

**INFLUENCE OF AGRICULTURAL COMMERCIALIZATION ON
MICRONUTRIENT NUTRITION AMONG RURAL HOUSEHOLDS IN OMORO
AND OTUKE DISTRICTS OF NORTHERN UGANDA**

BY

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**A DISSERTATION SUBMITTED TO THE DIRECTORATE OF RESEARCH AND
GRADUATE TRAINING IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN FOOD
SECURITY AND COMMUNITY NUTRITION OF GULU UNIVERSITY**

DECEMBER, 2023

DECLARATION

I Kisebe Lillian, declare that declare that the content of this dissertation is my original work and has not been previously submitted for any academic award in any university or higher institution of learning.

Sign 

Date 30th November, 2023

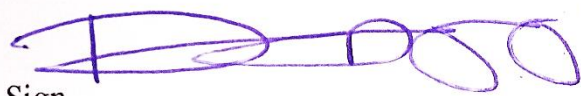
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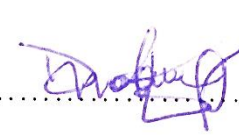
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DEDICATION

I dedicate this dissertation to my family, and friends. Special gratitude goes to Mr. Wokoto Steven and Mr. Tumwa Silver for their endless efforts towards my struggles. May the almighty God bless you and guide you through out your success journey.

ACKNOWLEDGEMENT

I utmost thank the almighty God for my life, and knowledge he has bestowed upon the work of my hands. I extend my sincere thanks to Mastercard Foundation @ RUFORUM, for supporting my Masters studies at Gulu University. I highly appreciate my supervisors Prof. Duncan Ongeng and Mr. Daniel Micheal Okello for their enormous support that enabled me to successfully complete this dissertation; I appreciate their guidance, patience, and advice throughout this journey. Lastly I appreciate the study participants and enumerators for their sacrifice and level of attention they provided to the details of the study during data collection.

TABLE OF CONTENTS

DECLARATION.....	i
ACKNOWLEDGEMENT.....	iii
DEDICATION.....	iii
LIST OF FIGURES	viii
LIST OF TABLES	viii
LIST OF ACRONYMS/ABBREVIATIONS.....	x
ABSTRACT.....	xii
CHAPTER ONE: INTRODUCTION	1
1.1 Background.....	1
1.2 Statement of the problem.....	4
1.3 Objectives of the Study.....	6
1.3.1 General Objectives.....	6
1.3.2 Specific Objectives	6
1.4 Research questions.....	6
1.5 Conceptual framework.....	7
1.6 Significance of the study.....	8
CHAPTER TWO: LITERATURE REVIEW.....	9

2.1 Agricultural commercialization and associated factors in low income country setting	9
2.2 Factors that influence food production in low income country setting	11
2.3 Factors that influence household nutrition in low income country setting	13
CHAPTER THREE: METHODOLOGY	15
3.1 Study Area	15
3.2 Research Design.....	15
3.3 Study population and participants.....	16
3.4 Sample size and sampling framework	16
3.5 Measurement of key variables	17
3.5.1 Assessment of the level of commercialization.....	17
3.5.2 Assessment of the level of production of iron, vitamin A and folate	17
3.5.3 Assessment of the level of intake of vitamin A, folate and iron.....	18
3.6 Study instrument	18
3.7 Data analysis	19
3.8 Ethical Consideration.....	22
CHAPTER FOUR: RESULTS	23
4.1 Socio-economic characteristics of study households.....	23
4.2 Household agricultural commercialization and associated factors	26

4.3 Influence of agricultural commercialization on household production of iron, folate and vitamin A	29
4.3 Influence of agricultural commercialization on household consumption of Iron, vitamin A and folate.....	33
CHAPTER FIVE: DISCUSSION.....	39
5.1 Household Agricultural Commercialization and associated factors	39
5.2 influence of agricultural commercialization on production of iron, folate and vitamins A	43
5.3 Influence of agricultural commercialization on consumption of iron, folate and vitamin A	46
CHAPTER SIX: CONCLUSON AND RECOMMENDATIONS.....	51
6.1 Conclusions.....	51
6.2 Recommendations.....	52
6.2.1 Recommendations for practice	52
6.2.2 Recommendations for further studies	52
REFERENCES.....	53
APPENDIX.....	74

LIST OF TABLES

Table 1:Description of variables used in the regression analyses.....	21
Table 2: Description of variables used in the regression analyses.....	24
Table 3:Socio-demographic characteristics of households measured as continuous variables	25
Table 4: Proportion of households cultivating the different crops	26
Table 5: Level of commercialization	27
Table 6: Determinants of household agricultural commercialization.....	29
Table 7: Association between household agricultural commercialization and micronutrient production	31
Table 8: Association between household agricultural commercialization and micronutrient production	31
Table 9: Influence of HCI on vitamin A production.....	32
Table 10: Influence of HCI on production of folate	33
Table 11: Association between household agricultural commercialization and micronutrient consumption.....	35
Table 12: Influence of agricultural commercialization on iron consumption.....	36
Table 13: Influence of HCI on vitamin A consumption	37
Table 14: Influence of HCI on folate consumption	38

LIST OF FIGURES

Figure 1: Conceptual framework for the study, (adopted from (Qaim et al., 2019) _	7
Figure 2: Level of production of micro nutrients aggregated by food source	30
Figure 3: level of consumption of micro nutrients aggregated by food source	34

LIST OF ACRONYMS

2SLS:	Two stage least square regression model
AC:	Agricultural Commercialization
CAADP:	Comprehensive Africa Agricultural Development Programme
CAO:	Chief Administrative officer
FAO:	Food and Agriculture Organization of the United Nations
FCT:	Food Composition Tables
Fe:	Iron
GUREC:	Gulu University Research Ethics Committee
HCI:	Household Commercialization Index
HIV:	Human Immune Deficiency Virus
IFAD:	International Fund for Agricultural Development
Kg:	Kilograms
KM:	Kilometers
Mcg:	Microgram
Mg:	Milligrams
NA:	Not applicable
NAADS:	National Agricultural Advisory Services

NGO:	Non-government Organization
RDA:	Recommended Dietary Allowance
SDG:	Sustainable Development Goals
SPSS:	Statistical Package for Social Science
SSA:	Sub Saharan Africa
TLU:	Tropical Livestock Unit
UBOS:	Uganda Bureau of Statistics
UNICEF:	United Nations Children's Fund
VIF:	Variance Inflation Factor
WFP:	World Food Program

ABSTRACT

Micro-nutrient deficiencies are a serious nutritional challenge among households in Otuke and Omoro districts of northern Uganda, majority of whom depend on farming for food and income. Agricultural commercialization (AC) is a strategy being promoted to address rural poverty and food and nutrition insecurity in localities such as Omoro and Otuke districts. However limited information exists on how AC influences rural household micronutrient nutrition in such localities. Making use of 400 randomly selected households, this study examined the influence of AC on micronutrient nutrition in Omoro and Otuke districts. Specifically, the study assessed the factors that influence AC and the influence of agricultural commercialization on production and consumption of vitamin A, iron and folate. Using household commercialization index as a measure of agricultural commercialization, results showed that the level of AC in the study area was 61% with Omoro having 63% while Otuke had 54%. Tobit regression analysis showed that gender of the household head ($p<0.023$), primary food source ($p<0.01$), credit availability ($p<0.01$), membership in farmer groups ($p<0.05$), and methods of land tillage ($p<0.001$) significantly influenced AC. Two-stage least square regression showed that AC affected the production of iron ($p<0.01$), folate ($p<0.01$), and folate consumption ($p<0.01$). This study has demonstrated that AC has the potential to enhance production and consumption of micro-nutrients of public health concern. Based on these findings, development of strategies and policies that promote AC to address rural household micronutrient intake should take into account the agricultural commercialization factors identified and how commercialization influences production and consumption of micronutrients.

