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Determinants of commercialization of African Indigenous Vegetables among smallholder farmers in Bungoma County, Kenya

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Abstract
Rising awareness of various lifestyle diseases and illnesses has led to an increased understanding of healthy eating habits, the increased demand for African Indigenous Vegetables (AIVs), and a strict healthier diet in Kenya. Apart from the awareness about the benefits of consuming the AIVs, their commercialization is still low due to how producers are less informed and not connected to market actors beyond their community. On the other hand, the literature on factors that influence commercialization is still limited. The purpose of this study is to sought to reduce that gap by determining the factors that influenced the commercialization of African Indigenous Vegetables (AIVs) among smallholder farmers in Bungoma County. In order to identify 384 respondents from whom data was collected, multistage sampling was used through personally administered questionnaires. The fractional regression model (FRM) was used to determine factors influencing the commercialization of AIVs in Bungoma County. The FRM results indicate that the eight explanatory variables included in the model significantly influenced the commercialization of AIVs among smallholder farmers. These variables are the gender of the farmer, land size, mode of payment, distance to the markets, AIV yields, AIV cost of production, duration to reach the market, and value addition. The researcher recommended that all gender should be engaged in the commercialization of AIVs and that the government to put in place policies and regulations that support the commercialization of AIVs, as they support other cash crops, which would equally enhance the quality and quantity improvement of AIVs that are distributed to various markets.

Keywords Market outlets · Market actors · Market facilities · Market information · Market channels

1 Introduction

Diseases and ailments related to people's lifestyles have increased the population's understanding of the benefits associated with African Indigenous Vegetables (AIVs) in Kenya. Unlike major vegetables such as cabbages, AIVs are yet to receive global recognition as significant contributors to human health and nutrition, social systems and sustainable development [1]. Despite AIVs lacking global recognition, various African communities in both rural and urban areas largely value AIVs as this primarily attributed to the customs, and traditions [2]. This is largely attributed to African custom and tradition. Decides, the production and marketing of AIVs has gained attention due to their increased inclusion in local diets for rural and urban households [3].

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Kenya produces AIVs worth $56 million annually on over 45,099 hectares of land [4]. This is equivalent to approximately 224,751 MT, of which about 90% is consumed [5]. In light of the observed large area under AIVs in Kenya, approximately 200 different species are grown in the country [6]. These species include black nightshade, spider plants, vegetable amaranth, cowpea, pumpkin leaves, and jute mallow [7]. African nightshade and cowpeas are the most widely produced AIV in Kenya by smallholder farmers in rural and urban areas at an approximation of 72% and 48% respectively [3]. The western part of Kenya is the part that mostly produces AIVs in Kenya, and these vegetables are widely produced by smallholder farmers in rural areas. Other areas that are known for AIV production in Kenya are Kisii, Kakamega, Nakuru, Kiambu, and Kajiado respectively, among others. Notably, over 10% of AIVs that are produced in Kenya account for the total national production of AIVs belongs to peri-urban areas [3].

The attention that AIVs have gained in Kenya is tremendous, and this has increased their demand in most cities compared to other leafy vegetables like kale, cabbages, and spinach. The increased consumption of AIVs is attributed to its increased awareness of the AIVs nutritional benefits among Kenyans in urban areas [8]. People from arid and semiarid areas have experienced the nutrition benefits that come with AIVs, which has led to their demand in these particular areas, leading to the reduced mortality rate of nutrition and food insecurity. Larger percentage of AIVs are sold through Informal markets to urban and peri-urban areas [6]. They are predominantly produced and marketed by women, and through this, they are able to generate more income for their households. African Indigenous Vegetables are sold at retail prices in urban areas by intermediaries who source them from rural areas.

The production and commercialization of AIVs is faced with many challenges including: Limited knowledge and awareness, Climate change, Pests and diseases, Limited infrastructure and technology, Limited access to markets, and low investment that limits overall performance and profitability [9]. The AIVs' barriers to commercialization include longer market distances, perishability nature; market price volatility due to different vegetable seasons and opportunistic behavior of the market which deprives farmers of profits [6]. AIVs and other vegetable species are usually marketed fresh, and this depends on destinations and locations. Rural dwellers prefer buying their vegetables from local open-air markets, while green food markets are mostly preferred by urban and peri-urban dwellers [6]. AIV producers on the other hand, prefer selling in the open-air markets due to instant payments. Due to the closeness to local consumers in production areas, some producers prefer selling at the farm [10]. According to Bokelman et al., [6]. AIVs are harvested early in the morning for sale, and the volumes harvested greatly depend on the market demand and supply that influence the general price. In most cases, during the dry season, the AIVs prices will rise and go down during the rainy season due to the abundant produce on the market. About 35% and above of producers of AIVs in Kenya produce for purposes of commercializing but out of the total percentage of AIVs that they produce, only 30% is marketed [11]. This implies that there is low levels of AIVs commercialization in Kenya.

