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UTILIZATION OF ALATE TERMITES (*MacrotermeSpp*) TO IMPROVE NUTRITIONAL SECURITY AMONG HOUSEHOLDS IN VIHIGA-KENYA

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ABSTRACT

Among key concerns all over the globe is the rising demand for high-value protein, expected to double by2050 due to the rapidly growing population in developing economies, Kenya included. To meet the new demand, conventional livestock may prove expensive as the current production system remains unsustainable. Calling for research on alternative sources of protein, hence a switch to affordable and environmentally acceptable protein sources of which approximately 1,900 insect species are consumed worldwide. Alate termites have thus received considerations in this line. However, information utilization and abundance is largely anecdotal and disjointed due to the limited knowledge of sustained off-season production, appropriate processing technology and packaging for all end-user market segments. This survey partly fills this knowledge gap by assessing the capacity of farmers on current harvesting and utilization of the alate termite. The research followed a cross-sectional descriptive survey design that informed data collection from a target population of 64,752 households. A Semi-structured questionnaire was used to collect data from a sample of 204 households obtained through multistage sampling procedure within Vihiga County Western Kenya. Descriptive and exploratory statistics was applied in summarizing the results while chi- square statistic was used to predict the likelihood of termite collection to improve household diet diversification. R version 4.0.2 (RCore Team, 2020) was employed to carry out data processing. The key findings revealed a strong association between the respondents' socio-economic status and respondents' capacity, including attitude on consumption, methods of utilization. There is a strong association of termite availability and their role in alleviating hunger through household income and food security.Training of the mass about sustainableharvesting methodsand limited use of agrochemicals would therefore go a long way in keeping termite ecosystem.

Keywords; Alate termites, Food security, edible insects, Livelihood

INTRODUCTION

The entire globe is faced by the issue of food insecurity especially Sub Saharan Africa. Threats of malnutrition and stuntingposea greaterchallenge withfearstofeedthedoublingpopulationprojectedbythe year2050.(FAO2013). Kenya as one of the affected economies has made substantive strides in reducing the prevalence of malnutrition, stunting and food insecurity, though several policy interventions which contributed to the fall in the cases of malnutrition from 35% in 2008 to 26% in 2014. (KNBS*et al*. 2015; ICF Macro, 2010). Additionally, there have been coordinated National Nutritional strategies and initiatives committed to eradicating hunger and attaining afood-secure nation is included in the development blueprint of the vision 2030, aligned as part of the broader medium-term development plans. Regardless of the efforts, Kenya continues to experience severe food insecurity with 3.4 million people in 2007 suffering from acute food insecurity (USAID, 2017a) due to persistent drought, devastating floods as a result of climate change, high cost of domestic food production, low purchasing power and displacement of farmers during the 2007 post-election violence. Therefore, to achieve the goal of environmental sustainability while meeting the increasing demand for protein calls for scaling up intervention research on sustainable solutions to guarantee access to affordable and accessible nutritious food. To meet the demand, animal proteinhas provenexpensive and unavailable due to challenges onproduction systems, pressure onagricultural land as well as effects of Green House gas emissions (GHGs) (Steinfeld H, *et.al.*,2006; Oonincx D.G., et.al., 2010).

Among the alternative food sources are the high-value edible insects that are being used to supplement the animal-based protein. Entomophagy, the collection and consumption of insect could be a possible solution as a food supply chain for developing countries, Kenya included (van Huis, 2013). Edible insects have proved potential and significant by research for future food and feed alternatives with high nutritional value and a lesser ecological footprint.(FAO,2013).Therefore,thereisa focusonthe supplysidetoestablishandoptimizeinsectproductionand develop functional edible insect value chain. Nevertheless, different studies have shown that entomophagy contributes positively to nutrition, health, environmental sustainability and household livelihood for those involved intheedibleinsectvaluechain(vanHuis,2013),ofwhichalatetermitesareamongtheedibleinsectsthathave gained substantial attention in collection, marketing and consumption. (Huis, 2012; Anankware *et al.*, 2016). Currently, over 1,900 insect species are consumed (van Huis, 2013), depending on their stage in the life cycle. Anankware *et al.*, (2015) reported consumption of some edible insect species including termites in Asia, South Africa (SA), North America (NA), Africa and Australia with SA, NA and Asia being high on the ranking. Entomophagy has been reported in Africa (van Huis, 2013) mainly collected from harvesting from the wild for either livestock feed or food. The most commonly consumed insect species include caterpillars *(Lepidoptera*) 18%, bees, wasps and ants (*Hymenoptera*) (14%), grasshoppers, locusts and crickets (*Orthoptera*) (13%), cicadas, leafhoppers, planthoppers, scale insects and true bugs (*Hemiptera*) (10%), termites (Isoptera) (3%), dragonflies (*Odonata*) (3%), flies (*Diptera*) (2 %) and other orders (5%) (FAO, 2013; Arnold van Huis, 2013). Over 2.5 billion people eat insects in Africa and Asia and sale for income generation in rural and urban areas. (FAO, 2010).

