Cross Current International Journal of Agriculture and Veterinary Sciences
Abbreviated Key Title: Cross Current Int J Agri Vet Sci
ISSN: 2663-2454 (Print) & Open Access
DOI: 10.36344/ccijavs.2024.v06i02.002

Volume-6 | Issue-2 | May-Jun, 2024 |

Review Article

Current Status and Challenges of Improved Bee Keeping Technology Adoption in Ethiopia: A Review

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| Received: 17.05.2024 | **Accepted:** 22.06.2024 | **Published:** 25.06.2024 |

Abstract: The aim of this review is to give an overview of current modern beekeeping technologies in Ethiopia and to highlight once again the challenges of adopting beekeeping technology. Bee-keeping in Ethiopia is common and one of the agricultural activities. Ethiopia is the leading honey producer in Africa and is one of the ten largest producers in the world (with around 23.6% of the African and 2.1% of the world production. Despite the long tradition of beekeeping in Ethiopia having the highest bee density and being the leading honey producer as well as one of the largest bee waxes exporting country in Africa, the share of sub sector in the GDP has never been commensurate with huge number of honey colonies and the country's potential for beekeeping. To increase production and productivity of honey and bee wax, different improved technologies have been used in the last 7-10 year. Backyard beekeeping can not only be conducted with traditional, but also with transitional or modern beehives. Lack of bee-keeping equipment (like modern beehives, wax molds, honey extractors, queen excluders) and accessories, training on beekeeping technology, awareness creation, extension contact and market problem were the major determinant factors of adoption of modern beekeeping technology. Despite variations in distribution and adoption levels, the utilization of beekeeping technology has now commenced across all regions of the nation hives, adding and reducing supper. The management of bee colonies constitutes a fundamental aspect of contemporary beekeeping practices within the country. Beekeeping equipment and accessories must be readily available to beekeepers, with a significant focus on enhancing productivity and implementing proper management techniques for contemporary beehives. Such measures have the potential to enhance the likelihood of beekeepers adopting and utilizing modern beehive technology.

Keywords: Beekeeping, current status, technology.

INTRODUCTION

Ethiopia is a landlocked country in sub-Saharan Africa and belongs together with Djibouti, Eritrea and Somalia to the Horn of Africa. In 2018, the population size of Ethiopia reached 109.2 million people distributed over an area of 1.1 million km2. From those, 79.2% live in rural areas, while the rest is situated in urban regions (FAOSTAT 2020). Agriculture plays a key role in the country. About 12 million smallholder farming households produce 95% of all agricultural goods (FAO 2020). In 2000, the agricultural sector employed 76.4% of the working population gradually declining to 66.2% in 2019 (UNDP 2019). This decline is accompanied by climate change (droughts), rural exodus and the change in policies and livelihood (Kristina *et al*., 2021).

Bee-keeping in Ethiopia is common and one of the agricultural activities. Traditional beekeeping was started before 5000 years back and the Hieroglyphs of ancient Egypt refers to Abyssinia (the former name of Ethiopia) as the source of honey and beeswax (Gezahegne, 2001; Mulualem and Mezgeb 2020). Honey and bee wax are the major bee products used for export earnings and also serve as sources of income for the rural community. Ethiopia is the leading honey producer in Africa and is one of the ten largest producers in the world (with around 23.6% of the African and 2.1% of the world production (Kassaye, 1990; Asmiro *et al*., 2017). Ethiopia, in East Africa, with more than 10 million honeybee colonies and nearly 1 million beekeepers, has long made a beekeeping part and parcel of rural livelihood making and income generation activities. However, the way of keeping bees has been of a little value and is very traditional.

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Citation: Edao Shanku and Fromsa Ijara (2024). Current Status and Challenges of Improved Bee Keeping Technology Adoption in Ethiopia: A Review. *Cross Current Int J Agri Vet Sci*, *6*(2), 23-30.

This way of beekeeping was deemed `not fit' by the government to meet current demands for honey in terms of quality and quantity (Yirdaw, E. 2002; Nuru, 2013).

Despite the long tradition of beekeeping in Ethiopia having the highest bee density and being the leading honey producer as well as one of the largest bee waxes exporting country in Africa, the share of sub sector in the GDP has never been commensurate with huge number of honey colonies and the country's potential for beekeeping. Productivity has always been low and relatively low export earnings. Hence, improved hives of different sorts have been introduced into the country. Thus, the beekeepers in particular and the country in general is not benefiting from the sector (Gezahegne, 2001; Nuru, 2002).