The barriers to AIV commercialization are longer distances to the market, product perishability; market price fluctuation; seasonality, and opportunistic market behaviour which deprives farmers of profits [6]. AIV marketing is influenced by unreliable market information, lack of price setting mechanism, poor transport facilities, lack of storage facilities leading to perishability and post-harvest losses, and inadequate market linkages [9]. AIV smallholder farmers encounter inadequate market information on prices and technology, weak market connections with market actors, high transaction costs, and credit constraints [11]. Nan appropriate approach need to be taken to overcome these barriers to commercialization, these approaches will increase access to sustainable markets by smallholder AIVs famers [12].

Studies that have been done in relation to AIVs that have been conducted in Kenya largely focused their attention on the nutritional benefits of AIVs, effects of AIVs on household income, food security effects of AIVs, production, consumption, and marketing of AIVs, factors for adoption of AIVs, Consumers demand on value-added products of AIVs, challenges to commercialization of AIVs and demand for AIVs [3, 4, 6, 10, 13–16]. There is insufficient documented evidence that shows how the market channels and outlets affect the commercialization of African Indigenous Vegetables. About 35% and above of smallholder AIV farmers in Kenya produce AIVs for commercial purposes but only 30% is these AIVs is marketed [11]. This is a clear indication of low levels of AIV commercialization in Kenya. This is attributed to the lack of market connections leading to low commercialization. Therefore, the evaluation of the different vertical market linkages will contribute to the increase in the commercialization of African Indigenous Vegetables among smallholder farmers.

1.1 African Indigenous Vegetables marketed in Kenya

Kenya has a diverse array of highly nutritious African Indigenous Vegetables grown and consumed in local diets throughout the country. AIVs that are more popular in Kenyan markets include amaranth (*terere*), spider plant (*saget*), African nightshade (*manage*), cowpeas (*kunde*), pumpkin leaves, jute mallow (*mrenda*), and vine spinach (*nderema* [17]. Riziki

et al., [10]. In recent years, AIVs have received wider attention, both domestically and internationally, leading to an increase in their production and [6]. Subsequently, the market for indigenous vegetables in Kenya is growing tremendously, and this is driven by both increasing demands from consumers and efforts to promote sustainable agriculture, food systems, nutrition and food sovereignty.

Specifically, most of the produced vegetables are sold in local markets throughout Kenya, as well as in supermarkets, roadside stands, farm gates, and neighbours, and some are sold on online platforms such as dried vegetables [6]. The increasing demand for these indigenous vegetables has also led to the establishment of specialized farmers' markets and cultural food festivals, which showcase the unique flavours and cultural significance of these vegetables [18]. Overall, the market for indigenous vegetables in Kenya is growing, driven by both increasing consumer demand and efforts to promote the sustainability of AIVs smallholder farmers.

1.2 Commercialization of African Indigenous Vegetables

The commercialization of African Indigenous Vegetables in Kenya has been proved to the potential in improving food nutrition, food security, improvement of the living standards of the smallholder farmers, and contribute to the growth economy of a country's development [19]. Commercialization is simply transcendence from production for household consumption to market-focused production [20, 21]. Latthachack et al., [22] referred to the commercialization of agricultural products as the portion of the total production of a household that is sold, while Chinsinga [23] defined agriculture commercialization as the reliance of households on the production and selling of agricultural produce in order to purchase other agricultural inputs such as labor. This shift is often associated with increased adoption of improved technologies, raised unit farm productivity, value addition, and exploration of regional and international markets [24]. However, commercialization is most commonly measured in terms of percentage of total output that is commercialized. The level of infrastructure development, resource endowment, and access to the markets of input and output are found to be the major determinants of commercialization among AIVs smallholder farmers [25].

According to Chinsinga [23] market opportunities that arise due to changing consumption behaviours among consumers tend to compel smallholder farmers to commercialize. Consequently, the demand for improved production technologies among smallholder farmers rapidly takes shape [26]. Change in behaviour is usually accompanied by the willingness to pay attractive prices due to positive shifts in preference and income levels. Smallholders who have embraced specialization have proven that limited resources can be used most efficiently as they leverage the power of comparative advantage. As the earnings from specialized ventures increase, the food security situation improves, the standard of living improves and the financial resources and asset base of smallholders widen.

