium, sodium, potassium, iron, thiamine, Vitamin A, Vitamin C (ascorbic acid), and riboflavin (Olarinde et al., 2008). Honey provides a valuable food when it is consumed in its unprocessed state such as liquid, crystallized or in the comb, honey is largely used on a small as food and medicine for healing many ailments (Shuaib et al., 2009), as well as at an industrial level in baked products, candy, confectionary, jams, marmalades, breakfast cereals, milk products, beverages, and many processed products (Ahmad et al., 2016). However, the bees are exposed to several threats such as reduced biodiversity, climate change, and invasive species, predators, parasites, diseases that reduce their honey production, quality of health and longevity (UNEP, 2010). Beeswax is a secondary product from the apiary farmers, it is used in both industrial and handcrafted products (Gao et al., 2021).

Beeswax is a valuable product that can provide a worthwhile income in addition to honey. Industries use beeswax as a hydrophobic and insulating component of numerous products for example in electronic circuits, electric cables to isolate copper from moisture, to protect leather, in the preparation of inks, varnishes, protective waxes from cuttings and matches (Hepburn, 2012). Beeswax is one of the natural waxes that have been used as a support ingredient in pharmaceutics and cosmetics formulations. Beeswax goes into the composition of creams and ointments as a thickener and fat base. Beeswax is used for candle manufacture, making models for pieces in jewelry and sculpture modeling due to its malleability (Mladenoska, 2012), for shoe polishes and creams to protect can from acidic attack from fruit juices and other corrosive agents. Sterols present in beeswax are therapeutically beneficial compounds effective in lowering cholesterol levels (Mellema, 2009). Beeswax is used for delicate skin care in cosmetology especially when it is dry, it cleans the epidermis and nourishes and softens the dermis thus preventing skin aging. The average composition of beeswax includes: -hydrocarbons (14%), monosters (35%), diesters (14%), hydroxyl monoesters (4%), triesters (3%), hydroxyl polyester (8%), monoesters acids (1%), polyester acids (2%), free fatty acids (12%). Nigeria produces about 2,500 tonnes of beeswax annually; this is less than 3% of its potential of 70,000 tonnes (FMARD 2017). In 2020, world production of beeswax was 62, 116 tonnes, led by India with 38% (23,716 tonnes), followed by Ethiopia with 5, 339 tonnes, and Argentina with 4,970 tonnes (FAOSTAT, 2022).

Technical efficiency is the capacity of honey and beeswax producers to maximize output from a stated input given available technology. The source of concern is the lack of technical know-how, and very little or nothing is known about the level of technical efficiency of honey and beeswax production. This means that if research is not strengthened, the technical efficiency and the sustainability of beekeeping for honey, beeswax and the production of other products may not be ascertained. Beekeepers encountered challenges of low yields of beekeeping products such as beeswax, honey, propolis and other products, this may be due to lack of training, and insufficient management practices. In addition, honey production is also affected by bad weather, bee diseases, predators, pests, low quality, and limited supply of honey in the value chain this may be caused by limited availability of bee forage, shortage of honeybee colonies, poor pre and post-harvest management, and backward technology (Vaziritabar and Esmaeilzade, 2016). Benefits of beekeeping also include the availability of necessary inputs locally, availability of technologies in rural localities, readily available markets both locally and internationally, and pollination of flowers for food production increases. In the USA, beekeepers are paid by farmers for providing a four-week pollination service with their bees. Beekeeping is an activity (business) that can reduce poverty and malnutrition.

Objectives of the Study

The broad objective of this study is to the evaluate technical efficiency of honey and beeswax production in Kaduna State, Nigeria. The specific objectives were to:

(i) determine the socio-economic profiles of honey and beeswax producers,
(ii) analyse the profitability of honey and beeswax production,
(iii) evaluate factors influencing the technical efficiency of honey and beeswax production,
(iv) evaluate socio-economic factors influencing technical inefficiency of honey and beeswax production,
(v) determine the technical efficiency scores of honey and beeswax producers,
(vi) determine the constraints faced by honey and beeswax producers in the study area.

Methodology

This research study was conducted in Kaduna State, Nigeria. Kaduna State occupies between Longitudes 06° 15│ and 08° 50│ East and Latitudes 09° 02│ and 09° 02│North of the equator. The State has a land area totalling 4.5 million hectares. They are involved in agricultural activities. The people are involved in honey and beeswax production. Crops grown include: okra, pepper, maize, ginger, sorghum, rice, yam, cassava, millet, and tomatoes. Animal reared include: cattle, goats, sheep, rabbit, and poultry.