To increase production and productivity of honey and bee wax, different improved technologies have been used in the last 7-10 years. Some of the technologies are a transitional beehive, a modern beehive, a honey presser, a water sprayer, a smoker, gloves, a honey extractor and a veil. A modern bee box-hive has been disseminated to the farmers through the offices of agriculture and different governmental and non-governmental organizations to improve the production potential of bees by creating a favorable working and living environment. Due to institutional, socioeconomic, biophysical and other implicit and explicit factors, the adoption and intensive use of modern beehives by the farmers is not described well through different organizations are struggling to disseminate modern beehives to farmers (Asmiro *et al*., 2017). Therefore the aim of this review is to give an overview of current modern beekeeping technologies in Ethiopia and to highlight once again the challenges of adopting beekeeping technology.

Beekeeping in Ethiopia

Traditional beekeeping was started before 5000 years back and the Hieroglyphs of ancient Egypt refers to Abyssinia (the former name of Ethiopia) as the source of honey and beeswax. Thus Abyssinia has been known for its beeswax export for centuries during when other items were not exportable (Gezahegne, 2001). They refer to honey and beeswax trading activities with the realm Abyssinia, the exonym of Ethiopia (Gezahegne 2001). Today, the country is the number one honey and beeswax producer in Africa and belongs to the top ten worldwide (Adeday *et al*. 2012; FAOSTAT 2020). For beekeeping activities, mainly the autochthonous Western honey bee Apis mmellifera is used and Ethiopian beekeepers do not choose a specific subspecies for beekeeping, instead they use the locally available strains. Bee breeding programs do not exist and beekeepers acquire new colonies from either local markets, from the wild or from colony multiplication (Gebretinsae and Tesfay 2014; Hailu and Tadesse 2016). Some studies Reported that honeybees of the highland areas are larger in size, docile in behavior and less productive compared to the small lowland honeybees that are very aggressive and more productive.

Classification and geographical distribution of Ethiopian honey bees have been intensively discussed within the research community but methodological variations have been leading into contrasting results and opinions. While some recently published articles based on mitochondrial.

DNA analysis described the Ethiopian honey bees, with their evolutionary lineage Y, to be genetically distinct from other *A. mellifera* subspecies in neighboring geographic areas (Boardman *et al*., 2020; Franck *et al*., 2001; Tihelka *et al*., 2020), Hailu *et al*., (2020) reported of maternal lineage to be present in northern Ethiopia. Honeybee colonies differ in their performance even (Nuru *et al*., 2002; Amsalu *et al*., 2004). Variations include all the desired and undesired traits in terms of production, productivity and behavior.

Beekeeping can may be traditional or modern systems in the country. Traditional beekeeping is practiced with hives constructed from natural materials from the surrounding areas (MoARD 2007; Sahle *et al*., 2018). Often, they are cylindrical single chamber hives, which are made of easily accessible materials such as wood, clay, straw, bamboo or mud. The practices used for traditional beekeeping are manifold and follow the area specific culture. For example, in southwestern Ethiopia, it is common to hang log hives into trees. Only males are involved in this forest beekeeping activity (Awraris *et al*., 2012). Reasons why women do not participate have mostly cultural origins and physical motives. The hives need to be hung on 10-m-high branches of trees situated in dense forests. Climbing trees with the heavy log hives requires a certain physical strength and special skills. The work is carried out during night and is considered to be labour intense and dangerous and the beekeepers often stay in the woods for several days to maintain and harvest the hives. It is not forbidden for women to join those trips, but they prefer to not join for safety reasons and other cultural duties such as household activities (Shackleton *et al*., 2011; Sebsib and Yibrah 2018).

Another form of traditional beekeeping is mostly practiced in the central, northern and eastern areas of Ethiopia and is called backyard beekeeping, where beekeepers use special backyard systems in safeguarded areas for honey bees. The systems are situated in the houses of the beekeepers, under the roof of the houses or other structures serving as weather protection for the hives (Yirga *et al*., 2012). This form of beekeeping is considered to have more potential, as it is safer than forest beekeeping. Further, it significantly contributes to the family's income without the requirement of own farming land (Sebsib and Yibrah 2018; Serda *et al*., 2015).