2 Materials and methods

2.1 Study area

The study was conducted Bungoma County, specifically in Kimilili, and Kabuchai, sub-counties as depicted in Fig. 1. The location of Kimilili Sub-County is situated in rural area with its headquarters located in Kimilili town with one of the largest open-air markets in Western region known as Kimilili old market. Two wards from Kimilili sub county i.e., Kimilili and Kamukuywa were considered in the study. In Kabuchai sub county there is Chwele market and in Kenya it is the second open air- market. Two wards from the Kabuchai sub-county were considered in the study i.e., Chwele and Mukuyuni wards making a total of 4 wards as shown in the map of the study. The study considered Bungoma County because an estimation of 52% of the people practices agricultural production that cater for 60% of all household incomes out of the total labor force of about 565,000 people [27]. The production of AIVs is highly recognized in Bungoma County, which is the common household foods fundamental contribute to the reduction of food insecurity for rural residents in Bungoma County. An estimation of about 61% of the female smallholder farmers practiced intercropping of AIVs with other crops in Bungoma County [16].

2.2 Study population and sampling

The sample size of study was determined using a proportionate sampling methodology specified by Cochran (1963) as in Eq. (1):

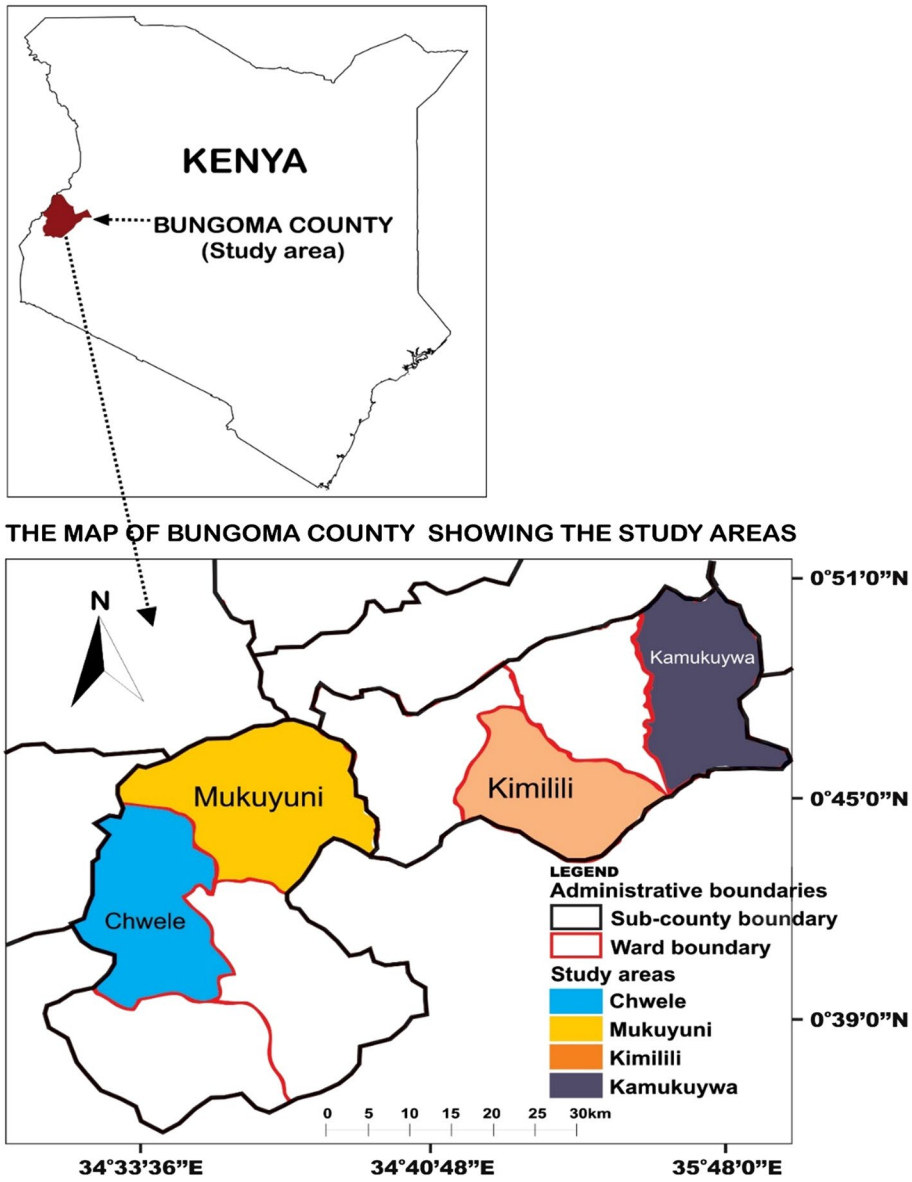

Fig. 1 Map of Bungoma County showing the study area

$$n = \frac{z^2 pq}{e^2} \tag{1}$$

where n = sample size, p = implied maximum possible variance q = 1 − p, z = the standard value at a given confidence level (α = 0.05), and e = the acceptable error (precision). The study desired a 95% confidence level and 5% precision level with a z score of 1.96. In addition, the study assumed that p = 0.5.