Keywords: *Agricultural Commercialization, micronutrient production, micronutrient consumption; iron, folate, vitamin A*

CHAPTER ONE: INTRODUCTION

1.1 Background

Undernutrition challenge has been a global concern over the past decades and is expected to increase over the coming decades as food systems change due to environment pressures (Myers et al., 2017). Undernutrition increased among children, adolescents and women globally during COVID 19 pandemic as food systems became disrupted (Heidkamp et al., 2021). For instance, over 1.8 billion adolescents worldwide with 90% coming from middle- and low-income countries were reported to be undernourished. There was increased cases of stunting and underweight among children and women under reproductive age (Parul & Smith, 2018). Furthermore anaemia among adolescents and lactating mothers continues to be a challenge among rural households (Office of Prime Minister, 2019).

Undernutrition is a major cause of death among children under five years in Sub-Saharan Africa (SSA) (Marx et al., 2014). Child death incidences associated with undernutrition have been shown to be more prevalent in countries of East and West Africa (Akombi et al., 2017). For instance, the prevalence of stunting and underweight in Uganda is 6.9% and 1.3% among children under the age of 5 years and women between the ages of 20- 49 in rural communities (Balci et al., 2021) majority of which are from the northern part of Uganda (Sserwanja et al., 2020).

Undernutrition was reported as highest in Otuke District in Lango sub region and Omoro district in Acholi sub region of northern Uganda where World Food Program (WFP) in their strategic annual report still identified the two districts to have higher cases of undernutrition (world food program, 2021). According to UNICEF (2019), 28% of the children in northern Uganda were reported to be stunted, 9% of children from Omoro district and 15% from Otuke

district were reported wasted, 34% of the children from Omoro district and 19% from Otuke district were suffering from anemia, 25 % of the adolescents and women were reported to be anemic. Omoro had higher cases of anemia (30%) compared to Otuke (19%).

In relation to undernutrition, micro-nutrient deficiencies are on the rise and remains a global nutritional concern (Ogutu et al., 2020). For instance, over 2 billion people around the world suffer from micro-nutrient deficiency. A decade ago, micronutrient deficiency rate was at 29% worldwide, 40% in low income and middle income countries while SSA ranked the highest at 60% in 2013 (Miller & Welch, 2013) .This figure became even higher in 2021, due to COVID-19 pandemic (Burki, 2022). Similarly, the prevalence of micronutrient undernutrition has increased by 15% since 2010 (Cesare et al., 2021). Micro nutrient deficiency is more common in Africa, with sub-Saharan Africa (SSA) having the highest rates. For instance, over 10% of people in SSA are undernourished and thus, suffer from micro nutrient deficiency in some way (Kansiime et al., 2021).

In Uganda, the prevalence of micronutrient deficiencies among children under 5 and women of reproductive age is above the World Health Organization target to lessen and sustain the prevalence under 5% by 2025 and the highest proportion of affected people are in northern Uganda (Adebisi et al., 2019). The rate of micronutrient malnutrition in northern Uganda is at 24.4% where Omoro district is at 10% and Otuke district leads by 15% (Development Initiative for Northern Uganda, 2019).

Nutritionally micronutrient deficiencies are caused by several factors including inadequate dietary intake of micro nutrients like vitamin A, iron, and folate which are of great significance. Poor vitamin A intake is linked to night blindness and infertility, which in severe situations leads to a disorder called *xerophthalmia*. On the other hand, iron deficiency is related to anemia

(Sahile et al., 2020) while folate deficiency can compromise synthesis, repair and methylation of DNA (Cantarella et al., 2017).

A number of strategies have been developed to alleviate micronutrient deficiency in low income countries. These include medical supplementation (Ernawati et al., 2021), genetic improvement of crops (Hoffman, 2017), agronomic bio-fortification and industrial fortification. Agricultural interventions such as genetic improvement and bio fortification have led to release of micronutrient crops such as orange flesh potatoes, iron rich beans, and yellow cassava (Wakeel et al., 2018). In the context of micronutrient availability, agriculture plays two key roles in addressing micronutrient deficiency. First, agriculture is responsible for the production of the much-needed foods that supply adequate micro-nutrients. Research shows that almost all locally grown foods contain some quantity of micronutrients. Food from animal sources and legumes are excellent sources of iron and folate (Hattab et al., 2019), whereas fruits, roots, and vegetables are excellent sources of vitamin A and folate, yet micronutrient deficiencies, still affect a sizable portion of the population (Kennedy et al., 2019). Secondly, agricultural is also a source of income to many households in the world, providing them with sustainable livelihood sources and income to among others to acquire the needed foods (Myeni et al., 2019). This illustrates the potential of agriculture in ameliorating micro-nutrient deficiencies in low income countries. In such countries, smallholder farmers dominate agricultural production, producing food on subsistence levels and occasionally selling the surplus food to provide for other basic needs (Raj & Hall, 2020). Agricultural is also a major source of income to many households in low income countries and as such it is a major livelihood base (Maja & Ayano, 2021).

Information available from the World Bank, (2019) indicates that investments in agriculture in low income countries are directed largely towards poverty reduction than nutrition

improvement. However, considering that investments in agriculture in those countries usually target smallholder rural producers, there is need for a tradeoff to be achieved between poverty and food insecurity if nutritional challenges such as micronutrient deficiencies are to be addressed sustainably (Von Braun et al., 2021).

The dual role of agriculture in supporting income and food security needs of rural households in low income countries has prompted the promotion of agricultural commercialization (AC) as a strategy to make agriculture more effective in poverty reduction and food and nutrition security improvement (Sergio, 2022). In such a way, households are able to produce food for consumption but also sell the surplus so as to meet other needs. Agricultural commercialization is expected to improve nutrition outcomes by making food more available and households accessing the food through market pathway or own production (Gordon, 2022). However, for agricultural commercialization to contribute efficiently to addressing micro nutrient challenges among rural households such as those in Omoro and Otuke districts, it should lead to enhanced production and consumption of micronutrients. Empirical evidence is required to enable tailoring of agricultural commercialization to address micronutrient challenges among rural households in localities such as Omoro and Otuke districts of northern Uganda.

1.2 Statement of the problem

Micronutrient deficiency is a serious nutrition challenge in Omoro and Otuke districts compared to other districts in northern Uganda. The latest demographic health statistics indicate that Otuke leads with 6.1% followed by Omoro at 5.9% (Uganda Bureau of Statistics, 2020). This implies that the health wellbeing of people in Otuke and Omoro districts is highly compromised compared to those of other districts in the region. This is because micronutrient deficiencies lead to development of negative health conditions. For instance vitamin A deficiency causes night blindness (Stevens et al., 2015) and is associated with frequent

infections, iron deficiency causes nutritional anemia especially among children, pregnant women and women under reproductive age (Feyrer et al., 2017) while folate deficiency is associated with line-1 hypomethylation in women (Agodi et al., 2015) as well as cerebral effects and mitochondrial disease (Pope et al., 2019). This situation if left unattended to will negatively affect human capital development and productivity and overall economic wellbeing of people in the two districts.

Agricultural commercialization is a strategy believed to improve food and nutrition security and micronutrient deficiency in turn among rural households. This is on the promise that it can enable production of sufficient nutritious food and generate more income that can be rationalized to buy other food items that are not produced by households through selling of the surplus produce (Latika et al., 2021). However, the rising cases of micro-nutrient deficiency, particularly vitamin A (Muriuki et al., 2020), iron and folate (Arias et al., 2020) despite efforts by government and other development agencies in promoting agricultural commercialization (Ministry of Agriculture Animal Industry and Fisheries, 2017), raises a question as to how agricultural commercialization impacts on micro-nutrient intake at household level in such localities. Empirical evidence from previous studies have illustrated how agricultural commercialization influences food and nutrition security largely in terms of food availability and macro-nutrient intake (see for example Carletto et al., 2017, Abdoellah et al., 2020). However, limited information exists on factors that influence agricultural commercialization, and how agricultural commercialization influences production and consumption of micronutrients of public importance such as vitamin A, iron and folate in rural localities such as Ouke and Omoro districts in Northern Uganda.

