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TECHNICAL EFFICIENCY OF HONEY AND BEESWAX PRODUCTION IN KADUNA STATE, NIGERIA: IMPLICATIONS FOR CLIMATE AND FOOD SECURITY SUSTAINABILITY

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Abstract. This study evaluated the technical efficiency of honey and beeswax production in Kaduna State, Nigeria. A 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 questionnaire. The gross margin and net farm income for honey and beeswax production per cycle were calculated at 924,235 Naira and 891,850 Naira respectively. This shows that honey and beeswax production was profitable in the study area. Significant predictors influencing the technical efficiency of honey and beeswax production were labour input, bee feed and sugar syrup, land size, number of beehives, quantity of antibiotics and vaccines, and cost incurred in honeybee pest, disease, and predator control. The socio-economic predictors negatively influencing the technical efficiency 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, a lack of credit facilities, inadequate extension services, inadequate training and capacity building, transportation problems, and disease, pest and predator attacks. The study recommends that modern beekeeping equipment should be provided for honey and beeswax producers to increase productivity. Furthermore, training and capacity building should be organized for honey and beeswax producers to increase both productivity and efficiency.

Keywords: technical efficiency, honey and beeswax production, climate and food security, sustainability, Nigeria

INTRODUCTION

Beekeeping, or apiculture, 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). Apiculture offers an enormous opportunity to ameliorate poverty and meet nutritional requirements. The demand for bee products is expanding in both international and local markets in Nigeria. Honey production in Nigeria is still in its developmental stage, which can be attributed to the inefficient use of available resources, and inadequate information on the beekeeping enterprise. Beekeeping is an activity (business) that requires little land and for which the quality of the land is less important (Tijani et al., 2011), and it serves as a means of empowering smallholder farmers who have limited access to capital investment (Farinde et al., 2005). Beekeeping for honey production has been identified as a lucrative business in many parts of the world (Ahmad et al., 2016), and it provides benefits in terms of the pollination of crops, employment, and the conservation of biodiversity (Didas, 2005). It is an economically sustainable

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occupation that offers an attractive opportunity for self-employment with multiple benefits, taking less time and promising higher returns than other income generating activities (Sadia et al., 2021). Compared to other agricultural activities, it has lower risks, and the skills required can be acquired more easily (Alropy et al., 2019). The beekeeping value chain is rich in employment opportunities, including in equipment manufacture, processing, value addition, and packaging, and there are also vast opportunities in marketing. The employment offered by beekeeping enhances household income, thereby improving food security for households.

Beekeeping practices need to be adapted to the changing climate, the impact of disappearing natural habitats, dwindling floral biodiversity, and the effect of emergent pests and diseases on bee populations. There is therefore a need for a concerted effort to conserve bee colonies and establish a healthy environment with abundant floral resources. The use of technology in climate-smart beekeeping also makes it possible to exploit all the primary bee products, yielding ecosystem benefits and enhancing farmers' incomes. Honeybees are pollinators, and their activities in pollination promote production in forestry and agriculture, and keep natural resources and biodiversity stable.

The global demand for honey has been projected to exceed 2.8 million tonnes by 2024. Nigeria consumes about 440,000 tonnes of honey annually and produces just 10% of this amount, or about 15,000 tonnes of honey annually, which is less than 3% of its potential output of about 800,000 tonnes (FMARD, 2017). In the United States of America, about 109,799,366.6 kg of honey (worth 24,200,000 USD) is produced each year. In 2021, the United States imported honey worth 651 million USD, becoming the largest importer of honey in the world. In the same year, honey was the 45th-most imported product in the United States, and it was primarily imported 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 in 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 the 10th-largest producer in the world, produces about 45,000 tonnes, which accounts for about 27% and 3% of African and world honey production respectively (FAOSTAT, 2022).

One of the products of the honeybee, honey contains 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 is a valuable food when it is consumed in its unprocessed state, such as in liquid form, crystallized or in the comb. It is largely used on a small scale as food and as a medicine for many ailments (Shuaib et al., 2009), and on an industrial scale in baked products, candy, confectionary, jams, marmalades, breakfast cereals, milk products, beverages, and many processed products (Ahmad et al., 2016). However, bees are exposed to several threats, such as reduced biodiversity, climate change, and invasive species, predators, parasites and diseases, that impair their honey production, health and longevity (UNEP, 2010).