The sample was determined as shown in Eq. 2

$$n = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 384 \tag{2}$$

The derived sample size for the study was 384 respondents.

2.3 Data collection

A pilot study on 50 respondents equivalent to 13% of the total sample size of the study area was conducted to test the validity and reliability of the research instrument. Primary data and secondary data were used to generate the information required for the study. The collection of primary data collection was conducted through observations and interviews using a semi-structured questionnaire which was administered to AIV smallholder farmers. Questionnaires contained both open and closed questions that allowed the researcher to collect data on factors that influence the commercialization of African Indigenous Vegetables (AIVs) among the smallholder farmers.

3 Data analysis

3.1 Factors that influence the commercialization of AIVs

Commercialization was measured using the Household Commercialization Index (HCI). It takes into consideration the total value of agricultural produce that is marketed by a household [28]. HCI was used as a dependent variable in determining the factors influencing commercialization among AIV smallholder farmers as indicated in Table 1. The index reflects a proportion of the total value of AIVs sold in the market out of the total value of AIVs grown by a smallholder farmer. The total value of AIVs grown by smallholder farmers took into consideration the value of AIVs grown from the different portions of land while the value sold considered the value of the volumes sold expressed in Eq. (3): The AIVs considered in the computation of HCI were, Jute mallow, African Nightshade, Amaranth, cowpeas, and spider plant.

Table 1 Description of variables and the expected signs

Variable	Description of variables	Expected sign
Dependent		
Comm	Commercialization	
Independent		
Age	Age of the farmer in years	+/−
Gender	Gender of the farmer (1 Male, 0 Female)	+/−
Education	Level of education of the farmer (Number of years in school)	+
Experience	Level of experience of the farmer (In years)	+
Marital status	Marital status of the farmers (1 Married, 0 Not married)	+/−
Training	Access to training by the farmer (1 Yes, 0 No)	+
Irrigation	Access to irrigation (1 Yes, 0 No)	+
Funds	Access to funding by the farmer (1 Yes, 0 No)	+
Land Size	Size of the farm in acres	+/−
Tenure	Land tenure system (1 Owned, 0 Rented)	+/−
Demand	Consumer demand for AIVs (1 High, 0 Low)	+/−
Crops grown (Spider plant, 2-Amaranth, 3-Africa nightshade, 4-Cowpea, and 5-Jute mallow)	1 Yes 0 No	+/−
Water available	Availability of water (1 Yes, 0 No)	+
Land percentage	Percentage of total land allocated to vegetable production (%)	+
Value add	Adding value to vegetables produced (1 Yes 0 No)	+/−
Infor	Access to information (1 Yes 0 No)	+/−
AIV_yield	The average yield of vegetables produced (kilograms)	+
AIV_cost	The average cost of producing vegetables produced (KES)	−
AIV_price	The average price of vegetables produced (KES)	+

$$HCI = \frac{Total\ value\ of\ AIVs\ sold}{Total\ value\ of\ AIVs\ grown} \times 100 \tag{3}$$

For determining the factors that influence commercialization, censored and truncated models such as Tobit have been widely used. These models are appropriate when the dependent variable is bounded [29]. Similarly, logit and probit models are only appropriate where the dependent variable has two options, yes or no. However, the Fractional Regression Model (FRM) can handle circumstances where the dependent variable is measured as a proportion or a percentage [30]. Therefore, since the HCI was measured as a percentage, FRM was the most appropriate for the study. The model also accounts for the continuous and bounded nature of the dependent variable, predicts responses within the dependent variable's limits and captures the data's nonlinearity.

The HCI value ranges from 0 to 100, [31] An index value of zero implies that a smallholder is fully pursuing farming for subsistence purposes, while an index value of 100 signifies the highest level of commercially focused production. Farmers who will have a high level of commercialization will be assumed to be intensively engaged in the market. Noncommercialized farmers were those with a zero-index value because they were assumed not to sell any of the AIVs that they grow. Commercialized farmers were those with index values greater than one because of their assumed participation in marketing. The study anticipated an index value of 100 because most of the farmers were assumed to retain some stock for household consumption, while some portion is kept for seed production. This will imply that selling the entire produce may be impractical for smallholder AIV producers.