According to a report by FAO, (2013), different studies have assessed the nutritive value of edible insects of which different percentages have been released that are not directly comparable due to variations of species and analytical procedures. However, International Network of Food Data System (INFOODS) and FAO are working to streamline nutritional data and the insects have proved efficient in terms of production as they have a short reproduction cycle, require less water and land, emits fewer greenhouse gases and can feed on biowastes. (FAO, 2013; van Huis, 2016). Insects are a potential source of protein (amino acids), fats, minerals and essential vitamins including vitamin A, B complex and C (Johnson, 2010). They pose low risks of zoonosis (Ayieko *et al.*, 2011) with high entrepreneurial opportunities for the population worldwide.

In Kenya, different insect species including the alate termites, grasshoppers, locusts, lake flies and crickets havebeen embraced as important parts of the diet (Ayieko, 2013;Kinyuru *et al.,* 2012). These insects have received a boost due to increased research on their potentiality. The consumption of the soldier termites of the*Macrotermes spp* has been reported in Zimbabwe as well as parts of Sub-Saharan Africa and SA by Van Huis, (2003). Termite collectionandconsumptionhasbeenreportedby Ayieko*et al.*(2010) inWesternKenyathat formsthestudyregion, with alate termites being the most commonly harvested at the onset of the first rains following a dry season.

Termites are sold in open markets in various parts of the world including Zambia and Uganda, however, in Kenya, commercialization has been majorlyina fewcounties inthe Westernregionthat formed the area ofstudyincluding; Vihiga, Kakamega and Bungoma counties. According to a report by GoK (2013), Vihiga county is depicted to be characterized by small scale crop and livestock production which predisposes the population to dangers of food insecurity and malnutrition. Additionally, a report by the county development plan of (2018-2022) indicates that the county faces a challenge of malnutrition resulting in stunting, wasting and underweight of approximately 21% of children population under the age of 5. Therefore, diversification of food resources and promotion of value chain activities of the available food resources would promote employment to contribute to household cushioning techniques against poverty, hunger and promote food security. Harvesting, commercialization and consumption of alate termites are experienced mostly during the long rainy season depicted by the high quantity of the harvested alate termites that supplements household diets through both the direct and indirect livelihood pathways.