1.3 Objectives of the Study

1.3.1 General Objectives

The main objective of this study was to determine the influence of agricultural commercialization on micronutrient nutrition among rural households in Omoro and Otuke districts of Uganda

1.3.2 Specific Objectives

The specific objectives of the study were:

1. To assess the determinants of agricultural commercialization in Omoro and Otuke districts
2. To evaluate the influence of agricultural commercialization level on household production of vitamin A, iron, and folate.
3. To determine the influence of agricultural commercialization level on the household consumption of vitamin A, iron, and folate

1.4 Research questions

The study answered the following questions:

- i. What factors influence agricultural commercialization among households in Omoro and Otuke districts?
- ii. How does the level of agricultural commercialization influence household's production of vitamin A, iron, and folate?
- iii. How does the level of agricultural commercialization influence household's intake of Vitamin A, iron, and folate?

1.5 Conceptual framework

Conceptual framework of the study is presented in Figure 1. The framework shows factors that influence agricultural commercialization and how agricultural commercialization influences production and consumption of micro-nutrients. The framework illustrates that agricultural commercialization is influenced by several factors that can be categorised as social economic, geographical and institutional factors. These factors in turn influence the production of micro-nutrients such as vitamin A, iron and folate. Production of such micro-nutrients increases their availability to households for consumption. On the other hand, through market purchase, households are able to access a variety of food crops that can improve nutrient consumption.

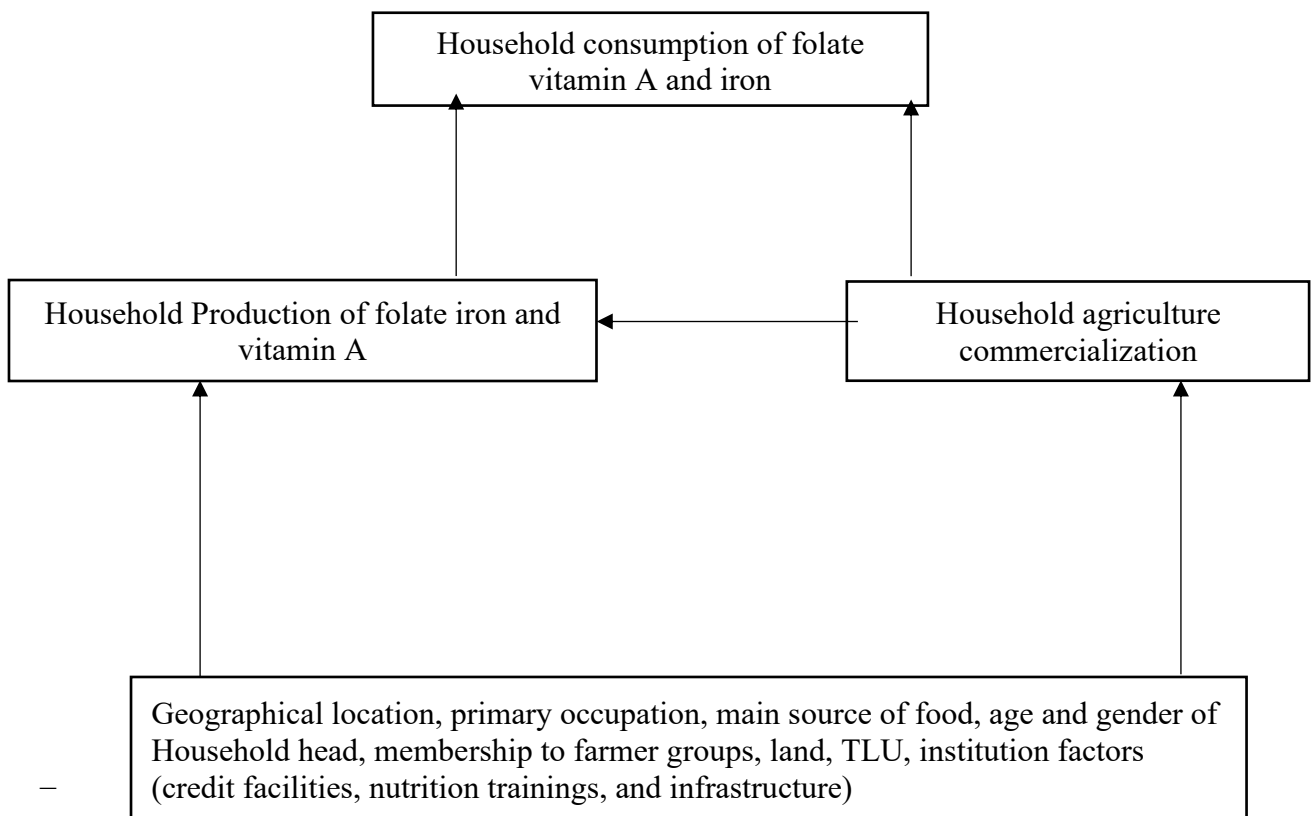


Figure 1: Conceptual framework for the study, (adopted from (Qaim et al., 2019))

1.6 Significance of the study

This study focused on assessing the impact of agricultural commercialization on micro-nutrient nutrition among households in Omoro and Otuke districts with emphasis on vitamin A, iron, and folate. The results are anticipated to influence how policies on agricultural commercialization can be improved to enhance production and consumption of vitamin A, iron, and folate among rural household such as those in Otuke and Omoro districts. The study provides information on factors those agricultural extension offices, farmers and other community agricultural development actors may need to consider in designing agricultural commercialization strategies to support production and consumption of micro-nutrients among rural households in localities such as Otuke and Omoro districts in Northern Uganda.

The results of the study will enable evaluation of the success of Nation development Plan (NDP) which involves supporting the country to achieve a middle income status through agriculture and other sectors. In so doing, the information will be used to design strategies that promote AC as well all nutrition security among these rural households. This will enable the two districts to address the Sustainable Development Goals (SDGs) 1, 2 and 3.

Additionally the main objective of CAADP is to have a transformed agricultural system in Africa (NEPAD Planning and Coordinating Agency, 2015). AC is one strategy that can aid the achievement of this objective. Understanding how AC influences micro nutrient nutrition can aid in developing policies that address nutrition sensitive agriculture amidst AC.

CHAPTER TWO: LITERATURE REVIEW

2.1 Agricultural commercialization and associated factors in low-income country setting

Agricultural commercialization refers to a gradual and progressive transition to market oriented systems in agriculture production (World Bank, 2008). In the context of low income countries it is usually defined as a progressive shift of the agricultural sectors from subsistence farming to reliance on the market for sale of agricultural produce and acquisition of agriculture production inputs including labour (Ochieng et al., 2020) and is measured using household commercialization index (HCI). The HCI ranges from 0 – 1 where 0 represents households that engage in completely subsistence farming and 1 represents completely commercialized farmers (Abraham et al., 2022). The goal of commercialization is to improve livelihood, economic position, and commerce among rural households (Chegere & Stage, 2019). According to Kumar et al. (2014), the expansion of agriculture in various food crops has contributed to more nutritional options and improved financial situations have improved for many households'. This makes it vital to understand the factors that influence agricultural commercialization in low income countries.

Several factors have been identified as influencers of agriculture commercialization. The factors can be grouped into social demographic factors, institutional factors, and geographical factors. Among the social demographic factors include age of household, gender of household head, house household size, level of education, occupation status. In low income countries, male gender engages in commercialization more often compared to the female gender. The female gender however provide labour to the households as accompanied by the children and relatives living within a household (Saint Ville et al., 2016). On the other hand, the primary occupation of the household heads highly influences the level of household involvement in agricultural commercialization. For example, households whose primary occupation is farming

largely involve in agricultural commercialization as a means to improve their livelihood (Nivievskyi et al., 2010). Additionally, the ability of households to afford agricultural products, like food and raw materials for agro-industries motivates their involvement in agricultural commercialization (Zhou et al., 2013).