For the conditional expectation of the fractional response variable, Woolbridge [30] and Chegere [31] suggested the following as shown in Eq. 4:

$$E(y_i|x_i) = G(xi\phi), i = 1, 2, \ldots .., N \tag{4}$$

where $0 \le y_i \le 1$ denotes the dependent variable, x_i represents the explanatory variables for observation *i* and $G(\cdot)$ is a known function satisfying $0 \le G(\cdot) \le 1$.

A typical choice of $G(\cdot)$ is a cumulative distribution function. This particular quasiminimal likelihood (QML) procedure is based on the Bernoulli log-likelihood function given by Eq. 5:

$$LL_i(\phi) = y_i \text{Log}[G(x_i\phi)] + (1 - y_i)[1 - G(x_i\phi)] \tag{5}$$

Since the Bernoulli distribution is a member of the linear exponential family (LEF), the QML estimator of ϕ defined by Eq. 6:

$$\phi = \arg\max \sum_{n=1}^{N} LLi(\phi) \tag{6}$$

Is consistent and asymptotically normal regardless of the true distribution of y_i conditional on xi, and y_i could be a continuous variable, a discrete variable or have both continuous and discrete characteristics. According to [30], the method generates consistent and robust methods for the estimation and inference of the model parameters under general linear model conditions.

The FRM regression equation will therefore be specified by Eq. 7:

$$y^* = b + f(x) + u \tag{7}$$

where: u = unobserved latent variable; x = set of explanatory variables; f = relationship between dependent and independent variables; y = HCI value (bounded dependent variable); b = vectors of parameters to be estimates.

4 Results and discussion

4.1 Descriptive statistics

The means of age, experience, size of the land, and percentage of land allocated to AIVs and the respective t-tests based on sub-county (Kimilili and Kabuchai) in Bungoma County are presented in Table 2. During the study these variables were identified as the major continuous variables that differed greatly across males and females during. The indication

Table 2 Means of selected socioeconomic characteristics of respondents

Variables	Mean	Std. dev	t-test (based on sub-county)
Age	45.9	14.391	−6.0852***
Experience	15.9	11.980	−3.8724***
Size of the land	2.1	1.612	−3.1782***
Land percentage	42.0	18.759	1.5795

***, ** and * means significant at 1%, 5% and 10% level respectively

in the results revealed that the age mean of respondents in Bungoma County is 45.9 years. This was in line with the fact that the production and marketing of AIVs on a small piece of land is not so tedious and does not require energetic and muscular individuals to manage. The fact that most of the producers are men who are mothers, at ages above 40 years, they may not secure physically demanding employment and thus focus on the production of AIVs to feed their households. In relation to Chepkoech et al. [32], the findings revealed that the mean age of AIV producers in Kenya is 44.5 years.

The results indicated that the production of AIVs in terms of experience in Bungoma County is 15.9 years. This is because the majority of AIVs producers are older people (Above 40 years) who started engaging in AIV production at an earlier age. Contrary to this, Mulaudzi et al. [33], reported that the AIV producers in South Africa mean age in years was 30.9. This variation could because of respondents high mean age which was 59.9 years. However, 32.5% of the respondents had between 1 and 15 years of experience. Similarly, Anyango [34], noted 7 years as the mean experience in the production of AIVs in Siaya County.

The mean land size owned by the respondents is 2.1 acres. This is because most of the respondents depended on land that is inherited from their parents which must be distributed equally among the children in each household. Thus, for each child to access land from their parents, land must be divided into small pieces for everyone to have a share of their parents' possession. This is consistent with FAO [35], and One Acre Fund [36], who found out that most smallholder farmers in Kenya own less than 2 hectares of land and over 3 million smallholder farmers in Sub-Saharan Africa own less than 1 hectare of land respectively.

The mean percentage of land allocated to AIV production is 42.0% which translates to approximately 0.9 acres. This could be attributed to the fact that AIVs are considered for both household consumption and source of income at the same time thus having the privilege of such a high land allocation. During the dry season, the land is not used for other agricultural activities and thus is purely used for AIV production. This is findings were closely consistent with Mwema and Crewett [37], report that 37% of the allocation of land ownership in Kenya by smallholder farmers is for AIV production. Ngenoh et al. [38], reported that 0.92 acres is the average size of the land that is allocated to production of AIV in Kenya.