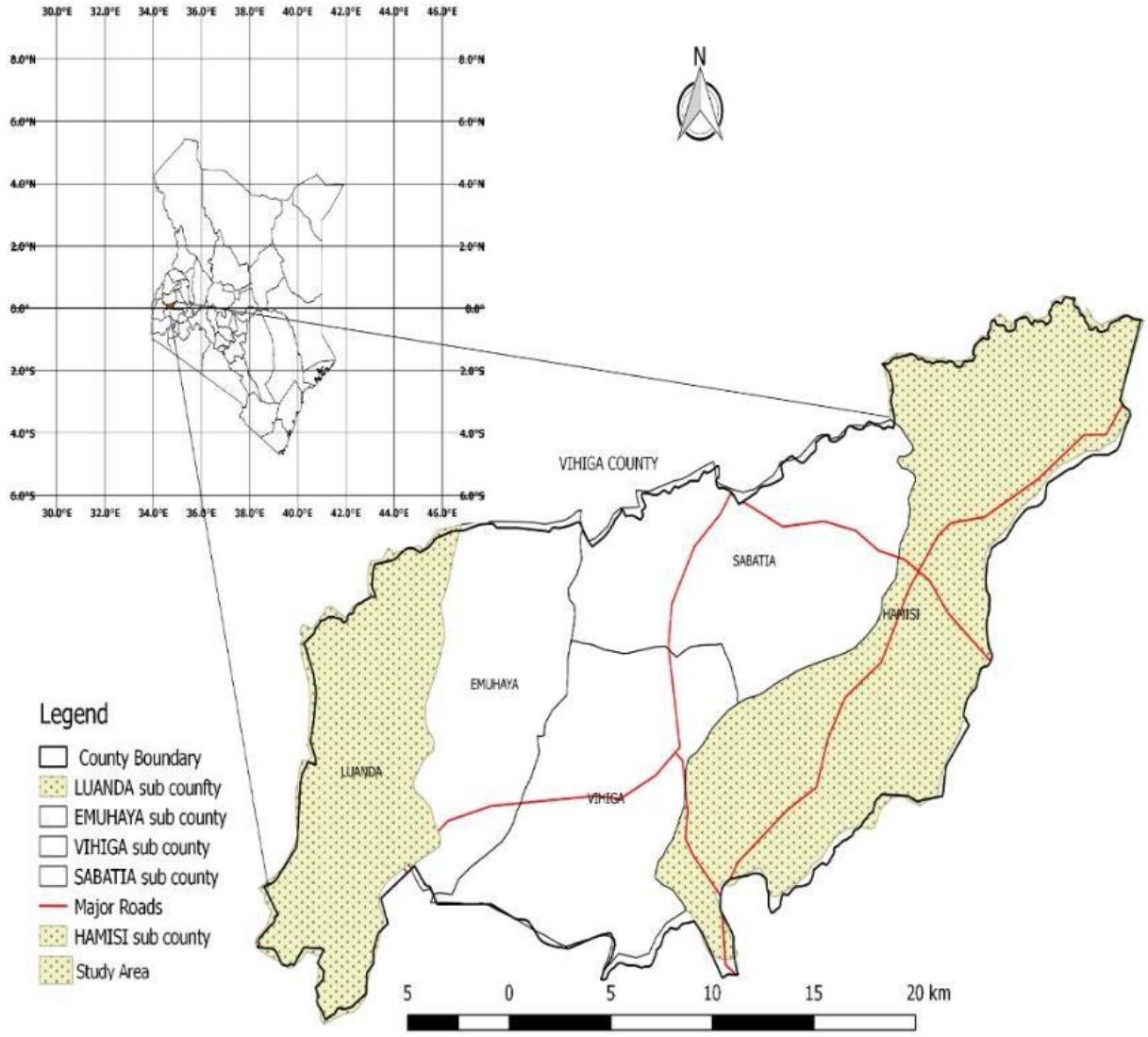
Termites are sold in whole after frying or in processed products such as Crackers, muffins, sausages and meatloaf. Thisshowsitspotentialforfoodsecurityand sourceofhouseholdlivelihoods. (Ayieko*et al*.,2010). Fromliterature, it is evident that termites and termite products are accepted by the greater population in the lake region of Kenya, therefore, there is need to explore their economic and nutritional potentiality by assessing the households already benefiting from the utilization of the termites. Studies have been done on cases of acceptance of insects and willingness to buy them (Ayieko *et al.*, 2010), however, facts on potentials of termites to contribute to household food security and benefits of utilization to a household in terms of economic aspects remains unexplored area of research. Thus this study focused on how utilization of alate termites contributes to household livelihood dietary diversification to make recommendations on its potentiality as an enterprise by promoting residents' capacity.

METHODS

Studyarea

The study was conducted in Luanda and Hamisi in Vihiga County Kenya as a sample representation of urban and rural households respectively as in figure 1. The study area was purposively selected due to data concentration looking into the emergence of termite commercialization and the population density within the county.

Cross-sectional survey design was used to obtain the extent of harvesting, commercialization and consumption of alate termites. Accordingto KNBS(2019),Hamisisub-countyrecorded thehighestnumber ofhouseholdsof37,982 selectedtorepresenttheruralresidents, whileLuandasub-countyrecorded26,766whichwasarepresentationofthe urban residents that forms the largest known termites' commercialization Centre within Vihiga county.