Agricultural commercialization is strengthened by the availability of financial institutions and their ability to provide rural households with financial support. Such support promotes expansion in agricultural production creating a surplus which can be sold off (Mgbenka et al., 2015). Financial support has enabled farmers to systematically access markets for both cash crops and staple crops, and as such has significantly increased agricultural commercialization (Orr et al., 2020). Furthermore, as rural households gain more access to financial institutions and transportation infrastructure, they increase their involvement in agriculture related trade (Oluwatayo and Rachoene, 2017). This leads to improvements in poverty reduction, more exports, and decreased food inflation rates (Carletto et al., 2017). On the other hand, investments made by public and development agencies (governments, donors, non-governmental organizations (NGOs)) such as trainings, extension services, seed support or financial support in agriculture promotes agricultural commercialization among rural households (Chen & Smith, 2017).

The geographical location of rural households is another factor that influences the type of crops grown. Geographical factors determine the type of soils, types of rainfall and type of farming methods households employ. These in turn influence the type of crops grown basing on market demand in such localities. These factors influence commercialization of such crops (Gollin, 2014).

Despite the fact that commercializing agriculture is essential to fostering development and reducing poverty, rural households still have difficulty gaining access to the credit and quality

inputs that they need to increase their output (Kirimi et al., 2013). As a result, there are still many arguments against rural households embracing agricultural commercialization to guarantee food and nutrition security (Agwu et al., 2016). Thus, there is limited information on factors that influence agricultural commercialization among rural households in low income country localities such as Omoro and Otuke districts.

2.2 Food production in low income country setting

Generally, there has been increased food production in most low-income countries. This is attributed to several factors which could cause a positive or negative effect among rural households in such countries. Among the different factors include human capital, which plays a major role in providing different kinds of labor and management of other factors of production (Shah & Steinberg, 2017). Food production in developing countries is greatly dependent on level of education. Households that have achieved a certain level of education are more likely to understand the dynamics of the market and gain more training on the type of crops to produce (Mwangi & Kariuki, 2015).

The level of food production among rural households in low income countries is also greatly associated with the age of household heads and household size within households. Household heads within productive age produce more food crops compared to elderly household heads (Kariyasa & Dewi, 2011). Additionally, households in developing countries utilize family labor as a way of cutting costs. This implies that a larger household size is able to produce in large quantities compared to small household sizes (Aniah et al., 2019).

Since agriculture in low income countries depends on rainfall for most farmers, rural households are able to increase production during favorable weather conditions accompanied with good extension services and technological transfer (Aydinalp & Cresser, 2008).

Agricultural extension services play a big role in supporting farmers through training and keeping farmers informed on the expected agricultural opportunities and challenges (Baloch & Thapa, 2018). Furthermore new varieties that are more resistant to draught, pests and diseases and with high yielding capacities have enabled rural farmers improve their productivity (Fakana, 2019).

Additionally, majority of the population in low income countries are actively involved in agriculture basing on provision of credit and financial services, public investment policies in agriculture, and political stability. Credit access enables farmers to invest more in agriculture and such services promote expansion, and hence increased food availability. However, rural households have been observed to have low access to credit facilities and this lowers their production potential (Takahashi et al., 2019). This implies that trends of agricultural production of most crops in low income countries are greatly influenced by agriculture policies that address market value of such crops

By and large, the highest population in low income countries is involved in agriculture and this population supply food to the majority of the markets. Their level of involvement is dependent on the amount of land available for agricultural production (Lal, 2020). This is expected to increase their food and income security which in turn promotes nutrition security. However, communities in low-income countries are the most affected by micronutrient deficiency challenges. Existing literature provides vital information on how agricultural commercialization improves food systems and food and nutrition security among households. It is however unclear how agricultural commercialization influences production of the micro-nutrients. It is thus vital to establish an understanding of how agricultural commercialization influences micronutrient production among rural households in low-income country localities such as Omoro and Otuoke districts.

2.3 Household micronutrient nutrition in low-income country setting

Dietary intake in low-income countries remains a challenge despite increasing interventions to alleviate micronutrient deficiency challenges. Agricultural commercialization is expected to ameliorate micro-nutrient deficiency not only through promoting agricultural production of nutrient dense foods but also market access of different varieties of food crops. However, micronutrient deficiency cases continue to rise, especially in low-income countries (Onoja & Adione, 2019). For example, Vitamin A, calcium, magnesium, iron, vitamin B complex, and vitamin E, zinc and folate deficiency is still an issue that has to be addressed (Ecker & Weinberger, 2010).

Dietary intake in such countries is influenced by a number of factors. These factors can be categorised into social demographic, institutional and geographical factors. Household nutrition in such rural areas is majorly depended on agriculture (Kilimani, 2020), which is still a challenge in low income countries. Most rural households often consume high calorie foods and less of fruit and vegetables. This is expected because high calorie foods are easier to produce and are relatively cheap (Shively & Hao, 2012). Nutrition in low-income countries also depends on seasonality. Majority of the households are food secure during harvesting seasons specifically the first season (Adong et al., 2014). However, as they sell off some food crops to cater for other basic needs, they are left with little to consume during times that they are not harvesting (Cinthia, 2021). This is expected as majority of the rural smallholder farmers depend on rain fed agriculture and thus cannot practice farming throughout the year (Kogo et al., 2019)

Poulsen et al., (2015), in their systematic review on urban agriculture and food security impacts in low income countries discovered that rural households that involved in agriculture especially vegetables managed to maintain their nutrition diet which was also reinforced by active

involvement of women in Agriculture. Additionally, nutrition among rural households in low income countries is dependent on accessibility to the market. For instance, households that are close to the markets are in a better position to access a variety of food which improves the nutrition status of such households compared to households that are at a distance (Westbury et al., 2021). Furthermore, rural household nutrition is normally affected by education status and income levels within a given household. For example, households that have civil servants as family members earn some extra income and are able to afford a balanced diet. Similarly, households that have other access routes to income other than agriculture such as business in low-income countries are more likely to maintain a balanced diet (Allen et al., 2017)

On the other hand, rural areas have a far higher rate of micronutrient deficiency than urban areas because most urban households consume foods that have been bio-fortified, which serve as a supplement for micronutrients and so reduce problems associated with micronutrient deficiency (Bouis and Saltzman, 2017). Other households compensate for the lack of micronutrients with food supplements, but only in the most severe cases of malnutrition (Nair et al., 2016). This is because not everyone can afford dietary supplements. Most smallholder farmers also lack knowledge of fortified foods like orange-fleshed sweet potatoes and iron-rich beans that are high in micronutrients such as iron and vitamin A. Because of this reason, most of them continue to plant the unfortified seeds for consumption (Ickowitz et al., 2016). The favorable influence of commercialization on global macronutrient intake have received a lot of attention, however there is limited information on the influence of agricultural commercialization on micro nutrient intake. It is thus equally important to evaluate how commercialization influence micronutrient intake in low-income country localities such as Otuke and Omoro districts.

CHAPTER THREE: METHODOLOGY

3.1 Study Area

The study was conducted in Omoro and Otuke districts of northern Uganda. The districts were selected purposively. According to Uganda Bureau of Statistics (UBOS) Otuke and Omoro districts have the highest incidences of malnutrition in northern Uganda (UBOS 2020). Omoro district is located on geographical coordinates of 2.7152° N and 32.4920° E while Otuke district is located on geographical coordinates 2.5214° N and 33.3486° E. The main ethnic groups in Omoro and Otuke are Acholi and Lango, respectively. Otuke has a total population of 122,700 persons, 26,976 households and a population density of 81 persons per square kilometer while Omoro district has a total population of 196,400 persons, 38,810 households a population density of 126 persons per square kilometre. Omoro district occupies about 1,556 square kilometers, while, Otuke district occupies 1,550 square kilometers. Most of the households in the two districts practice agriculture with a high proportion being smallholder farmers. The two districts are known for production of cassava, sorghum, sesame, rice, soya beans, beans, sunflower and maize, while 25% of the households keep livestock. The typical livestock types kept include cattle, goats and poultry. The most used farm implement is a hand hoe. Rain-fed agriculture is a prominent farming system practiced by most farmers (Lugoi et al., 2023).