Table 3 Type of land ownership, access to training, and water for irrigation

Variable	Frequency	Percentage (%)
Source of land		
Own	310	80.7
Rented	24	6.25
Both	50	13.02
Total	384	100
Access to training		
Yes	297	77.34
No	87	22.66
Total	384	100
Access to irrigation		
Yes	191	49.74
No	193	50.26
Total	384	100

The results in Table 3 portray other socioeconomic characteristics including type of land ownership, access to training, and water for irrigation among smallholder AIV producers. Access to land is crucial when it comes to AIV production. The ownership of land implies that the producers have the legal rights to use and control the land for agricultural production. In this study land access by the respondents is represented in the database where producers can fall either in owning, renting or both owning and renting categories. According to the results of the study, the majority of AIV producers own (80.7%) the land on which they grow AIVs and those who are not privileged rely on renting the land (6.3%). The results further present that there is 13% of those who both own the land and still they also manage to rent extra land for AIV production. Land ownership is attributed to the fact that some respondents own land through inheritance, others own land from spouses through marriages and others through land purchasing. Ngenoh et al. [38] agree that land ownership in Kenya is characterized by many benefits, some of the benefits include investment, control and autonomy, generational inheritance, economic stability, stability in production, and a sense of security.

Producers of AIVs gain production and marketing knowledge in different ways. Most of them depending on the number of years they have been in vegetable production, are able to gain more knowledge as time goes on. According to this study, AIVs producers gain more experience through learning and training, therefore access to training is a major attribute in the production and marketing of AIVs. The results in the table below imply that the majority of AIVs producers 77.3% had access to training while 22.6% of the producers did not access training. This is attributed to the fact that the majority of AIV producers are older people who practice agriculture as their main hustle therefore they have much time and they tend to give it full attention and ready to gain knowledge that can help them improve in their production and marketing.

Water is important for agricultural production, according to the study the mean percentage of the AIVs producers who had access to irrigation was 49.7% and this is attributed to the fact that they have resources that can help them channel water into their farms and other had their land near water sources which made it easier for them to access water from the rivers. This implied that they can supply vegetables to the market throughout the year because their production is continuous and they are not limited by water-related factors. Those who did not have access to irrigation were 50.2%, this implied that their production was seasonal because their main source of water was rainfall.

4.2 Level of commercialization of AIVs in Bungoma County

To get the level of AIVs commercialization, the Household Commercialization Index (HCI) was used. The index reflects a proportion of the total value of AIVs sold in the market out of the total value of AIVs grown by a smallholder farmer. This is presented as follows

$$HCI = \frac{Total\ value\ of\ AIVs\ sold}{Total\ value\ of\ AIVs\ grown} \times 100$$

$$HCI = \frac{41184}{49984} \times 100$$

$$= 82\%$$

The level of commercialization of AIVs among smallholders in Bungoma County was calculated and reported as 82% based on the results from the HCI. This implies that the majority of AIVs smallholder farmers produce for commercial purposes [39]. According to the study, African Indigenous Vegetables (AIVs) are the vegetables that are highly produced in many regions in Kenya and this is a result of the available market for AIVs. Increased sales in AIVs are attributed to the fact that their nutritional benefits are highly recognized making them more popular in many family dishes [40, 41]. The increased level of commercialization in AIVs is a result of a change in production pattern as most of the people are now producing at a large scale throughout the year and those that were producing for subsistence purposes are now producing for commercialization, and this is attributed to access to AIVs markets through vertical market linkages, another reason is that many families are now consuming AIVs because of its nutrition benefits and solution for health issues that are emerging making people cautious of what they consume. Chepkoech et al. [32], reported that over 90% of the respondents in Kenya and Tanzania reported having preferred consuming African nightshade.

Table 4 Fractional regression results on factors that influence commercialization of AIVs

Commercialization	Coef	Std.Err	Z	P > z	[95% Conf	Interval]
Gender	−0.185	0.083	−2.230	0.026**	−0.348	−0.023
Age	−0.003	0.004	−0.710	0.475	−0.011	0.005
Marital	0.088	0.074	1.190	0.234	0.057	0.234
Educ	−0.070	0.065	−1.070	0.285	−0.198	0.058
Expe	−0.013	0.012	−1.110	0.268	−0.035	0.010
Land	0.036	0.022	1.680	0.093*	−0.006	0.079
Finance	0.219	0.370	0.590	0.555	−0.507	0.944
Training	−0.058	0.105	−0.550	0.583	−0.263	0.148
Consumer	−0.137	0.090	−1.520	0.128	−0.312	0.039
Payment	−0.249	0.096	−2.600	0.009***	−0.436	−0.061
Distance	−0.184	0.050	−3.650	0.000***	−0.282	−0.085
Valadd	0.047	0.024	1.950	0.051**	−0.000	0.095
Info	0.029	0.022	1.290	0.197	−0.015	0.073
AIV_yield	0.026	0.019	2.530	0.011**	0.000	0.000
AIV_cost	−0.089	0.073	−3.140	0.002***	−0.000	−0.000
AIV price	−0.020	0.001	−1.550	0.120	−0.004	0.000
_cons	2.763	0.551	5.010	0.000	1.682	3.843