Backyard beekeeping can not only be conducted with traditional, but also with transitional or modern beehives. It is often not a one person activity, instead the whole family including women participate. Keeping bees next to the households allows women to play a bigger role in either assisting their husbands, or in starting their own apiary to become economically independent and increase self-esteem (Olana and Demrew 2018). Traditional hive systems have several disadvantages such as unsustainability or lower honey productivity (Beyene *et al*., 2016; CSA 2019; Gemechis 2016). The hive is not manageable at all and honey harvest is always destructive for the nest and the colony. There are no movable frames in the hives and the natural comb-construction is severely damaged when the hive is opened. Internal inspection, providing feeding systems or swarm control is not possible (Fikru 2015; Sebsib and Yibrah, 2018). The honey yield of traditional hive systems has been demonstrated to be lower than those of transitional or modern systems despite the same availability of resources within the flight radius (Beyene *et al*., 2016; Gemechis 2016; Girma *et al.* 2008).

Besides many disadvantages, traditional hive systems also have positive aspects. The beekeepers who use them do not need special skills, the starting costs are low because locally available materials are often cheap and easily accessible, no management means less time-effort, less to no equipment is needed and bees kept in such systems produce more beeswax and propolis which can be traded at higher prices per kg compared to honey (Fikru 2015; Girma *et al*., 2008; Nuru *et al.*, 2002b; Serda *et al*., 2015; Kristina 2021).

Transitional (intermediate) systems are in between of traditional and modern hives and have been promoted by GOs and NGOs since 1978 (Beyene *et al*., 2016; Yirga and Teferi 2010). They are manageable, increase the safety of beekeepers that do not need to climb on trees anymore and promise higher honey yields than traditional hives. The most popular types are the Kenyan top bar hive and the "Chefeka" hive (Gemechis 2016; Kristina 2021). The latter is exclusively made of locally available materials (e.g. bamboo), making it more affordable than other top-bar hive types.

Modern beekeeping is mostly practiced in the southwestern and in the central highland areas of Ethiopia. Popular systems include Zander, Langstroth and Dadant (Gupta *et al*., 2014; Hailemichael 2018). Modern hives are characterized by movable frames and their high management potential including honey stored in supers. Depending on the colony's activity and status, the modern hive persists of up to four boxes.

The ongoing transition to modern hives in the past 2 to 3 years is not directly reflected by increased honey yields per hive.

Table 1. CSA (Central Statistics Agency) Ethiopia data from 2019/20 and 2020/21. Number of beehives [n], types of beehive systems used and Average Frequency (Harvests/Year) (kg) and are presented. critical evaluation of these values, see text. Data source:

Bee Hive (no)	**2019/20**	**2020/21**	**2021/22**
All bee hive	6,958,004	6,986,100	5,982,336
Traditional bee hive	6,680,885	6,699,219	5,761,701
Transitional bee hive	94,159	102,957	99,215
Modern bee hive	183,960	183,924	121,419
Honey production (kg)			
All hive	150,257,615.00	129,301,078	52,034,413.00
Traditional bee hive	145,327,500.00	124,791,328	8,539,950.00
Transitional bee hive	1,453,942.0	920,058	958,867.00
Modern bee hive	3,476,172.00	3,589,692	2,535,596.00
Average Frequency (Harvests/Year)			
All hive	1.73	1.66	1.69
Traditional hive	1.73	1.65	1.69
Transitional hive	1.82	1.73	1.81
Modern hive	1.67	1.74	1.79

Challenges of Modern beekeeping technology adoption In Ethiopia

Adoption was defined by Feder, *et al.*, (1985) as the degree of use of new innovation by a farmer when he has got full information about the new innovation and its potentials. Accordingly, they defined individual adoption as the farmer's decisions to incorporate a new technology into the production process and aggregate adoption as the process of diffusion of a new technology within a region or population. The term behavioral change refers to a desirable change in knowledge, understanding, and ability to apply technological information, change in motivation such as a change in interest, attitudes, aspirations, value, and change in ability and skills (Tarekegn *et al*., 2018; Dereje *et al*., 2020).

In recent years, the Ethiopian government, under its agricultural-led development policy, has given due attention to apiculture. To this effect, different

private and public institutions such as the Amhara Agricultural Research Institute, the Small and Medium Enterprises, the Amhara Region Agriculture Bureau, and other nongovernmental organizations have been involved in technology generation and adaptation, modern beehive box production, and dissemination. Moreover, public and private companies such as Lalibela Honey and Bee Wax Museumand TIRET (a private company) Honey and Bee Wax Factory are being established (Asmiro *et al*., 2017).