Beeswax is a secondary product from apiculture which is used in both industrial and handcrafted products (Gao et al., 2021). It 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, in electric cables (to isolate copper from moisture), to protect leather, in the preparation of inks and varnishes, and in waxes to protect against cuts and matches (Hepburn, 2012). Beeswax is one of the natural waxes used as a support ingredient in pharmaceuticals and cosmetics, being added to creams and ointments as a thickener and fat base. It is used for candle manufacture, to make models for jewelry and in sculpture modeling due to its malleability (Mladenoska, 2012), and it is also used in shoe polishes and creams, and to protect cans from acidic fruit juices and other corrosive agents. The sterols present in beeswax are therapeutically beneficial compounds effective in lowering cholesterol levels (Mellema, 2009). Beeswax is used to care for delicate skin in cosmetology, especially when it is dry, because it cleans the epidermis and nourishes and softens the dermis, thus preventing skin aging. The standard components of beeswax include: hydrocarbons (14%), monoesters (35%), diesters (14%), hydroxyl monoesters (4%), triesters (3%), hydroxyl polyester (8%), monoester acids (1%), polyester acids (2%), and free fatty acids (12%). Nigeria produces about 2,500 tonnes of beeswax annually, which is less than 3% of its potential production of 70,000 tonnes (FMARD 2017). In 2020, world production of beeswax was 62,116 tonnes, led by India with 23,716 tonnes (38%), 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 the available technology. One source of concern in Nigerian apiculture 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. When beekeepers encounter challenges including low yields of beekeeping products such as beeswax, honey, propolis and other products, this may be due to a lack of training and insufficient management practices. In addition, honey production is affected by bad weather, bee diseases, predators, pests, low quality, and limited supply of honey in the value chain, which may be caused by limited availability of bee forage, a shortage of honeybee colonies, poor pre- and post-harvest management, or backward technology (Vaziritabar and Esmaeilzade, 2016). The benefits of beekeeping include the promotion of the availability of necessary inputs locally and the availability of technologies in rural localities, readily available markets both locally and internationally, and increased pollination of flowers for food production. In the USA, beekeepers are paid by farmers to provide a four-week pollination service with their bees. Beekeeping is thus an activity (business) that can reduce poverty and malnutrition.

OBJECTIVES OF THE STUDY

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

- determine the socio-economic profiles of honey and beeswax producers;
- analyze the profitability of honey and beeswax production;
- evaluate factors influencing the technical efficiency of honey and beeswax production;
- evaluate socio-economic factors limiting the technical efficiency of honey and
- beeswax production;
- determine the technical efficiency scores of honey and beeswax producers; and
- 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 sits between the longitudes 06°15’E and 08°50’E and the latitudes 09°02’N and 10°36’N. The state has a land area totaling 4.5 million hectares. Its inhabitants are involved in agricultural activities, including honey and beeswax production. Crops grown include: okra, pepper, maize, ginger, sorghum, rice, yam, cassava, millet, and tomatoes. Animals reared include: cattle, goats, sheep, rabbits, 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 the technical efficiency and socio-economic factors limiting the technical efficiency 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 high number and concentration of honey and beeswax producers in the area. The second stage involved the 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 production. 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 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:

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

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 a structured questionnaire. The data included information on the socio-economic profiles of farmers and the production of honey and beeswax.

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:

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

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

where:
- P_i – price of honey and beeswax (₦/Kg)
- Q_i – quantity of honey and beeswax (Kg)
- P_j – price of variable inputs (₦/Unit)
- X_j – quantity of variable inputs (units)
- TR – total revenue obtained from sales of honey and beeswax (₦)
- TVC – total variable cost (₦)
- 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:

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

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

$$Operating\ Ratio = \frac{TVC}{GI} \quad (5)$$

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:

$$Y_i = f(X_i, \beta_i)e^{vi-ui} \quad (6)$$

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

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 man days; 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 – quantity of antibiotics and vaccines (grams), $X_5 > 0$
- X_6 – cost incurred in honeybee pest, disease, and predator control (Naira), $X_6 < 0$

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

where:
- Z_1 – age (years), which 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 – membership 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 honey and beeswax producers with average technical efficiency (ATE) and honey and beeswax producers with the least technical efficient (LTE) is:

$$\text{cost savings} = \left[\left[1 - \frac{\text{ATES or LTES}}{\text{MaxTES}}\right] \times 100\right] \quad (9)$$