Research Design

A descriptive cross-sectional research design was employed in this study to describe the socio-economic profiles or characteristics of honey and beeswax producers, and to evaluate factors influencing technical efficiency and socio-economic factors influencing technical inefficiency of honey and beeswax production.

Sampling Techniques and Sample Size

A multi-stage sampling technique was adopted for this study. In the first stage, a purposive sampling procedure was used to select Kaduna State based on the numerous numbers and concentration of honey and beeswax producers in the area. The second stage involved a random selection of four (4) local government areas using the ballot box method. In the third stage, three (3) villages were selected randomly from each local government area based on the intensity of honey and beeswax producers. In the fourth stage, from a sampling frame of 171 honey and beeswax producers, a proportionate and simple random sampling technique was used to select the desired sample size of 120 honey and beeswax producers. This study employed the formula advanced by Yamane (1967) in the determination or estimation of the sample size. The formula is stated thus:

$n = \frac{N}{1+N(e^2)}$ =120……………(1) Where,

n = Desired Sample Size N = Finite Size of the Population
e =Maximum Acceptable Margin of Error as Determined by the Researcher

Methods of Data Collection

The primary data for this study was collected from the honey and beeswax producers through structured questionnaire. The data involved information on socio-economic profiles of farmers and technical production of honey and beeswax data.

Methods of Data Analysis

Data were analyzed using the following descriptive and inferential statistics:

Farm Budgetary Technique: Gross margin and net farm income analysis of honey and beeswax production was estimated using the following models:

$$GM = TR - TVC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$NFI = \sum_{i=1}^{n} P_i Q_i - \left[\sum_{j=1}^{m} P_j X_j + \sum_{k=1}^{k} GK\right] \ldots\ldots\ldots (3)$$ Where

P_i = Price of Honey and Beeswax ($\frac{N}{Kg}$),
Q_i = Quantity of Honey and Beeswax (Kg),
P_j = Price of Variable Inputs ($\frac{N}{Unit}$),
X_j = Quantity of Variable Inputs (Units),
TR = Total Revenue obtained from Sales from Honey and Beeswax (N),
TVC = Total Variable Cost (N),
GK = Cost of all Fixed Inputs (Naira)
NFI = Net Farm Income (Naira)

The farm budgetary technique was used to analyze the profitability of honey and beeswax production as stated in specific objective two (ii).

Financial Analysis: According to Alabi *et al*. (2020), gross margin ratio is defined as:

$$Gross\ Margin\ Ratio = \frac{Gross\ Margin}{Total\ Revenue} \ldots\ldots\ldots\ldots (4)$$

According to Olukosi and Erhabor (2015), operating ratio (OR) is defined as:

$$Operating\ Ratio = \frac{TVC}{GI} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$ Where,

TVC = Total Variable Cost (Naira), GI = Gross Income (Naira),

The financial analysis was used to analyze the profitability of honey and beeswax production as stated in specific objective two (ii).

Stochastic Production Frontier Model

According to Alabi *et al*. (2022), the stochastic production frontier model is stated thus:

$$Y_i = f(X_i, \beta_i)e^{v_i - u_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$l_nY = \beta_0 + \beta_1 l_n X_1 + \beta_2 l_n X_2 + \beta_3 l_n X_3 + \beta_4 l_n X_4 + \beta_5 l_n X_5 + \beta_6 l_n X_6 + V_i - U_i \ldots\ldots\ldots (7)$$ where,

Y_i = Output of Honey and Beeswax Production (HBW) (kg)
X_i = Vectors of Factor Inputs β_i = Vectors of Parameters
V_i = Random Variations in Honey and Beeswax Output
U_i= Error Term due to Technical Inefficiency
X_1 = Labour Input in Mandays, this is expected to be positively related to (HBW) $X_1 > 0$
X_2 = Bee Feed and Sugar Syrup (Kg), $X_2 > 0$
X_3 = Land Size (Ha), $X_3 > 0$
X_4 = Number of Beehives (Units), $X_4 > 0$
X_5 = Quantities of Antibiotics and Vaccines (grams), $X_5 > 0$
X_6 = Cost Incurred in Honeybee Pests, Diseases, and Predators Control (Naira), $X_6 < 0$

$$U_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 \ldots. (8)$$ where,

Z_1 = Age (Years), it is expected to be positively or negatively related to Technical Inefficiency, $Z_1 > 0$ $Z_1 < 0$
Z_2 = Gender (1, Male; 0, Otherwise), $Z_2 > 0$ $Z_2 < 0$
Z_3 = Household Size (Units), $Z_3 < 0$
Z_4 = Educational Level (Years), $Z_4 < 0$
Z_5 = Experience in Beekeeping (Years), $Z_5 < 0$
Z_6 = Members of Cooperative Organizations, $Z_6 < 0$
α_0 = Constant Term $\alpha_1 - \alpha_6$ = Parameters to be Estimated
U_i= Error Term due to Technical Inefficiency