A study by Tamrat (2015) shows that the main determinants of modern beehive adoption in Arsi zone, Ethiopia, were farmyard size, a number of local beehives beekeepers possessed, training provided, participation on demonstration, wealth status of bee-keepers, and participation of bee-keepers on non-farm income sources. Moreover, chemical application, bee predators, lack of knowledge and skill on modern beehives, lack of modern beehive accessories, lack of bee forage, and lack of capital were the major bee-keeping bottlenecks. The educational level of the beekeepers can have a significant impact in identifying and determining the type of development and extension services that need to be designed for the area (T. Alemu, *et al*., 2015) and significantly affect the probability of adoption (A. Abeje *et al*., 2017; Addisu and Desalegn, 2021). The high level of education significantly influenced the effectiveness of improved beekeeping adoption.

Despite the potential of the study areas for beekeeping, in recent years, there has been a decreasing trend of honeybee colony populations. According to this study, 96.3% of the respondents agreed on the decreasing trend of bee colonies due to different threatening factors on bees and their products. Based on this fact, 60.74%, 46.67%, 45.93%, 27.41%, and 22.22% of the respondents put pesticide and herbicide application on crops, lack of management, predators, pests, and drought, respectively, major reasons for the colony decline in the study areas. (Addisu and Desalegn, 2021). Lack of bee-keeping equipment (like modern beehives, wax molds, honey extractors, queen excluders) and accessories (like smokers, cloths, bee veils, brushes) as the third major constraint of the bee-keeping sector which hinders the farm households from implementing appropriate improved beehive management practices (like internal inspection of hives, adding and reducing supper) on time (Asmiro *et al.*, 2017). From the listed hypothesize factor for beekeeping technology adoption, only training on beekeeping technology, awareness creation, extension contact, market problem and availability of protective close were the major determinant factors of adoption of modern beekeeping technology. Lack of beekeeping materials, Low-quality of beekeeping materials, High cost of beekeeping materials, Reduction of honey bee colony, Lack of extension support where the major challenges of modern beekeeping technology adoption in study area (Mulualem and Mezgeb, 2020).

Current Status of Improved Beekeeping Technology in Ethiopia

Modern beekeeping technologies were defined as any beekeeping technologies (modern, hives, transitional hives and the accessories) other than traditional hive Based on this definition, out of 120 beekeepers interviewed 57 (47.5%) were adopters of modern beekeeping technologies and the remaining 63(52.5%) of them were non adopters. Regarding box hive adoption 48/120 (40%) of the beekeepers were using the hive during interview. Out of the total respondents interviewed 54(45%) were experienced use of modern box hive but 6/54(11.11%) discontinued using modern box hive because of lack of bees wax, absconding of the colony after transferring from traditional hive to box hive and in availability and high cost of modern beekeeping technologies including accessories. (Mulualem and Mezgeb, 2020). Improved beekeeping technology requires knowledge of their practical activities. Participation of beekeepers in demonstration and workshop of improved beekeeping technologies were significantly associated with the adoption of the technology. This may be due to the fact that beekeepers who participated in demonstration and field day of improved beekeeping technology had a chance to exchange knowledge and experience with experts, researchers, and other beekeepers. This motivates the beekeeper to adopt improved technology (Dareje *et al.*, 2020).

Generally, the beekeepers know how was found to be better at the Midland agro ecology (Wondo) with 66.67% response of 'yes' and at the highland agro ecology (Kofale) with 75% response of 'yes' indicating that they are well accustomed with the use of Queen Excluder**.** It can be inferred from this data that the responding beekeepers' modern hives' sources are almost entirely private (Desta *et al*., 2023).

Based on the beekeeper farmers response, the majority 27/41(65.9%) of modern beekeeping equipment and accessories were purchased, in the market and the remaining 35.1% given by livestock agency, research centers and NGOS.

Colony Management Practices

For safety reasons, Ethiopian beekeepers open their hives mostly when the sun has already set to protect themselves from stings (Shackleton *et al*., 2011). Several survey-based studies reported that external hive inspection and cleaning of the apiary is far more common than internal hive inspection (Fikru *et al*., 2015; Kebede *et al*., 2018; Nuru *et al*., 2002a; Sebsib and Yibrah 2018; Serda *et al*., 2015). Internal inspection of traditional hive types is not practiced as it would be accompanied by a destruction of the bees' nest (Kerealem *et al.*, 2009; Kristina *et al*., 2021).