Source:GIS(Feb 2020)

Figure5:MapofVihigaCounty

Studyandsamplingdesign

The target population was obtained through multistage sampling procedures where for first and second stage, purposive sampling was employed to select Vihiga County as area of study, with total population frame of 64,752 households within which Luanda and Hamisi sub-counties were selected to represent the urban and rural population respectively due to the emergence of harvesting and commercialization of alate termites. In the third stage of sampling,two wards wereselectedrandomlyfromeachsub-countytoobtainagoodrepresentationdata where, from Luanda sub-county, Luanda south and Luanda Township were selected whereas, from Hamisi sub-county, Tambua andGisambaiwardswereselected.Thesamplingprocedurewasguidedbyinformationfromsub-countyagricultural offices under the guidance of the extension staff who acted as the contact persons in the data collectionprocess. The last stage

comprised the use of simple random sampling procedure to obtain 120 and 84 respondents from Hamisi and Luanda sub-counties giving a total of 204 respondents including harvesters, marketers and consumers. The research data was collected by the use of structured pretested questionnaire administered through face to face interviews bytrained research assistants using the online data kit (ODK collect).The application of the ODK was to ensure efficiency, convenience, cost-effectiveness and reduction of human errors that would be committed during data entry. The questionnaire was organized into four sections containing information on respondents' demographic characteristics, farmers' capacity on collection and utilization of alate termites, termite collection and household income and food security.The data was cleaned and managed using the R version 4.0.2 (RCore Team, 2020).

Analyticalframework
Statistical methods *Chi-square tests*

Achi-squarestatistic wasused to evaluate whether thedistributionofcategorical variablesdiffers fromoneanother. The procedure compares the tallies or counts of categorical responses between two independent groups. The null hypothesis assumes that there is no association between two variables whereas the alternative hypothesis assumes that there is independence as it is for other tests like ANOVA, where a test statistic is computed and compared to a critical value. The critical value for chi-square statistic is determined bythe level of significance (0.05 in this study) and the degrees of freedom.

Thedegreesoffreedomforchi-squareiscalculatedusingtheformula;

$$df=\overset{r-1}{\underset{c-1}{\_\_}} \quad 1$$

Where*r*isthenumberofrowsand*c*isthenumberofcolumns.Iftheobservedchi-squareteststatisticisgreater than the critical value, the null hypothesis can be rejected.

Thechi-squareteststatisticisprovidedby;

$$\underset{E_i}{\chi^2}=\sum\frac{(O_i-E_i)^2}{\_\_\_\_\_} \quad \mathbf{2}$$

Where $O_{is}$are observed frequencies and $E_{is}$are the expected frequencies, and $x^2$is the chi-square test of independence.

RESULTSANDDISCUSSION

Thissurveyassessed attitude ofrespondentsonpreferencefortermiteproducts,levelofawareness, knowledge/skills on utilization and methods of utilization. There was an inclusion criterion (*table 1)* of which only respondents that participated in either consumption, harvesting and commercialization of alate termites were interviewed. The age of respondentsranged from1 to over 65, with60% ofrespondentsbeing female. About 58.1% withinthe age of15-44, and theleastrepresentationof7.7%oftherespondentsofage65and above. Asignificant proportion(about93%)of the respondents were educated, however, there was a direct correlation between involvement in alate termite consumption and education level of the respondents, 38% of the respondents were pure farmers

Consumptionofalatetermites.

Frequency distribution revealed that 81% of the respondents consume alate termite attributing to the higher rate of utilization of alate termites (*Macrotemes spp.*). This corroborates with the findings of Nyeko and Olubayo, (2005) who cited that both male and female of all ages consume soldiers, alates and workers in Uganda. However, twoother termite species were also mentioned to be harvested for other purposes in Vihiga county, including the subterranean and Kalotermitidae, (Boafo, H.A, Afledzie-Obresi, S.,2019), collected for chicken feeding in Ghana. The consumption rate in Vihiga was higher regardless of the age of respondent, this concurs with a studyby Sere *et al.*, (2018), that the consumption rate is distributed among the various age categories.