Cost Saving Formula: The cost saving formula for average technical efficient (ATE) honey and beeswax producers and least technical efficient (LTE) honey and beeswax producers is stated as:

Cost Savings = $\left[\left[1 - \frac{\text{ATES or LTES}}{\text{MaxTES}}\right] \times 100\right]$ ….(9) Where,

ATES = Average Technical Efficiency Score (Units)
LTES = Least Technical Efficiency Score (Units)
MaxTES = Maximum Technical Efficiency Score (Units)

This was used specifically to achieve objective three (iii), which is to evaluate factors influencing the technical efficiency of honey and beeswax production, and objective four (iv) which is to evaluate socio-economic factors influencing the technical inefficiency of honey and beeswax production, and objective five (v), which is to determine the technical efficiency scores of honey and beeswax producers in the study area.

Principal Component Analysis: The constraints facing honey and beeswax producers and militating against honey and beeswax production were subjected to principal component analysis. This was used to achieve specific objective six (vi).

Results and Discussion

Socio-Economic Profiles of Honey and Beeswax Producers

The socio-economic profiles of honey and beeswax producers under consideration were gender, marital status, age level of education, household size, farming experience, extension contact, membership of cooperatives, and land size (Table 1).

Table 1: Socio-Economic Profiles of Honey and Beeswax Producers

Variables	Frequency	Percentage	Mean
Gender			
Male	109	90.83	
Female	11	09.17	
Marital Status			
Single	21	17.50	
Divorced	17	14.17	
Married	82	68.33	
Age (Years)			
31 – 40	24	20.00	
41 – 50	67	55.83	**45.92**
51 – 60	29	24.17	
Level of Education			
Non-Formal	09	07.50	
Tertiary	35	29.17	
Secondary	47	39.17	
Primary	29	24.16	
Household Size (Units)			
1 – 5	47	39.17	**7.00**
6 – 10	37	30.83	
11 – 15	36	30.00	
Farming Experience			
(Years)	32	26.67	**9.54**
1 – 5	47	39.17	
6 – 10	13	10.83	
11 – 15	28	23.33	
16 – 20			
Extension Contact	87	72.50	
Yes	33	27.50	
No			
Memberships of	92	76.67	
Cooperative	28	23.33	
Yes			
No	79	65.83	**1.10**
Land Size (Hectares)	21	17.50	
Less than 1.0	11	09.17	
1.1 – 2.0	09	07.50	
2.1 – 3.0	**120.00**	**100.00**	
3.1 – 4.0			
Total			

Source: Field Survey (2022) Profitability Analysis of Honey and Beeswax Production per Cycle

The gender distributions categorize honey and beeswax producers into male and female. About 90.83% (109) of honey and beeswax producers were male, while 09.17% (11) were female. The marital status distributions show that 17.50% (21) of honey and beeswax producers were single, 14.17% (17) were divorced, and 68.33% (82) were married. This finding is in line with similar results of Ahmad *et al*. (2016) who reported in their study that 90% of honey producers were male, and 78% of the respondents were married. About 75.83% of honey and beeswax producers were less than 50 years of age, the mean age was 45 years. This implies that the respondents were young, active, and resourceful in their youthful age. Also, 92.5% of honey and beeswax producers had formal education, while 07.50% of the respondents had non-formal education. The formal education attained by honey and beeswax producers includes: - tertiary (29.17%), secondary (39.17%), and primary (24.16%). According to Amanza and Maurice (2005), the level of education attained by honey and beeswax producers will determine to a large extent the producer's level of adoption of innovations, this will make them efficient in resource use which in turn will increase the output of honey and beeswax production, and hence subsequently increase profit obtained by producers. The household sizes were large with an average of 7 members per household. About 70.00% of honey and beeswax producers had less than 10 members per household. Also, 65.84% of honey and beeswax producers had less than 11 years of experience in beekeeping. According to Iheanacho (2000), the higher the number of years spent in beekeeping business, the more the apiarist becomes aware of new production techniques that can increase the level of productivity. Furthermore, 72. 50% of honey and beeswax producers had extension contact, while 27. 50% do not have extension contact. Mulatu *et al.* (2021) reported that extension activities increase the honey and beeswax producers' likelihood of adopting new technology by increasing the store of information about the current production technique. Timely contact with extension officers is important to ensure the efficient use of beekeeping technology. This extension contact helps beekeepers manage his/her productivity as well as promotes proper exploitation of honey products. About 76.67% of honey and beeswax producers belong to membership of cooperatives, while 23.33% do not belong to any cooperative associations. Memberships of cooperatives allow the honey and beeswax producers to exchange ideas skills and experiences about new production and marketing techniques. The average land size was 1.10 hectares, and about 65.83% of honey and beeswax producers had less than 1.0 hectares of land size.