3.2 Research Design

The study employed a cross-sectional survey research design because it was a population-based survey. Cross sectional design was more effective because of its simplicity and reliability to provide a large amount of data and compare different variables within a short time. The study applied both comparative and quantitative methods. The comparative methods determined the most affected population in regards to the influence of agriculture commercialization and

micronutrient production and intake, whereas the quantitative methods were used to measure the level of agriculture commercialization in the two districts and its influence on micronutrient production and consumption.

3.3 Study population and participants

The study population comprised rural household residents in Omoro and Otuke districts who engaged in agriculture as their primary source of income and food. Households that were considered were those that were residents of either district for the last one agricultural production year or more. Participants were household heads aged 18 years and above and had the ability to communicate in Acholi, Lango, and or English.

3.4 Sample size and sampling framework

The sample size was determined using Slovin's formula (Galero-Tejero, 2011). The formula assumes a degree of variability (proportion) of 0.05 and a confidence level of 95% as expressed in equation (1).

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

Where: n = sample size; N = study population (65,786); e = the level of precision. In this study, the level of precision was 0.05.

Two sub-counties were purposively selected from each district and five parishes each containing a maximum of 12 villages was selected from each sub county. One village was randomly selected using simple random sampling from each parish giving a total of five representative villages from each sub county. A list of households for each village was obtained

from local council one leaders. From equation 1, twenty-one respondents were randomly selected from each village collectively giving a total of 420 respondents.

3.5 Measurement of key variables

3.5.1 Assessment of the level of commercialization

Household commercialization index (HCI) expressed in equation 2 by Agwu et al.(2013) was used for measuring level of commercialization.

$$HCI_i = \frac{\text{gross value of crop sales per hh I year}}{\text{gross value of all crops produced by hh I year}} * 100 \quad (2)$$

HCI is the ratio of the gross value of crops produced to the amount sold. The index ranges from $HCI_i = 0$ which is pure subsistence to $HCI_i=100$ which represents completely commercialized production system. The main advantage with HCI index is that it takes into consideration both the sellers and non -sellers and can go beyond traditional dichotomies of staple foods and cash crops produced by a household as adopted by (Ochieng et al., 2019)

3.5.2 Assessment of the level of production of iron, vitamin A and folate

A list of food quantities produced in the last production year (2021) was collected. Harvest Plus Food Composition Tables (FCT) (Muggaga et al., 2022) was used to determine the amount of vitamin A, iron and folate obtained in what was produced that year by each household. This enabled the determination of quantities of vitamin A, iron and folate produced by each household. The specifics follow equation 3.

$$MicroNutrient_{prod} = \sum_{i=0}^n (Qty_prod_i * micronutrient\ z_i) \quad (3)$$

Where: Qty_prod_i is the quantity of food item produced by a given household, micronutrient z_i is the contribution of the given micronutrient (vit A, iron or folate) per kg of food item i. A

separate equation was estimated for $z=1$ (vitamin A), $z=2$ (iron) and $z=3$ (folate) to obtain the total quantities of vitamin A, iron and folate consumed by a given household.

3.5.3 Assessment of the level of intake of vitamin A, folate and iron

From the quantities of foods items determined under sub-section 3.5.2, amount sold and or used for other non-food purposes was subtracted and the remaining amount was considered as consumed. The Harvest Plus Food Composition Tables (FCT) was employed to derive the quantity of vitamin A, iron and folate consumed from each food item. Equation 4 was then used to determine the overall consumption.

$$MicroNutrient_{cons} = \sum_{i=0}^{i=n} (Qty_cons_i * micronutrient\ z_i) \quad (4)$$

Where: Qty_cons_i is the quantity of food item consumed by a given household, micronutrient z_i is the contribution of the given micronutrient (vitamin A, iron or folate) per kg of food item i. A separate equation was estimated for $z=1$ (vitamin A), $z=2$ (iron) and $z=3$ (folate) to obtain the total quantities of vitamin A, iron and folate produced by a given household.

3.6 Study instrument

Data was collected using a structured questionnaire (see appendix I). The questionnaire had 3 sections. Section A was used for collecting information on social demographic characteristics of the households. The characteristics considered were household heads, age, gender, household size, education level, land under agricultural production, credit access, methods used for land preparation, distance to the market, information on agriculture extension service, electronic agricultural information access, and nutrition training statistics. Section B was used for collecting information on crops cultivated, sold and consumed throughout the production year. Section C was used for information on livestock production and consumption of animal

products. The questionnaire was pretested, prior to data collection. Sample 5 respondents from each sub-county were first interviewed before considering the whole sample size.

3.7 Data analysis

Data were analyzed using Stata and SPSS. Stata was used for regression analyses of the determinants of agricultural commercialization and the influence of agricultural commercialization on production and consumption of vitamin A, iron and folate. SPSS was used to derive descriptive statistics on social demographic characteristics and household production and consumption of the micro nutrients.

Descriptive statistics were used in assessing the social demographic characteristics. Frequencies were obtained in the analysis of categorical variables and chi-square was used to determine goodness of fit on the frequency distribution of these variables. In the case of continuous variables, the mean and standard deviation and mean differences of these variables were determined and a t-test was used to check for significant differences of the variables across districts.

In assessing the determinants of commercialization, the dependent variable used was the household commercialization index specified in equation 2. Given that this index ranges between 0 (0%) and 1 (100%), a censored tobit regression model was appropriate. Studies with similar specifications of the dependent variables also used the tobit model (Falola et al., 2022). Thus, the study employed a tobit regression model which implicitly followed equation 5.

$$HCI^* = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, \varepsilon) \quad (5)$$

Where; HCI = household commercialization index, x_1 = log of age of household head, x_2 = gender of household head, x_3 = primary occupation, x_4 = main source of food, x_5 = distance

to the market, x_6 =land under agriculture production, x_7 = access to credit, x_8 =access to extension services, x_9 = phone ownership, x_{10} =nutrition training, ε = the error term. The explanatory variables are described in Table 1.

A two -stage least squares regression model (2SLS) was used to assess the influence of agricultural commercialization on household production or dietary intake of vitamin A, iron and folate. The 2SLS model was ideal since it controlled for the inherent endogeneity associated with level of production and commercialization (Seven & Tumen, 2020). Separate models were estimated for vitamin A, iron and folate. With regard to influence of agricultural commercialization on production of micronutrients, the implicit form of the regressions follow specifications in equations 6 and 7:

$$Y_{ij} = \alpha_0 + \alpha_1 HCl_{1i} + \alpha_2 A_i + \varepsilon_i \quad (6)$$

$$A_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \dots \dots \dots + \beta_n X_{nit} + \mu_i \quad (7)$$

Where; Y_{ij} is the level of production of the respective micronutrient (vitamin A, iron, or folate). In the first stage of the regression (equation 6), α_0 = the constant of Y_{ij} when the regressors are zero, $\alpha_1 HCl_{1i}$ = instrumented HCl, $\alpha_2 A_i$ = other factors (instruments) that influence micronutrient production, ε_i = error term.

For the second stage regression model (equation 7), A_{it} = vitamin A, iron or folate production, β_0 = constant of A_{it} when the regressors are zero, $\beta_1 X_{1it} + \beta_2 X_{2it} + \dots \dots \dots + \beta_n X_{nit}$ are factors (instruments) that influence production of the nutrients, μ_i =error term in the second stage

With regards to the influence of agricultural commercialization on dietary intake of the micro nutrients, the implicit forms of the regression model are specified in equations 8 and 9.

$$Z_{ij} = \alpha_0 + \alpha_1 HCI + \alpha_2 A_i + \varepsilon_i \quad (8)$$

$$A_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \dots + \beta_n X_{nit} + \mu_i \quad (9)$$

In the first stage model (equation 8), Z_{ij} is the level of consumption of the respective micronutrient (vitamin A, iron, or folate), α_0 =the constant of Z_{ij} when the regressors are Zero, $\alpha_1 HCI$ = the instrumented HCI, $\alpha_2 A_i$ = other factors that influence micronutrient consumption, and ε_i = error term. In the second stage model (equation 9), A_{it} = vitamin A, iron, folate consumption, β_0 =constant of A_{it} when the regressors are zero, $\beta_1 X_{1it} + \beta_2 X_{2it} + \dots + \beta_n X_{nit}$ =other factors (instruments) that influence iron, vitamin A and folate consumption μ_i = error term.