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, objective four (iv), which is to evaluate the socio-economic factors limiting the technical efficiency 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). The gender distributions categorize honey and beeswax producers into male and female. About 90.83% (109) of honey and beeswax producers were male, while 9.17% (11) were female. The marital status distributions show that 17.5% (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 the 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 and the mean age was 45 years. This implies that the respondents were young, active, and correspondingly resourceful. Also, 92.5% of honey and beeswax producers had had a formal education, while 7.5% of the respondents had had no formal education. The educational levels attained by honey and beeswax producers were: 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 their level of adoption of innovations. Adopting more

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	45.92
41–50	67	55.83	
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)			
1–5	32	26.67	9.54
6–10	47	39.17	
11–15	13	10.83	
16–20	28	23.33	
Extension Contact			
Yes	87	72.50	
No	33	27.50	
Memberships of Cooperative			
Yes	92	76.67	
No	28	23.33	
Land Size (Hectares)			
Less than 1.0	79	65.83	1.10
1.1–2.0	21	17.50	
2.1–3.0	11	09.17	
3.1–4.0	09	07.50	
Total	120.00	100.00	

Source: field survey, 2022.

innovations will make them efficient in resource use, which in turn will increase honey and beeswax production, and hence subsequently increase their profits. The household sizes were large, with an average of seven members per household. About 70% of honey and beeswax producers had fewer than ten 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 the beekeeping business, the more the apiarist becomes aware of new production techniques that can increase their level of productivity. Furthermore, 72.5% of honey and beeswax producers had extension contact, while 27.5% did not have extension contact. Mulatu et al. (2021) reported that extension activities increase honey and beeswax producers' likelihood of adopting new technology by increasing their store of information about current production techniques. Timely contact with extension officers is important to ensure the efficient use of beekeeping technology. This extension contact helps beekeepers manage their productivity as well as promoting proper exploitation of honey products. About 76.67% of honey and beeswax producers were members of cooperatives, while 23.33% did not belong to any cooperative association. Membership of cooperatives allows honey and beeswax producers to exchange ideas, skills, and experiences related to new production and marketing techniques. The average land size was 1.1 hectares, and about 65.83% of honey and beeswax producers had less than 1 hectare.

Profitability analysis of honey and beeswax production per cycle

Table 2 shows the profitability of honey and beeswax production per cycle. The revenue obtained from honey and beeswax production and the costs 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 Naira, comprising a total variable cost of 35,765 Naira (52.47%) and a total fixed cost of 32,385 Naira (47.53%). The total variable cost consists of marketing costs (6%), bee feed costs (8.31%), transportation costs (5.47%), labour costs (5.68%), insecticide costs (4.76%), tool and equipment costs (13.57%), and honey extraction costs (8.27%). The gross margin and net farm income of honey and beeswax production were 924,235 Naira and 891,850 Naira respectively. This shows that the beekeeping business was profitable

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 Litre	……..	3,500.18	
Price of beeswax per Kg	……..	3,000.07	
Mean quantity of honey (Kg)	162.84	……….	
Mean quantity of beeswax (Kg)	129.99	……….	
Total revenue of honey		570,000	
Total revenue of beeswax		390,000	
Gross income of honey		600,000	
Gross income of beeswax		400,000	
Variable cost			
Marketing cost		4,350.00	06.00
Bee feed cost		5,670.00	08.31
Transportation cost		3,730.00	05.47
Labour cost		3,875.00	05.68
Insecticide cost		3,250.00	04.76
Tools and equipment cost		9,250.00	13.57
Honey extraction cost		5,640.00	08.27
Total variable cost		35,765.00	52.47
Fixed cost			
Beehives		3,870.00	05.00
Rent on land		2,450.00	03.59
Interest on operating capital		1,250.00	01.83
Colony cost		2,275.00	03.33
Bucket		1,250.00	01.83
Touch light		5,600.00	08.21
Rain boot		1,750.00	02.56
Cutlass		1,230.00	01.80
Gloves		1,050.00	01.54
Knife		1,150.00	01.68
Bee suites		3,570.00	05.23
Extractor		3,790.00	05.56
Hat		1,670.00	02.45
Ropes		1,480.00	02.17
Total fixed cost		32,385.00	47.53
Total cost		68,150.00	100.00
Gross margin (honey + beeswax)		924,235.00	
GMR		0.962	
NFI		891,850.00	
OR		0.0357	

1 USD = 760 Naira.
GMR – Gross Margin Ratio, NFI – Net Farm Income, OR – Operating Ratio.
Source: field survey, 2022.

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, which means that 3% of honey and beeswax 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 is reported to be a positive sign.