***, **, and * means significant at 1%, 5% and 10% level respectively

4.3 Factors that influence the commercialization of African Indigenous Vegetables (AIVs) among smallholder farmers in Bungoma County

A fractional regression model was used. The results indicated in Table 4 show that eight of the explanatory variables significantly influenced the commercialization of AIVs among smallholder farmers. These variables included the sex of the farmer, land size, mode of payment, distance to the markets, AIV yields, AIV cost of production, duration to reach the market, and value-added.

The gender of the respondents negatively and significantly influenced the commercialization of AIVs among smallholder farmers at the 5% significance level. The results indicated that 18% of male-gendered smallholder AIV famers are less likely to commercialize AIVs than their female counterparts. In Bungoma County, men associate themselves with commercial crops that can fetch high and instant cash compared to women who control indigenous crops and subsistence food crops. Therefore, the engagement of men in AIV production tends not to be focused on income generation but rather on household food supply. Adenike [42], explained that an increase in the number of female-headed households increased the level of commercialization of agricultural produce in Nigeria. Additionally, Mahlangu et al. [43], reported that gender negatively influences the commercialization of traditional vegetables in Limpompo and Mpumulanga provinces in South Africa [44]. They asserted this to the fact that female- as opposed to male-headed households focus on both household food security and income generation, while males focus on cash crop production and marketing.

The allocation of land for the production of African Indigenous Vegetables significantly influenced the commercialization of AIVs positively among smallholder farmers at 10%. These results explain that an increase of 1% in the land proportion allocation for AIV production is attributed to an increase of 3.6% in the AIV commercialization among smallholder farmers. The land is a crucial resource for the production of AIVs; thus, an increase in the area cultivated directly results in an increased volume of output produced, marketing, and further income increase. This will lead to income increases for smallholder farmers, and the tendency to expand farmland increases, hence increasing the commercialization level of smallholder farmers and AIV commercialization. In line with Agnew et al. [11], the findings indicated that land size positively and significantly influenced the commercialization of traditional vegetables in Kiambu County in Kenya.

Another variable that negatively influenced the AIVs commercialization is the contractual mode of payment among smallholder farmers at a 1% significance level. This signifies that using the contractual mode of payment compared to when smallholders use the instant cash mode of payment reduces the likelihood of commercialization by 24.9%. Farmers face numerous challenges and have daily cash needs to alleviate their current problems and those that come along [45]. The choice of payment mode for AIV smallholder farmers depends on the market target and their production goal.

Additionally, in Bungoma County smallholder AIV farmers predominantly transact with final consumers who do not require a formal means of payment and transaction. Ochieng et al. [46], reported that there was a significant rise in the vegetable farmers who were calling off the contractual agreements due to delayed payments.

The distance to the markets covered by a smallholder AIV farmer negatively influenced the commercialization of African Indigenous Vegetables at the 1% significance level. An increase in the market distance reduces the likelihood of AIVs smallholder producers to commercialize by 18.4%. With the unpredictability of AIV prices and high transaction costs incurred in selling AIVs, smallholder farmers prefer to either sell at the farmgate or use AIV for household consumption rather than trekking distances to an unpredictable market. According to Kangile et al. [47], the longer the distance to larger markets, the more smallholder farmers in Tanzania will consider selling their product at the nearest market or using the produce for household consumption. This clearly shows that distance cannot be overlooked when targeting the marketing of agricultural produce among smallholder farmers.

The time duration taken to reach the market is another factor that influenced commercialization significantly and positively at 10%. This signified that the duration impacts the commercialization in that a unit increase in the duration time taken to access the market increases the likelihood of commercialization of AIVs by 0.3%. This is attributed to the fact that smallholder farmers in Bungoma County who produce AIVs are approximately less than 1 km away from the proximity of the market. Thus, an increased unit in the time taken to reach the market would not greatly discourage a farmer from delivering the produce to the market. Mayekiso et al., [48] findings shows that distance positively influenced the commercialization of vegetables in South Africa due to the closeness of farmers to the local markets. In contrast, Jalango et al., [49] reported that the time required by farmers in Siaya to reach the market negatively influenced commercialization due to the high transaction cost involved. These contradictions are attributed to the fact that the farmers in Bungoma were very close to the market and used less than one hour to deliver AIVs compared to those in Siaya County, who were generally very far from the market.