For all 2SLS regressions, separate models were estimated for Vitamin A, folate and iron. Before analysis the regressors were checked for pairwise correlation, heteroskedasticity, regression specification-error test (estat omitted variable test) which was insignificant ($p>1$), variance inflation factor (estat VIF) which gave a VIF of 1.34 and robust to control the outliers. The variables used in the regression analyses are presented in Table 1. To establish the relationship between agricultural commercialization and production or dietary intake of the three micronutrients, Pearson correlation analysis was used. The study considered a 95% significant interval for level of statistical significance.

Table 1: Description of variables used in the regression analyses

Variables	Description	Apriori		
		tobit	2sls produced	2sls consumed
Iron produced	Mg/kg			
Vitamin A produced	Mcg/kg			
Folate produced	Mcg/kg			
HCI	Percentage	NA	+	-
Age of household head	Years	+	+	+
Gender of household head	0=male, 1=female	-	+	+
Primary occupation	1=Farming, 0= others	+	+	+
Access to credit	0=No, 1=Yes	+	+	+
Extension services	0=No, 1=Yes	+	+	+
Land under agriculture production	Acreage	+	+	+
Distance to the market	Km	-	+	+
Distance to all weather roads	Km	-	+	+
Phone ownership	0=No, 1=Yes	+	+	+
Membership to farmer groups	0=No, 1=Yes	-	+	+
Access to agriculture information	0=No, 1=Yes	+	+	+
Access to nutrition training	0=No, 1=Yes	-	+	+
Location	0=Omororo, 1=Otuke	+/-	+/-	+/-
Main source of food	0=Own production, 1= market purchase	+	+	+
Methods used for land clearing	0=Hand hoe, 1=ox plough	+	+	+
Tropical livestock unit	Number of livestock converted to common units	-	+	+
Crop diversity	0= No, 1=Yes	+	+	+

3.8 Ethical Consideration

Ethical approval for the study was obtained from Gulu University Research Ethics Committee (GUREC) (appendix II). On the other hand, permission to conduct the study among the districts was obtained from the Chief Administrative Officers (CAO) (appendix III) of the respective districts. In addition, translated informed consent was obtained from the respondents by way of signature or thumb print before proceeding with the interviews (appendix IV and V).

CHAPTER FOUR: RESULTS

4.1 Socio-economic characteristics of study households

Social economic profile of the household based on categorical variables is presented in Table 2. Overall, results showed that most of the households were headed by men (79%) and only 21% of households were headed by females. There was no significant association between gender of household head and district of location ($p > 0.1$). Over 81% depended on farming as their primary occupation with the rest relying on other economic activities as their primary occupation. There was a significant association between household primary occupation and district of location ($p < 0.05$). Specifically, Omoro district had the highest number of farmers depending on farming as their primary occupation while Otuke district had the highest percentage of households who relied on other occupations as their primary sources of livelihoods. More than half (56%) of the households depended on own production as their main source of food while the rest relied on market pathway as the main source of food. Only about 18% of the households used agrochemicals on their farms with significant association ($p < 0.01$) between agro-chemical use and location of households. Specifically, Omoro district had the highest percentage (23%) of the farmers who applied agrochemicals compared to Otuke district (12%). Similarly, about 12% applied fertilizers to their farms. More than 73% of the household heads had access to credit while another 70% received extension services. Over 41% of the households belonged to farmer groups. About 69% of the household heads owned phones. There was a significant ($p < 0.01$) association between ownership of mobile phones and district of location. Specifically, Otuke district had the highest number of farmers that owned mobile phones compared to Omoro district.

Table 2: Description of variables used in the regression analyses

Variable	Category	Frequency (%)			Chi-square	p-value
		Overall (n=400)	Omoro (n=204)	Otuke (n=196)		
Gender of household head	Female	83(20.8)	44(21.6)	40(20)	0.170	0.680
	Male	317(79.2)	160(78.4)	156(80)		
Primary occupation	Farming	325(81.3)	175(85.8)	151(77)	5.068	0.023
	Others	74(18.7)	29(14.2)	45(23)		
	Own production	225(56.3)	124(60.8)	102(52)		
Main source of food	Market purchase	175(43.7)	80(39.2)	94(48)	3.109	0.078
Use of agro chemicals	Yes	71(17.8)	47(23.0)	24(12)	7.978	0.005
	No	329(82.2)	157(77.0)	172(88)		
Use of fertilizers	Yes	47(11.7)	28(13.8)	177(90)	1.567	0.211
	No	353(88.3)	176(86.2)	19(10)		
Use of tractors	Yes	4(1.0)	2(1.0)	2(1)	0.002	0.968
	No	396(99.0)	202(99.0)	194(99)		
Use of ox plough	Yes	268(67.0)	145(71.1)	123(63)	3.132	0.077
	No	132(33.0)	59(28.9)	73(37)		
Access to credit	Yes	293(73.3)	154(75.5)	139(71)	1.066	0.302
	No	107(26.7)	50(24.5)	57(29)		
Extension services	Yes	280(70.0)	135(66.2)	145(74)	2.898	0.089
	No	120(30.0)	69(33.8)	51(26)		
Farmer group membership	Yes	165(41.3)	79(38.7)	86(44)	1.095	0.295
	No	235(58.7)	125(61.3)	110(56)		
Phone ownership	Yes	275(68.8)	127(62.3)	148(76)	8.175	0.004
	No	125(31.2)	77(37.7)	48(24)		
Nutrition training	Yes	85(21.3)	30(14.7)	22(11)	1.071	0.301
	No	315(78.7)	174(85.3)	174(89)		

Results of other social-economic characteristics of households measured as continuous variables are presented in Table 3. The overall mean age of the household heads was 45 years with no significant ($p > 0.1$) difference across districts (Table 3). The average household size was seven persons per household with no significant difference between the two districts ($p > 0.1$). On average, the household heads had a mean of 7 years of formal education (at least primary seven), but education level did not vary significantly between the two districts. The average owned land under agricultural production was about 3.4 acres per household with a significant ($p < 0.1$) difference between the two districts. Specifically, households in Omoro

district had significantly more owned land under agricultural production than those in Otuke district. The average hired land under agriculture production was 0.5 acres per household across districts with significantly ($p < 0.1$) more hired land in Otuke than Omoro district.

Table 3: Socio-demographic characteristics of households measured as continuous variables

Variable	Mean (SD)			Mean diff	p-value
	Overall	Omoro	Otuke		
Age of the household head (years)	45.25(14.11)	44.55(14.16)	45.97(14.05)	-1.425	0.314
Household size (number)	6.98(3.17)	6.59(2.71)	7.38(4.81)	-0.789	0.130
Education level (years)	7.21(5.89)	6.98(4.81)	7.45(6.84)	-0.474	0.422
Land owned under Production (acres)	3.42(2.98)	3.43(2.50)	3.42(2.98)	0.010	0.051
Land hired under Production (acres)	0.54(1.00)	0.44(0.84)	0.63(1.13)	-0.194	0.053
Nearest road to the input Market (km)	3.74(3.23)	4.43(3.39)	2.93(2.86)	1.593	0.000
Distance to the nearest output market (km)	3.76(3.15)	4.62(3.64)	2.85(2.21)	1.770	0.000
Distance to the nearest all-weather roads (km)	19.50(21.09)	31.87(22.57)	6.53(7.29)	25.540	0.000

On average the distance to the nearest input and output market was 3.7 km with a significant ($p < 0.01$) difference between the two districts. Specifically, households in Omoro district had significantly shorter distance than those in Otuke district. Results also showed that the average distance to the nearest all-weather roads was about 19.5km with a significant ($p < 0.01$) difference between the two districts. Specifically, households in Omoro district had a shorter distance to all weather roads than those in Otuke.