Table 2 shows the profitability of honey and beeswax production per cycle. The revenue obtained from honey and beeswax production and the cost incurred were based on the prevailing market price at the time of the field survey. The total cost of honey and beeswax production was 68 150.00 Naira, this comprises of a total variable cost of 35,765.00 Naira (52.47%) and total fixed cost of 32,385.00 Naira (47.53%). The total variable cost consists of marketing cost (06.00%), bee feed cost (08.31%), transportation cost (05.47%), labour cost (05.68%), insecticide cost (04.76%), tools and equipment cost (13.57%), and honey extraction cost (08.27%). The gross margin and net farm income of honey and beeswax production were 924, 235.00 Naira and 891, 850.00 Naira respectively. This shows that the beekeeping business was profitable in the study area. This result is in line with studies conducted by Ahmad *et al*. (2016), Tijani *et al*. (2011), and Kuboja *et al*. (2016). The gross margin ratio of 0.962 implies that for every one naira invested in honey and beeswax production about 96 kobo covered profits, expenses, taxes, and depreciation. The operating ratio of honey and beeswax production was estimated at 0.0357, this means that 3% of honey and beeswax produce sales revenue was used to the cover cost of honey and beeswax sold and other operating expenses. The operating ratio is used to measure the operating efficiency and profitability of honey and beeswax production, a low operating ratio is preferable and it's reported to be a positive sign.

Table 2: Average Profitability Analysis of Honey and Beeswax Production per Cycle

Items	Kg	Amount (Naira)	% of Total Cost
Price of Honey per Kg = 0.7	……..	3,500.18	
Litre	……..	3,000.07	
Price of Beeswax per Kg	162.84	……….	
Mean Quantity of Honey (Kg)	129.99	……….	
Mean Quantity of Beeswax (Kg)		570,000	
Total Revenue of Honey		390,000	
Total Revenue of Beeswax		600,000	
Gross Income of Honey		400,000	
Gross Income of Beeswax			
Variable Cost		4,350.00	06.00
Marketing Cost		5,670.00	08.31
Bee Feed Cost		3,730.00	05.47
Transportation Cost		3,875.00	05.68
Labour Cost		3,250.00	04.76
Insecticide Cost		9,250.00	13.57
Tools and Equipment Cost		5,640.00	08.27
Honey Extraction Cost		**35,765.00**	**52.47**
Total Variable Cost			
Fixed Cost		3,870.00	05.00
Beehives		2,450.00	03.59
Rent on Land		1,250.00	01.83
Interest on Operating Capital		2,275.00	03.33
Colony Cost		1,250.00	01.83
Bucket		5,600.00	08.21
Touch Light		1,750.00	02.56
Rain Boot		1,230.00	01.80
Cutlass		1,050.00	01.54
Gloves		1,150.00	01.68
Knife		3,570.00	05.23
Bee Suites		3,790.00	05.56
Extractor		1,670.00	02.45
Hat		1,480.00	02.17
Ropes		**32,385.00**	**47.53**
Total Fixed Cost		**68,150.00**	**100.00**
Total Cost		**924,**	
Gross Margin (Honey +		**235.00**	
Beeswax)		**0.962**	
GMR		**891,850.00**	
NFI		**0.0357**	
OR			

Source: Field Survey (2022), 1 USD = 760 Naira GMR = Gross Margin Ratio, NFI = Net Farm Income, OR = Operating Ratio