Factors influencing the technical efficiency of honey and beeswax production

The maximum likelihood estimates of factors influencing the technical efficiency of honey and beeswax production are presented in Table 3. All the predictors included in the technical efficiency component of the analysis had positive coefficients. All the signs of the predictors included in the technical efficiency component were in line with a priori 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 ($P < 0.01$), quantity of antibiotics and vaccines ($P < 0.10$), and cost incurred for honeybee pest, disease and predator control ($P < 0.05$). The coefficient of number of beehives was 0.2107, which implies that a 1% increase in the number of beehives will lead to a 21.07% increase in honey and beeswax production (if other predictors remain constant). The calculated return to scale (RTS) was 1.4608, which implies an increasing return to scale, signifying that an increase in all the predictor inputs included in the technical efficiency analysis would lead to a more-than-proportionate increase in the output of honey and beeswax. The coefficient of variance ratio (γ) was 0.7138, which implies that 71.38% of the variation in honey and beeswax production was 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 the earlier results of Olarinde et al. (2008) and Shiferaw and Gebremedhin (2016).

Socio-economic Factors Limiting the Technical Efficiency of Honey and Beeswax Production

Table 3 also shows the maximum likelihood results of socio-economic factors limiting the technical efficiency 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 of the analysis were in line with a priori expectations. The significant socio-economic factors negatively influencing technical efficiency include: age

Table 3. Maximum likelihood results of the Stochastic Frontier Production Model

Variables	Parameters	Coefficient	Standard Error	t-Value
1	2	3	4	5
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	β_6	0.1308**	0.0440	2.97
Diseases and predators control				
RTS		1.4608		

Table 3 – cont.

1	2	3	4	5
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		

RTS – return to scale.
Significant at: *$P < 0.10$, **$P < 0.05$, ***$P < 0.01$.
Source: data analysis, 2022.

($P < 0.10$), gender ($P < 0.05$), household size ($P < 0.05$), educational level ($P < 0.01$), experience in beekeeping ($P < 0.05$), and membership of cooperatives ($P < 0.05$). The coefficient of educational level is –0.2453, which implies that a 1% increase in experience in beekeeping will lead to a 24.53% decrease in the technical efficiency of honey and beeswax production. This result is in line with the earlier findings of Walle (2020).

Technical efficiency scores of honey and beeswax producers in the study area

Table 4 shows the summary statistics of the technical efficiency scores of honey and beeswax producers. The majority (86.6%) of honey and beeswax producers were operating at between 21% and 80% efficiency. The mean technical efficiency was 56.30%, leaving a gap of 43.70% for improvement. This implies that most producers had an average level of technical efficiency. In addition, the lowest technical efficiency score was 11%, while the best-performing honey and beeswax farm had a technical efficiency of 92%. If the average honey and beeswax producers were to achieve the level of technical efficiency of their more efficient counterparts, they could make cost savings of 38.81%, calculated as [[1 – (56.30/92.00)] × 100]. The same calculation for the most technically inefficient honey and beeswax producers reveals a potential cost saving of 88.05%, calculated as [[1 – (11.0/92.00)] × 100].

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	0.0502	0.1604	0.1604
Lack of credit facilities	1.8705	0.1981	0.1509	0.3113
Inadequate extension services	1.6724	0.0122	0.1723	0.4836
Inadequate training or capacity building	1.6602	0.2098	0.1803	0.6639
Transportation problem	1.4504	0.0499	0.1209	0.7848
Diseases pest and predator attack	1.4005	0.0745	0.0207	0.8055
Bartlett test of sphericity				
Chi square	793.01***			
KMO	0.7107			
Rho	1.00000			

KMO – Kaiser-Meyer-Olken.
Source: field survey, 2022.

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 eigenvalues greater than one (1) were retained by the principal component model. A lack of modern beekeeping equipment was ranked 1st, with an eigenvalue of 1.9207, and this explained 16.04% of all the constraints retained by the model. A lack of credit facilities was ranked 2nd, with an eigenvalue 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 eigenvalue 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 the constraints included in the analysis. The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) of 0.71 and the Bartlett test of sphericity result of 793.01 were statistically significant at the 1% probability level, which demonstrated that principal component analysis was feasible for the variables. 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).