Table 4: Proportion of households cultivating the different crops

Crop	Frequency	Percent (n=400)
Beans	244	61.0
Soya beans	170	42.5
Sesame	157	39.3
Fresh cassava	144	36.0
G.nut shelled	134	33.5
Cow peas leaves	127	31.8
Mango	124	31.0
Sweet potato	116	29.0
Sorghum	99	24.8
Maize	96	24.0
Roselle (Malakwang)	80	20.0
Peas	79	19.8
Pawpaw	59	14.8
Unshelled G.nuts	54	13.5
Others	52	13.0
Okra	39	9.8
Eggplant	38	9.5
Amaranthus	29	7.3
Yellow peas	29	7.3
Millet	23	5.8
<i>Asystasia gangetica</i> (alaju)	23	5.8
Lemon	22	5.5
Dried cassava	20	5.0
Garden eggs	20	5.0
Tomatoes	17	4.3
Guava	13	3.3
Green gram	10	2.5
Orange flesh potatoes	7	1.8
Yam	5	1.3

4.2 Household agricultural commercialization and associated factors

As already indicated under sub-section 4.1, agricultural commercialization was measured using crops. Among the crops profiled, beans were highly cultivated (61.0%) in overall while yellow peas were the least produced (2.5%) (Table 4). Sorghum was the most cultivated cereal (24.8%) while millet was the least produced cereal (5.8%). Households stored more shelled groundnuts (33.5%) while the unshelled groundnuts were the least stored (13.5%). Among the roots, cassava was the most cultivated (36%) while orange flesh sweet potatoes were the least produced (1.8%). Cowpea (boo) was the most cultivated vegetable with a percentage frequency of 31.6%. Other crops cultivated are represented in (Table 4).

Before the determinants of commercialization could be ascertained, the levels of commercialization had to be established first. Results depicting the proportion of households at various levels of commercialization are presented in Table 5. The results show that 23% of the households depended entirely on subsistence farming and did not sell any crop produce, while 13% sold between 0.01 -50% of their crops, 23% sold between 51-79% of their crops and 18% sold all their crops for the past production year examined. In general, the average level of commercialization was 61%, with households in Omoro selling more of their output than those in Otuke district.

Table 5: Level of commercialization

Level of commercialization (%)	Frequency	%
0	91	23
0.01-50	53	13
51-75	93	23
76-99	90	23
100	73	18
Mean (Standard Deviation)		
Overall mean	0.61(0.38)	
Omoro	0.63(0.39)	
Otuke	0.54(0.21)	

Table 6 presents tobit model regression results for factors influencing the observed level of agricultural commercialization. VIF test had mean VIF of 1.34 and all the variables in the model had VIF values of less than 3 which is highly acceptable. The results show that the household agricultural commercialization was significantly influenced by gender of household heads ($p < 0.05$), main source of food ($p < 0.01$), land under agricultural production ($p < 0.01$), use of ox-plough ($p < 0.01$), access to credit ($p < 0.01$) and membership to association ($p < 0.05$). Specifically, female headed households had a lower level of commercialization than male headed households. On the other hand, households whose heads relied on farming as the main occupation were more commercialized than those who relied on other sources of livelihoods. Households with more land under agricultural production and used ox plough for

land preparation had a significantly higher level of commercialization. Additionally, households that had more access to credit had a higher level of agricultural commercialization. Additionally, households that had easy access to good roads significantly had a higher level of agricultural commercialization. However, households that depended on own production as the main source of food had a significantly lower level of agricultural commercialization. Similarly, households that had membership in farmer groups had a significantly lower level of commercialization.

Table 6: Determinants of household agricultural commercialization

Explanatory variable	Coefficient	Std. Err.	t	P>t
Age of household head (years)	-0.038	0.058	-0.650	0.514
Gender of household head (1=female)	-0.102	0.045	-2.280	0.023
Primary occupation (1=farming)	0.016	0.044	0.360	0.722
Main Source of Food (1=own production)	-0.125	0.038	-3.320	0.001
Land under agriculture production (acres)	0.195	0.038	5.180	0.000
Use of ox plough (1=yes)	0.218	0.045	4.820	0.000
Distance to the market (km)	-0.023	0.024	-0.940	0.347
Distance to all weather road (km)	-0.028	0.015	-1.890	0.059
Access to credit (1=Yes)	0.219	0.050	4.400	0.000
Extension services (1=Yes)	0.029	0.042	0.680	0.499
Membership to farmer group (1=yes)	-0.105	0.043	-2.440	0.015
Phone ownership (1=Yes)	-0.039	0.043	-0.910	0.363
Access to agriculture information (1=yes)	0.032	0.059	0.550	0.585
Nutrition training (1=yes)	-0.050	0.040	-1.240	0.214
Location (1=Omore)	0.064	0.041	1.570	0.118
Constant	0.343	0.248	1.380	0.168
Sigma	0.263	0.027		
Number of observations	400			
Left censored observations at $HCI \leq 0$	91			
Uncensored observations	239			
Right censored observations $HCI \geq 1$	73			
Log Likelihood	-330.95			
LRchi2 (15)	102.12			
Prob > chi2	0.000			

4.3 Influence of agricultural commercialization on household production of iron, folate and vitamin A

In order to establish the influence of agricultural commercialization on the production of iron, folate and vitamin A, the Level of production of each micronutrient had to be ascertained. The pooled median household production of iron, vitamin A and folate was X 3204 mg (range, 0-83,630mg), Y 2910 μ (range0- 702,000 μ), and Z 9670 μ (range, 0-4,670,000 μ) respectively. When segregated by district, the median household production of iron, vitamin A and folate was x 2974mg (range, 0-50,170mg),y 2900 μ (range, 0-372000 μ) and z 118800 μ (range, 0-3730000 μ) for Omoro district and A 2152.6mg (range, 0-33460mg), B 2800 μ (range, 0-

330000 μ) and C 81100 μ (range, 0-940,000 μ) for Otuke district respectively. Figure 2 presents the distribution of level of production of the three micronutrients by food source. On average, legumes contributed the highest amount of iron in the past production year followed by cereals, nuts, roots, vegetables, and fruits in a decreasing order of magnitude. Fruits contributed highest amount of vitamin A followed by vegetables and roots, while the contribution from legumes and cereals were largely marginal. Vegetables contributed the highest amount of folate followed by legumes, nuts, roots, cereals and then fruits.