Factors Influencing Technical Efficiency of Honey and Beeswax Production

The maximum likelihood estimates of factors influencing the technical efficiency of honey and beeswax production was presented in Table 3. All the predictors included in the technical efficiency component had positive coefficients. All the signs of the predictors included in the technical efficiency component were in line with apriori expectations. The significant predictors included in the technical efficiency component of the stochastic frontier production model were labour input ($P < 0.10$), bee feed and sugar syrup ($P < 0.05$), land size ($P < 0.05$), number of beehives ($P < 0.01$), quantities of antibiotics and vaccines (P < 0.10), cost incurred in honeybee pests, diseases and predators control (P < 0.05) respectively. The coefficient of number of beehives was 0.2107, this implies that a 1% increase in a number of beehives keeping other predictors constant will lead to 21.07% increase in honey and beeswax production. The calculated return to scale (RTS) was 1.4608, this implies an increasing return to scale. The increased return to scale signifies that an increase in all the predictor inputs included in the technical efficiency components will lead to more than proportionate increase in the output of honey and beeswax produced. The coefficient of variance ratio(γ) was 0.7138, this implies that 71.38% of variations in the output of honey and beeswax production were due to differences in technical efficiency. The coefficient of total variance (σ^2) was 1.7209, which was statistically significant at $(P < 0.01)$. This signifies a good fit for the model. The Log-Likelihood function was 331.21. This finding is in line with earlier results of Olarinde *et al.* (2008), and Shiferaw and Gebremedhin (2016).

Socio-Economic Factors Influencing Technical Inefficiency of Honey and Beeswax Production

Table 3 also shows the maximum likelihood results of socio-economic factors influencing technical inefficiency of honey and beeswax production. All the socio-economic factors included in the technical inefficiency component had negative coefficients. All the signs of the socio-economic factors included in the technical inefficiency component were in line with a priori expectations. The significant socio-economic factors negatively influencing technical inefficiency includes: - age (P < 0.10), gender (P < 0.05), household size (P < 0.05), educational level (P < 0.01), experience in beekeeping (P < 0.05), member of cooperatives (P < 0.05). The coefficient of educational level is -0.2453, this implies a 1% increase in experience in beekeeping will lead to a 24.53% decrease in technical inefficiency of honey and beeswax production. This result is in line with earlier findings of Walle (2020).

Table 3: Maximum Likelihood Results of the Stochastic Frontier Production Model

Variables	Parameters	Coefficient	StandardError	t-Value
Constant	β_0	2.0134*	1.0220	1.97
Labour Input	β_1	0.3450*	0.1568	2.20
Bee Feed and Sugar Syrup	β_2	0.4201**	0.1428	2.94
Land Size	β_3	0.1932**	0.0673	2.87
Number of Beehives	β_4	0.2107***	0.0544	3.87
Quantities of Antibiotics and Vaccines	β_5	0.1602*	0.0793	2.02
Cost Incurred in Honeybee Pests, Diseases and Predators Control	β_6	0.1308**	0.0440	2.97
RTS		**1.4608**		
Inefficiency Component				
Constant	α_0	1.910**	0.3906	2.56
Age	α_1	-0.1227*	0.0504	-2.43
Gender	α_2	- 0.1607**	0.0640	-2.51
Household Size	α_3	- 0.1302**	0.0487	-2.67
Educational Level	α_4	-0.2453***	0.0687	-3.57
Experience in Beekeeping	α_5	-0.2108**	0.0709	-2.97
Member of Cooperatives	α_6	-0.1708**	0.0595	-2.87
Diagnostic Statistics				
Total Variance	σ^2	1.7209***		
Variance Ratio	γ	0.7138		
Log-Likelihood		-306.12		
Likelihood Ratio Test		331.21		

Source: Data Analysis (2022), RTS = Return to Scale
*Significant at $(P < 0.10)$., **Significant at $(P < 0.05)$.***Significant at $(P < 0.01)$.

Technical Efficiency Scores of Honey and Beeswax Producers in the Study Area

Table 4 shows the summary statistics of technical efficiency scores of honey and beeswax producers. The majority (86.6%) of honey and beeswax producers were between 21 to 80 % efficiency levels. The mean technical efficiency was 56.30 % leaving a gap of 43.70 % for improvement. This implies that most producers were average technically efficient. In addition, the least technical efficiency score was 11.0 %, while the best performing honey and beeswax farm had the maximum technical efficiency of 92.0%. If the average honey and beeswax producers were to achieve the level of technical efficiency like most of its efficient counterparts, then the average honey and beeswax producers could make 38.81 % cost savings calculated as $\left[\left[1 - \frac{56.30}{92.00}\right] \times 100\right]$. The calculated value for the most technically inefficient honey and beeswax producers reveal a cost savings of 88.05 % calculated as $\left[\left[1 - \frac{11.0}{92.00}\right] \times 100\right]$.