Table10:RespondentsInvolvementrateinfrequencies.

Parameter	Variable	Frequency	Percentages
Consumptionofalatetermites.	YES NO	164	81%
		40	19%
Harvestingofalatetermites	YES	64	31%
	NO	140	69%
Commercializationofalatetermites.	YES	32	50%
	NO	32	50%

ConsumerPreferenceonFormsofAlateTermites

Results of this survey in *Table 2* reveals a greater percentage of respondents consumes raw (straight from the mound) and fried alate termites (AT) due to the taste thus preferred to blanched and sundried (Van Huis *et. al*.,2013) which are mostly utilized for preservation purposes. Chi-square statistics on the categorical variables socio- economic characteristics and their influence on the choice of alate termites revealed a statistical significance *(p=0.023)* between occupation and consumption of blanched alates, (*p=0.029*) level of education on the consumption of raw alates and (p=0.018,0.036,0.05) between marital status and consumption of blanched, sundried and raw alates respectively. In all, 81% of the respondents alluded to be consuming alates. However, there was no statisticalcorrelationbetweenpersons'genderandconsumptionofeitherformsalatetermites.Theconsumptionrate was dependent on consumers' attitude looking at forms being either being easy to prepare or nutritious to the retention of the nutrient properties.

Table11:Correlationbetweenconsumers'preferenceontheformofutilizationandselecteddemographic variable.

	Fried		Blanched		Sundried		Raw	
Variable	**Freq**	**p-value**	**Freq**	**p-value**	**Freq**	**p-value**	**Freq**	**p-value**
Occupation								
Farmer	67		33		65		55	
Educationist	31	0.421	7	0.023*	20	0.772	18	0.712
Casuallabourer	29		16		28		24	
Other	48		36		48		39	
Education								
Non-formal	12		6		13		10	
Primary	54	0.082	34	0.111	52	0.651	49	0.029*
Secondary	58		28		57		48	
Tertiary	41		24		39		29	
Maritalstatus								
Married	104		62		102		82	
Single	34	0.065	17	0.018*	32	0.036*	28	0.05*
Divorced	3		1		2		3	
Widow/er	24		12		25		23	

Note;*showsthelevelofsignificance.At95% C.I

χ2-Wasusedtodeterminetherelationshipbetweenthecategoricaldemographicvariablesandconsumers preferred forms of alate termite preparation.

Figure6:MethodsofalatetermiteutilizationinVihigacounty

Awarenessofmethodsofalatetermiteutilization
Alate termite utilization within the studyarea was determined bylooking into the respondents' opinion as displayed in *figure 2*. First, the results showed a proportion of the respondents to be using alates as chicken feed (53%), of which 70% were female who purported to be collecting alate termites to feed their chicken this attributed to the fact that women could be the most involved in poultry management. Supported by findings of Boafo, H.A, *et.al*., (2019) that only 11% of the respondents said they never give termites to their poultry in Ghana. Chi-square test provided a $p>0.05$depictingthat gender has no significantinfluence of the respondents'opinionon utilizationaschicken feed.

However, with education level, a total of 104(51%) agreed out of which 74 (71%) represented respondents in primary and secondary education level, even though respondents with tertiary education disagreed alluding thatthere are more health benefits associated with alate consumption and not as feed. More importantly, the statistical association was realized between the use of late termites as chicken feed and respondents level of education at $p=0.00044$, probablybecause farmers with higher education are those that have industrial or semi-industrial poultry farms and these are less suitable for the use of termites as protein feed. These farmers tend to stock a larger number of birds under intensive or semi-intensive systems and would require larger amounts of termites to feed their birds. On the other hand, occupation of the respondents showed a scientific significance as a proportion of 47(45%) out of total respondents were farmers as well the married population who agreed to the opinion to use alate termites.