CONCLUSION

This study has established that beekeeping is profitable in the study area. Honey and beeswax producers were mostly middle aged farmers, and the enterprise was dominated by males. The gross margin and net farm income were calculated at 924,235 Naira and 891,850 Naira respectively. Labour input, bee feed and sugar syrup, land size, number of beehives, the quantity of antibiotics and vaccines, and the costs incurred in honeybee pest, disease and predator control were the significant predictors influencing the technical efficiency or output of honey and beeswax production. The significant socio-economic factors negatively influencing the technical efficiency of honey and beeswax production included: age, gender, household size, educational level, experience in beekeeping, and membership of cooperatives. The mean technical efficiency scores for honey and beeswax producers were 56.3%, leaving a gap of 43.7% 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 building (4th), transportation problems (5th), and diseases and predators (6th).

RECOMMENDATIONS

The following recommendations are made based on the research findings:

(i) Modern beekeeping technologies should be provided for honey and beeswax producers to increase productivity and 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) The government should make credit facilities more accessible and affordable for honey and beeswax producers. This will enable them to access new beekeeping technologies.

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

REFERENCES

Ahmad, O.S., Alabi, O.O., Daniel, P.O. (2016). Resource-use efficiency of honey production in Kachia Local Government Area, Kaduna State, Nigeria. J. Agric. Stud., 4(1), 117–125. https://doi.org/ 10.5296/jas.v4i1.8790

Alabi, O.O., Anekwe, C.E (2023). Economics of Climate Smart Agricultural Practices (CSAPs) used by smallholder sorghum producers in Nigeria. Austral. J. Sci. Technol., 7(1), 65–71.

Alabi, O.O., Chiogor, O.H. (2023). Technical efficiency of tiger nut (*Cyperus esculentus*) production in Katsina State: Socio-economic drivers and implications for consumers health benefits. Austral. J. Sci. Technol., 7(1), 46–53.

Alabi, O.O., Oladele, A.O., Maharazu, I (2022). Economies of scale and technical efficiency of smallholder pepper (*Capsicum species*) production in Abuja, Nigeria. J. Agric. Sci. (Belgrade), 67 (1), 63–82. https://doi.org/10.2298/JAS2201063A

Alabi, O.O., Oladele, A.O., Oladele, N.O. (2020). Economic market decisions among marginal maize farmers in Abuja, Nigeria: Applications of double hurdle model and factor analysis. Russ. J. Agric. Soc.-Econ. Sci., 8(104), 114–125. https://doi.org/ 10.18551/rjoas.2020-08.14

Alropy, E.T., Desouki, N.E., Alnafissa, M.A (2019). Economics of technical efficiency in white honey production: Using Stochastic Frontier Production Function. Saudi J. Biol. Sci., 26, 1478–1484.

Amanza, P.S., Maurice, D.C. (2005). Identification of factors that influence technical efficiency in rice-based production systems in Nigeria. Paper presented at workshop on policies and strategies for promoting rice production and food security in Sub-Saharan Africa. November 7–9, 2005, Cotonou (Benin).

Canadian Statistics (2003). Honey production. Canad. Bee J., 35(4), 61–72.

Didas, R (2005). Beekeeping project in South Western Uganda. Bee World, 86, 69–76.

Farinde, A.J., Soyebo, K.O., Oyedokan, M.O. (2005). Improving Farmers' Attitude towards honey production experience in Oyo State, Nigeria. J. Human Ecol., 18(1), 21–33.

FAOSTAT (2022). Beeswax Production in 2020, Crops/Regions/ World List/Production Quantity. UN Food and Agriculture Organization, Corporate Statistical Database Retrieved 23 July, 2022.

FMARD (2017). Federal Ministry of Agriculture and Rural Development of Nigeria, Annual Report.

Gao, Y., Lei, Y., Wu Y., Liang, H., Li, J., Pei, Y., Li, Y., Li, B., Luo, X., Liu, S (2021). Beeswax: A potentials self emulsifying agent for the construction of thermal-sensitive food w/o emulsion. Food Chem., 2, 021, 349, 129203. https://doi.org/10.1016/j.foodchem.2021.129203

Hepburn, H.R. (2012). Honeybees and wax: An experimental natural history. Springer Science & Business Media.