Value addition positively and significantly influenced the commercialization of AIVs at the 5% significance level. This implies that an additional value added to AIVs increases the likelihood of commercialization by 4.7%. Adding value to AIVs, grading, sorting, and packing impacts the commercialization of AIVs, which is attributed to the fact that it creates new market opportunities for AIVs and increases profitability for smallholder AIV farmers. According to Arumugam et al. [50], adding value to AIVs is the most important activity that smallholder farmers in Zambia can venture into to obtain a favourable price for AIVs. However, value addition in Africa is found to be favourable due to the poorly developed marketing strategies for AIVs [45].

The yields of AIV had a significant positive influence on the commercialization of AIVs at the 5% significance level. An increase in the yields of AIVs increased the likelihood for commercialization of AIVs by 2.6%. This is attributed to the fact that high yields reduce the cost of production per unit, making the products more competitive in the market and potentially increasing the profitability of the business. On the other hand, low yields of AIVs limit the availability of the products and increase the cost of production per unit, thus decreasing the competitiveness of AIVs in the market. This results in reduced profit by smallholder farmers. Low yields can also make it difficult for farmers to meet the demand for the products, which can result in lost sales and reduced market share. Mersha and Ayenew [51] note that an increase in the yield of traditional crops in Nigeria is associated with increased commercialization, incomes, and the ability to diversify household diets.

AIV production costs negatively influenced the commercialization of AIVs at 1% significance level. These results indicated that when keeping other factors constant, the increase in the AIVs costs reduces the likelihood of commercializing at 8.9%. The higher the cost of production, the higher the final price of sale. At a higher price, buyers are reluctant to buy and those willing to buy always offer lower prices thus lowering the general profitability of the producers [52]. The higher cost of production equally discourages producers from widening production, instead, they focus on production for household consumption. According to Woltering [53], the low commercialization level of vegetables among smallholder farmers in Zimbabwe is attributed to the high cost of motor pumps and drip irrigation required in the production of vegetables.

5 Conclusions and recommendation

The aim of this study was to identify the factors that influence the commercialization of African Indigenous Vegetables (AIVs) among smallholder AIV farmers. According to the study, the most produced AIV in Kenya is African nightshade, then cowpeas, spider plants, jute mallow, and vegetable amaranth respectively. The results from a fractional regression model revealed that eight of the explanatory variables significantly influenced the commercialization of AIVs among

smallholder farmers. These variables included the gender of the farmer, land size, mode of payment, distance to the markets, AIV yields, AIV cost of production, duration to reach the market, and value-added. The factors that positively influenced commercialization were land size, AIV yields, duration to reach the market, and value-added to AIVs. Those that negatively impacted commercialization comprise of, the gender of the farmer, mode of payment, distance to the markets, AIV cost of production, and duration to reach the market.

6 Recommendation

There is a need to establish a mechanism policy that considers the permanent mode of payment to be done in the market to ensure that smallholder AIV farmers are not disadvantaged. Encouraging the organization of farmers into organizations, cooperatives, and community-based groups can ease access to vegetable transportation and finding markets for AIVs. Facilitating AIV training and education for smallholder farmers can capacity build their expertise and hands-on skills in production and marketing, financial literacy, and value addition. This approach can immensely reduce the volume loss of produce due to poor postharvest handling. Like other cash crops, the county government should put concerted efforts into supporting the production of AIVs by engaging several households, especially men, to participate in producing and marketing AIVs as it is often perceived to be female-dominated. This would equally facilitate the contribution to improved quality of AIVs supplied to various markets, as men are curious about better markets.

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Author contributions SNN identified the research problem, prepared the research tools, collected data, analyzed the data and wrote the manuscript. HB provided technical advice and supervised the work right from problem identification. KWS provided academic advice, provided constant comments and supervised the work.

Data availability The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate This study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the Egerton University Research Ethics Committee (EUREC) approval number EUISERC/APP/236/2023 and the National Commission for Science, Technology, and Innovation (NACOSTI) approval (licence number (NACOSTI/P/23/25926). Informed consent was obtained from participants involved in this study who were briefed in the presence of a witness (local experts) that their participation in this study was voluntary and that confidentiality would be maintained at all times. All study participants were above 20 years of age and provided informed verbal consent prior to study enrolment. The collected data were kept anonymous, confidential, and in accordance with international and national ethical guidelines. Consent for publication was equally obtained at this point.

Competing interests We declare that this work is original academic research conducted by the authors. The manuscript has not been submitted elsewhere and is not under consideration by any other journal. We declare no conflict of interest.

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