Constraints Faced by Honey and Beeswax Producers

The constraints faced by honey and beeswax producers were subjected to principal component analysis (Table 5). Five (5) constraints with Eigen-value greater than one (1) were retained by the principal component model. Lack of modern beekeeping equipment's was ranked 1st with an Eigen-value of 1.9207, and this explained 16.04% of all constrained retained by the model. Lack of credit facilities was ranked 2nd with an Eigen-value of 1.8705, and this explained 15.09% of all constraints retained by the principal component model. Inadequate extension service was ranked 3rd with an Eigen-value of 1.6724, and this explained 17.23% of all constraints retained by the model. All constraints retained by the principal component model jointly explained 80.55% of all constraints included in the analysis. The Kaiser-Meyer-Olkin measures of sampling adequacy (KMO) of 0.71 and Bartlett test of sphericity of 793.01 and were statistically significant at 1 % probability level which demonstrated that the variables were feasible for principal component analysis. This result is in line with the findings of Alabi and Anekwe (2023), Alabi and Chiogor (2023), Olarinde *et al.* (2008), and Shiferaw and Gebremedhin (2016).

Table 4: Summary Statistics of Technical Efficiency Scores

Efficiency Score	Frequency	Percentage
0.00 – 0.20	08	06.67
0.21 – 0.40	12	10.00
0.41 – 0.60	45	37.50
0.61 – 0.80	47	39.17
0.81 – 1.00	08	06.67
Mean	0.5630	
Standard Deviation	0.1955	
Minimum	0.11	
Maximum	0.92	

Source: Field Survey (2022)

Table 5: Principal Component Model of Constraints Encountered by Honey and Beeswax Producers

Constraints	Eigen-Value	Difference	Proportion	Cumulative
Lack of Modern Beekeeping Equipments	1.9207	0.3207	0.1604	0.1604
Lack of Credit Facilities	1.8705	0.2621	0.1509	0.3113
Inadequate Extension Services	1.6724	0.1749	0.1723	0.4836
Inadequate Training or Capacity Building	1.6602	0.3607	0.1803	0.6639
Transportation Problem	1.4504	0.2816	0.1209	0.7848
Diseases Pest and Predator Attack	1.4005	0.2104	0.0207	0.8055
Bartlett Test of Sphericity				
Chi Square	793.01***			
KMO	0.7107			
Rho	1.00000			

Source: Field Survey (2022), KMO – Kaiser-Meyer-Olken

Conclusion

This study has established that beekeeping activity (business) is a profitable in the area. Honey and Beeswax producers were middle aged farmers, and the enterprise is dominated by male. The gross margin and net farm income were calculated at 924, 235.00 Naira and 891, 850.00 Naira respectively. Labour input, bee feed and sugar syrup, land size, number of beehives, the quantity of antibiotics and vaccines, cost incurred in honeybee pests, diseases and predator control were the significant predictors influencing technical efficiency or output of honey and beeswax production. The significant socio-economic factors influencing negatively the technical inefficiency of honey and beeswax production include: age, gender, household size, educational level, experience in beekeeping, and member of cooperatives. The mean technical efficiency scores for honey and beeswax producers were 56.30% leaving a gap of 43.70% for improvement. The constraints faced by honey and beeswax producers by ranking include: lack of modern beekeeping equipment (1st), lack of credit facilities (2nd), inadequate extension services (3rd), inadequate training or capacity buildings (4th), transportation problem (5th), diseases and predators attack (6th).

Recommendations

The following recommendations were made based on the research findings:

(i) Modern beekeeping technologies should be provided for honey and beeswax producers for increase productivity, climate and food security sustainability.

(ii) Extension officers should be employed to disseminate research findings, innovations and new technologies to honey and beeswax producers.

(iii) Credit facilities should be made accessible and affordable by the government for honey and beeswax producers. This will enable them to access new beekeeping technologies.

(iv) Training and capacity building should be provided for honey and beeswax producers for increase productivity.

Statement of Conflict of Interest

The author(s) declare no conflict of interest for this study.

Author's Contributions

The contribution of the authors is equal

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