Iheanacho, A.C. (2000). Pattern and technical efficiency of resource use in millet based crop mixtures in Borno State of Nigeria. Res. J. Sci., 6 (1 and 2), 97–103.

Kuboja, N.M., Isinika, A.C., Kilima, F.T.M. (2016). Comparative economic analysis of beekeeping using traditional and improved beehives in the Miombo Woodlands of Tabora and Katavi Regions, Tanzania. Huria J., 22, 109–123. https://doi.org/10.4314/huria.v2211

Masuku, M.B. (2013). Socio-economic analysis of beekeeping in Swaziland. A case study of the Manzani Region, Swaziland. J. Dev. Agric. Econ., 5(6), 236–241. https://doi.org/10.5897/JDAE2013.002

Mellema, M. (2009). Co-crystals of beeswax and various vegetable waxes with sterois studied by X ray diffraction and diferentials scanning calorimetry. J. Am. Oil Chem. Soc., 86(6), 499–505. https://doi.org/10.1007/s11746.009-1385-4

Mladenoska, I. (2012). The potential application of novel beeswax edible coatings containing coconut oil in the minimal processing of fruits 1(2), 26–34.

Mulatu, A., Marisennayya., S., Bojago, E. (2021). Adoption of modern hive beekeeping technology: The case of Kacha-Birra Woreda, Kembata Tembaro Zone, Southern Ethiopia. Adv. Agric., 1–20. https://doi.org/10.1155/2021/4714020

Olarinde, I.O., Ajao, A.O., Okunola, S.O. (2008). Determinants of technical efficiency in beekeeping farms in Oyo State, Nigeria: A Stochastic Production Frontier Approach. Res. J. Agric. Biol. Sci., 4(1), 65–69. Retrieved from: http://

www.aensiweb.net/AENSIWEB/rjabs/rjabs/2008/65-69.pdf

Olukosi, J.O., Erhabor, P.O. (2015). Introduction to farm management economics: Principles and applications. Agitab Publishers Limited, Zaria, Kaduna, Nigeria (p. 77–83).

Sadia, F.T., Hossain, M.S., Begum, R., Sujan, M.H.K. (2021). Comparative profitability analysis and resource use efficiency of beekeeping using wooden and poly hive in some selected areas of Bangladesh. Int. J. Agric. Res. Innov. Technol., 11(1), 84–91. http://dx.doi.org/10.3329/ijarit.v11i1.54470

Shiferaw, K., Gebremedhin, B (2016). Technical efficiency of smallscale honey producers in Ethiopia: A Stochastic Frontier Analysis. LIVES Working Paper 20, Nairobi, Kenya: International Livestock Research Institute (ILRI) 1 – 21. Retrieved from: https://core.ac.uk/reader/132686470

Shuaib, A.U., Kyiogwom, U.B., Baba, K.M. (2009). Resource-use efficiency of modern beekeeping in Selected Local Government Areas of Kano State, Nigeria. Proceedings of the 23rd Annual National Conference of Farm Management Society of Nigeria, held at Usmanu Danfodio University Sokoto, Sokoto, Nigeria. 14th-17th December 2009 (p. 630–634).

Tijani, B.A., Ala, A.L., Maikasuwa, M.A., Ganawa, N. (2011). Economic analysis of beekeeping in Chibok Local Government Area of Borno State, Nigeria. Niger. J. Basic Appl. Sci., 19(2), 285–292. Retrieved from: http://www.ajol.info/index.php/njbas/index

UNEP (2010). Environment for Development: Indigenous Knowledge in Africa. http:// www.unep.org/ik/Pagos.asp?Id=Swaziland accessed 27-10-2010

Vaziritabar, S., Esmaeilzade, S.M. (2016). Profitability and socio-economic analysis of beekeeping and honey production in Karaj State, Iran. J. Entomol. Zool. Stud., 4(4), 1341–1350. Retrieved from: https://www.entomoljournal.com/archives/2016/vol4issue4/PartO/4-4-34-701.pdf

Walle, D. (2020). Technical efficiency and its determinants of honey production: The case of Bibugu District of Amhara Region, Ethiopia. Acad. J. Res. Sci. Publ., 2(18), 141–172. Retrieved from: https://www.ajrsp.com/en/Archive/issue-18/Technical%20Efficiency%20and%20its%20Determinants%20of%20Honey%20production.pdf

Yamane, T (1967). Elementary sampling theory (vol. 1, 371–390). Englewood Cliff: Prentice Inc.