65% of the respondents agreed to be utilizing the alate termites for health reasons, based on the nutritional proportions which are important for curbing malnutrition as cited byIjeomah, H. M., Oyebade, B.A.and Mazi, E.C., (2015) in Nigeria who relate the nutrition capacity of termites to crayfish thus considered healthy for children growth. Consideringrespondents'occupation,there is statisticalsignificance of $p=0.0371$, with farmers who tend to agree at 32% of total occupation categories. Likewise, respondents' marital status influenced the decision for the method of utilization where X^2 =26.59 ($P=0.0322$) with the married (41%) who tend to agree, this could be because the married are more concerned with the health status of the family. Even though, education status of respondents had no significance p>0.05, since respondents within primary (24%) and secondary (20%) are the greatly involvedin collection of the alate termites.

Results on the utilization of alate termites in figure 3 shows only 6.8% agreed to use of alate termites for poverty reasons. Gender and marital status of respondents had no correlation p>0.05. However, education level (X^2=27.314, p=0.026) and occupation ($X^{2=}$35.94, p=0.0017) of respondents were statistically significant. Occupation influences individuals' income level thus some collect for poverty having a majority of respondents in the primary and secondary level of education with low economic status are greatly involved in termite collection and consumption. Thisindicatesthepotentiality ofalatetermitesfor food,this isalsodepicted bya studyon thepotentialof insects for food and feed (Van Huis, 2015)

Harvestingofalatetermites
Informationcompiled fromthisstudyreveals62(30%) oftherespondentsparticipate inalate termitecollection, with a greater percentage being female supported by Josiah Taru & Bernard Chazovachii (2015) that females andchildrencontinueto dominate theprocessoftrappingin mostcases. Higher quantitiesofalate termitesareharvested soon after the first rainfall in the period of long rains between March to June 26(42%), and short rains around November to December 28 (45%) with least quantities during drought periods. Respondents (57%) perceived best harvesting time to be afternoon and morning hours. This is contradicted by Boafo, H.A, *et.al*., (2019) who cited that *macrotermes* are harvested throughout the year in some parts of Ghana, though this could be due to varying ecological conditions and the sub specie.

Harvesting is dominated by respondents of all the ages and gender (Huis, 2012) who mentioned that the knowledge of the species to be harvested is indigenous thus considered the size of the termite and the type of wings, this somewhat contradicts the results by Netshifhefhe, S.R, Kunjeku, E.C and Duncan, F.D, (2017) reporting that the harvesters used size, taste and colour of termites as well as the mound type and size to identify the species in Limpopo South Africa. This could be mainlybecause the researcher referred to the harvesting of both the alates and the soldier termites.

Common harvesting methods withinthestudyarea involved theuseofthesource oflightto attractthealate termites which are then collected into containers (30%), a similar harvesting method was reported in Zimbabwe by Chavunduka(1975).However,newemergingtechniquesincludeuseofabucketputupsidedownoveran

emergence hole/mound mentioned by (60%) of the respondents, this coincides with a study in Limpopo SA by Netshifhefhe, *et.al,* (2017), Boafo, H.A, *et.al*., (2019). Although in Limpopo, the hole was covered with sticks and leaves of either banana (*Musa paradisiaca Linnaeus* and *M. sapientum Linnaeus*) or *Peltophorum africanum,* while in Ghana Fresh branches with leaves from any plant are used. In Vihiga the banana leaves are used with grass or plant debris which were claimed to provide good shade for the alates and as they flyto the bottomofthe hole where they are trapped and collected.

Some harvesters do not own the mounds (individual land) therefore, have to travel averagely less than 4 km while many otherswalk 6-10KMtoharvest. But still harvestedfrom smalleremergenceholes away from themounds. The harvested quantities in case of surplus are preserved through sun drying (50%), pan-frying (41.66%) and refrigeration (8.33%). Even though, larger quantities are sold raw (direct from the mound).

Factorsmilitatingabundanceofalatetermites

The abundance of alate termites influences the extent of utilization, this was assessed by looking at respondents' information level. The respondents who had stayed in the area for more than 20 years (49.7%) alluded that there is variation in termite abundance over years. Most of the harvesters did not own mounds thus there was low harvest quantitiesdepending withregions,and could cover averagelylessthan1KM whilea majoritywould cover 6-10 KM to the mounds, this contributed to low quantities since the alates could emerge and be attracted by other sources of illumination as they swarm. Supported by a study in Imo states Nigeria, statistically showed low quantities of alate harvested in areas away from mounds, (Ijeomah, H. M., *et.al.*,2015). This, however, contradicts results from this study which revealed alates could swarm from wet grounds away from the mounds.