The sample respondents indicated that they remove all combs from traditional hives and they find it

difficult to change the old combs for modern hives due to shortage of wax, the cost of wax, and lack of aware ness (Asmiro *et al*., 2017).

Supplementary feed is important for honeybee colonies to develop the colony with an optimum population during nectar flows and prevents the colony from being attacked by different diseases and pests easily (Dareje *et al*., 2020). Regional differences are also found in supplementary feeding of bees in times of food shortage or droughts: while 3.1% of respondents feed their bees in the Haramaya District (Serda *et al*., 2015), up to 60% provide supplementary carbohydrates (e.g. sugar syrup, honey solutions, flour) and proteins (e.g. chickpeas or peas) in the western Amhara region. According to the survey results, almost more than half of bees feeding practices are undertaken by women than men (Asmiro *et al.*, 2017).

Other survey-based studies focusing on South-East and East Ethiopia reported that beekeepers cut parts of brood combs, remove queen cells, add supers, or provide empty hives to prevent reproductive swarming (Fikru *et al*., 2015; Solomon 2009). In contrast to the articles surveying the most common hive management techniques, recent research articles empirically demonstrated potential improvements in hive management. These range from feeding regimes to cope with dearth seasons, migratory beekeeping (Kumsa *et al*., 2020), methods to increase propolis production (Nuru et al. 2002b), to maintain colonies with two queens at least transiently (Wakjira *et al*., 2020) While techniques for multiple queen colonies with other A. mellifera subspecies were already developed (Zheng *et al*. 2009a, b), for the Ethiopian highlands, Wakjira *et al.*, (2020) for the first time investigated this method to increase colony development, food stores and profits mostly by reduced beeswax, feeding and labor costs (Kristina *et al*., 2021).

CONCLUSION AND RECOMMENDATION

Beekeeping in Ethiopia holds a rich historical background, with the local community recognizing the benefits that honey bees offer. Ethiopia stands out as the primary honey producer on the African continent and ranks among the top ten globally, contributing to approximately 23.6% of Africa's production and 2.1% of the global output. Ethiopian beekeepers exhibit a unique approach by not selecting a particular subspecies for their beekeeping practices; instead, they utilize the strains readily accessible within their locality. In the country still traditional beekeeping holds prominence through the utilization of hives made from organic materials sourced from the neighboring regions. The gradual shift towards contemporary hives within the recent 2 to 3 years does not exhibit a proportional rise in honey production per hive.

The beekeeping sub-sector in Ethiopia receives significant attention from the government in efforts to promote modern beekeeping technologies; however, the adoption and utilization of these technologies remain minimal. Various challenges contribute to this situation, including the inadequate availability and quality of beekeeping materials, high costs associated with such materials, decline in honey bee colonies, lack of extension support, beekeepers' demographics, education levels, and awareness levels, as well as the use of pesticides, herbicides, predators, pests, and drought affecting beekeeping activities. Despite efforts to enhance skills and knowledge in artificial queen rearing, the primary method of obtaining bee colonies continues to be through catching swarms using bait hives hung on tall trees.

Identified beekeeping technologies encompass modern hives, transitional hives, along with various accessories such as anti-protection gear, protective cloth, queen excluders, queen cages, smokers, wax molds, and honey extractors. Despite variations in distribution and adoption levels, the utilization of beekeeping technology has now commenced across all regions of the nation.

The management of bee colonies constitutes a fundamental aspect of contemporary beekeeping practices within the country. Given the prevailing dominance of traditional beekeeping methods and hives in Ethiopia, beekeepers commonly inspect their hives after sunset to minimize the risk of bee stings. Furthermore, regional disparities exist in the provision of supplementary feed to bees during periods of food scarcity or drought. In light of these findings, the ensuing recommendations are formulated:

- Beekeeping equipment and accessories must be readily available to beekeepers, with a significant focus on enhancing productivity and implementing proper management techniques for contemporary beehives. Such measures have the potential to enhance the likelihood of beekeepers adopting and utilizing modern beehive technology.
- Farm households must receive sufficient training, encompassing both practical and theoretical aspects. Moreover, emphasis should be placed on training that highlights the timely utilization of various chemicals, particularly herbicides, in order to mitigate the impact on honey bee populations.
- The investigation of suitable prevention and management strategies for pests and predators, with a specific focus on wax moths and birds, necessitates further examination by researchers in the field of biology. Moreover, the exploration of effective coping strategies for beekeeping in times of drought warrants additional investigation by biological scholars.

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