A chi-square test was run to determine the association between respondents' socioeconomic characteristics and awareness on factors determining the abundance of alate termites. Results obtained showed that respondents with formal education agreed with the fact that there is variation in abundance based on soil type, season and agrochemical utilization (p=0.034, p=0.003,0.008 respectively). Implying that through the formal education process they were able to learn as well as observe a reduction in quantities of alate species per harvest in a specific area.This influences the abundance of the alates. On the other hand, respondents' who had no formal education, mentioned that they use inherited knowledge and skills but are able to note the change in quantities with limited ideas on the facilitating forces.

However, there is a negative correlation between, marital status and awareness on factors limiting abundance although gender showed statistical significance in association to season influence *(p=0.002),* as female (61%) being more involved in harvesting than male. More importantly, there was a statistical significance between occupationand awareness *p=0.025*, with farmers (31%) who tend to agree most alluding that availability is influenced by the type of soil and continuous use of agrochemicals that contributes to change in soil properties and mound characteristics. However, variance based on agro-ecological conditions (35.8%) was also mentioned where the amount of rainfall and microclimate in an area influences abundance and swarming of the alate termites

Figure7:Factorsmilitatingabundanceoflatetermites

Therefore, the major factors determining abundance and utilization of alate termites (*figure 3*) include seasonality and weather (63.2%), type of soil in the localityand the continuous use ofagrochemicals. Thispartlycoincides with resultsbyIjeomah *etal*.(2015)inselectedcommunities inNigeriathat seasonisa majorfactor whichdetermines its abundance.Thisisbecauseduringtherainyseasonthealatesgoes forthe 'nuptial flight'howeverthisstudyhasalso revealed that continuous use of agrochemicals in the agricultural fields contributes to the reduced availability of the alate termites due to change in the chemical composition of the soil thus reduced abundance.

CONCLUSION

Considering facts as obtained in the data, quite a number of households have explored the options of livelihood diversification by benefiting from collection and utilization of alate termites. As a proof to the potentiality of the alate termites, most respondents supported the fact that alate termites are key in enhancing household diet diversification which in turn reduces cases of malnutrition as well as food insecurity. The two pathways ofhousehold food security were depicted by, greater percentage of respondents who uses the termites as food directly either,raw,blanched,sundriedorfriedinownoilas wellascommercializationtoobtainincome usedtoattainother household needs including, quality education, health care and maternity care. Farmers consider termites as very important because they are an easily available protein and play an important role in improving options of food consumed among rural and urban households when it is available. However, the species utilization is decreasing among the younger generations and urban dwellers even though it serves as a cheap substitute for conventional proteininthe diets of manyrural dwellers. It is good for childrenand women who require nutritious food and a high calorie diet. Its prices and high relative protein content can be harnessed to improve the nutrition of lactatingwomen. It can as well be used as an inexpensive and rich dietary supplement for households. The consumption of alate termites should thus be encouraged among city dwellers. The main challenge is on the collection of termite becausetheiravailabilityvarieswithseasonand weather,excessiveuseofagrochemicalsaswellastypeofsoiland, in some cases, farmers must walk long distances to obtain them. Therefore, trapping techniques should be promoted and the existing methods should be improved. In regions where trapping is uncommon, Research should also be conducted on methods to effectively preserve the species to make it available during the off-season as well as improve processing technologies for the farmers to ensure continuous supply in the diets.

RECOMMENDATION

Looking in to the responses it's clear that frequent training on value addition and marketing options to the farmers would enhance year round supply of alate termite enriched food products. Quite a number of organizationshave been making greater strides to promote all year round production technologies of edible insects however, alate termites are seasonal insects thus promoting storage techniques through value addition could promote all year supply. Likewise, even though most people consume alate termites there is need to promote awareness on the potentiality of the alate termites as an economic weapon against malnutrition and food insecurity in other parts ofthe world. There is dire need to carryout continuous training and awareness seasons to reduce over exploitation and natural habitat destruction through reducing the use of synthetic fertilizers.

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