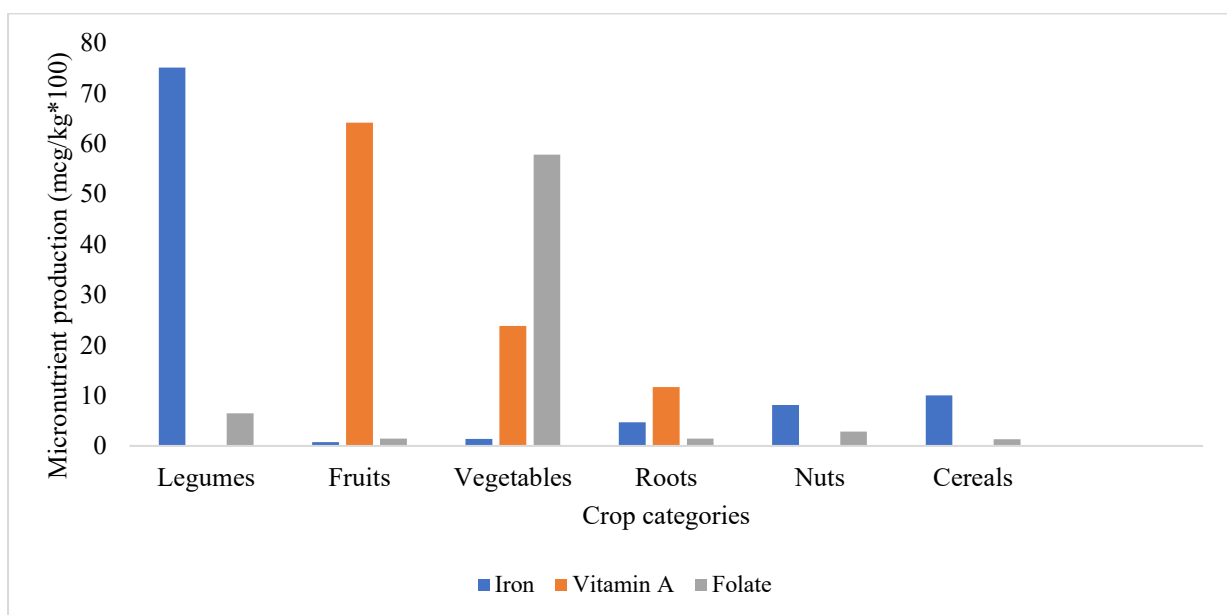


Figure 2: Level of production of micro nutrients aggregated by food source

Following the ascertainment of production of the three micronutrients, Pearson correlation analysis was applied to establish the relationship between household agricultural commercialization and production of each micronutrient. Results showed no association ($p > 0.1$) between household agricultural commercialization and production of iron or vitamin A but a positively weak correlation ($p < 0.01$) with folate production (Table 7).

Table 7: Association between household agricultural commercialization and micronutrient production

	HCI	
	Pearson correlation	p-value
Iron	0.018	0.717
Vitamin A	0.032	0.521
Folate	0.332	0.000

The results of the 2SLS regression model depicting the influence of agricultural commercialization and production of iron, vitamin A and folate are presented in Tables 8, 9 and 10, respectively. In the case of iron, the results showed a significant positive influence ($p < 0.01$) of agricultural commercialization on the level of iron produced through farming by the household (Table 8). The level of iron produced was also influenced by other factors including method used for land preparation ($p < 0.05$), distance to all-weather roads ($p < 0.01$), and location of the farmer's household ($p < 0.01$). Specifically, households that used ox-plough for land preparation and had an easy access to all weather roads produced more iron. On the other hand, Omoro district produced more iron compared to Otuke district.

Table 8: Association between household agricultural commercialization and micronutrient production

Explanatory variables	Coef.	Std. Err.	T	P>t
HCI	0.005	0.001	6.640	0.000
Primary occupation (1=farming)	-0.002	0.001	-1.570	0.117
Main Source of Food (1=own production)	0.001	0.001	0.760	0.447
Method used for land preparation (1=ox plough)	0.002	0.001	2.430	0.015
Distance to the market (km)	0.001	0.000	1.830	0.068
Distance to all weather roads (km)	0.001	0.000	2.820	0.005
Extension services (1=Yes)	0.001	0.001	1.180	0.239
Nutrition training (1=Yes)	-0.001	0.001	-1.230	0.218
Number of crops cultivated	0.001	0.001	0.810	0.421
Tropical livestock unit	0.001	0.001	1.780	0.076
Location	0.003	0.001	3.350	0.001
Phone ownership (1=Yes)	-0.039	0.043	-0.910	0.363
Membership to farmer groups (1=Yes)	0.000	0.000	0.830	0.408
Constant	-0.003	0.002	-2.020	0.044

In the case of Vitamin A the results showed no significant influence ($p > 0.1$) of agricultural commercialization on the level of production of the micronutrient (Table 9). As shown in the case of iron, the level of vitamin A produced was also influenced by other factors including main source of food ($p < 0.01$), nutrition training ($p < 0.01$) and type of crops grown in a household ($p < 0.05$). Particularly, households that relied on own production as their main source of food produced more of the micronutrient. Additionally, households that attended nutrition training also produced more vitamin A. The number of crops produced in a household positively influenced vitamin A production.

Table 9: Influence of HCI on vitamin A production

Explanatory variables	Coef.	Std. Err.	Z	P> z
HCI	2.42E-05	1.43E-05	1.69	0.090
Farming (1=farming)	-1.72E-06	3.25E-06	-0.53	0.598
Main Source of Food (1=own production)	1.03E-05	3.91E-06	2.64	0.008
Method used for land clearing (1=ox plough)	-7.39E-06	6.75E-06	-1.09	0.274
Distance to the market(km)	-4.24E-06	2.24E-06	-1.9	0.058
Distance to all weather roads (km)	-9.76E-07	1.06E-06	-0.92	0.355
Extension services (1=Yes)	4.24E-06	3.51E-06	1.21	0.228
Nutrition training (1=Yes)	1.35E-05	5.51E-06	2.45	0.014
Number of crops cultivated	1.07E-05	4.64E-06	2.32	0.021
Location	-9.26E-06	5.08E-06	-1.82	0.069
Constant	-9.22E-06	8.22E-06	-1.12	0.262

For folate, the results showed a significant positive influence ($p < 0.01$) of agricultural commercialization on the level of production of the micronutrient (Table 10). As was the case for iron and vitamin A, the level of folate produced was also influenced by other factors including phone ownership ($p < 0.05$), distance to all-weather roads ($p < 0.01$), and location of the farmer's household ($p < 0.01$). Specifically, households who owned phones and had easy

access to all weather roads produced more folate. However, households in Omoro district produced less folate compared to households in Otuke district

Table 10: Influence of HCI on production of folate

Explanatory variables	Coef.	Std. Err.	Z	P>z
HCI	0.000794	0.000245	3.24	0.001
Primary occupation (1=farming)	-3.4E-05	0.000054	-0.63	0.531
Main Source of Food (1=own production)	7.11E-05	4.67E-05	1.52	0.128
Method used for land clearing (1=oxplough)	-0.00012	6.76E-05	-1.71	0.087
Distance to the market (km)	0.000028	2.02E-05	1.39	0.166
Distance to all weather roads (km)	4.34E-05	1.59E-05	2.73	0.006
Credit (1=Yes)	-6E-05	5.49E-05	-1.09	0.276
Extension services (1=Yes)	-2.1E-05	4.11E-05	-0.51	0.613
Membership to farmer groups (1=Yes)	3.11E-05	3.76E-05	0.83	0.408
Phone ownership (1=Yes)	7.76E-05	3.53E-05	2.2	0.028
Nutrition training (1=Yes)	1.08E-06	3.61E-05	0.03	0.976
Number of crops cultivated	-3.6E-05	4.03E-05	-0.88	0.377
Location	0.0001	4.14E-05	2.42	0.016
Constant	-0.00038	0.000139	-2.74	0.006

4.4 Influence of agricultural commercialization on household consumption of Iron, vitamin A and folate

Before the influence of commercialization of micronutrients could be determined, the level of household consumption of each micronutrient was first ascertained. The pooled median household consumption of iron, vitamin A and folate was X 3320.4mg (range, 0-27710mg), Y 2380 μ (range 0- 432,000 μ), and Z 34100 μ (0-660,000 μ) respectively. When segregated by district, the median household consumption of iron, vitamin A and folate was A1776mg (range, 0-16090mg), B 6000 μ (range, 0-211000 μ) and C 56600 μ (0-290,000 μ) for Omoro district and C1132.2mg (range, 0-11,620mg), W 4690 μ (range,0-221000 μ) and z 37800 μ (range, 0-370000 μ) for Otuke district respectively. Figure 3 presents the distribution of level of household consumption of the three micronutrients aggregated by food source. On average, consumption of iron largely came from legumes followed by cereals, nuts, roots, vegetables and fruits in decreasing magnitude. On the other hand, fruits contributed highest amount of

vitamin A to household diet followed by vegetables, and roots while the contribution from nuts, legumes, and cereals was limited. Highest amount of folate consumed was from vegetables while the contribution from other food categories was limited.

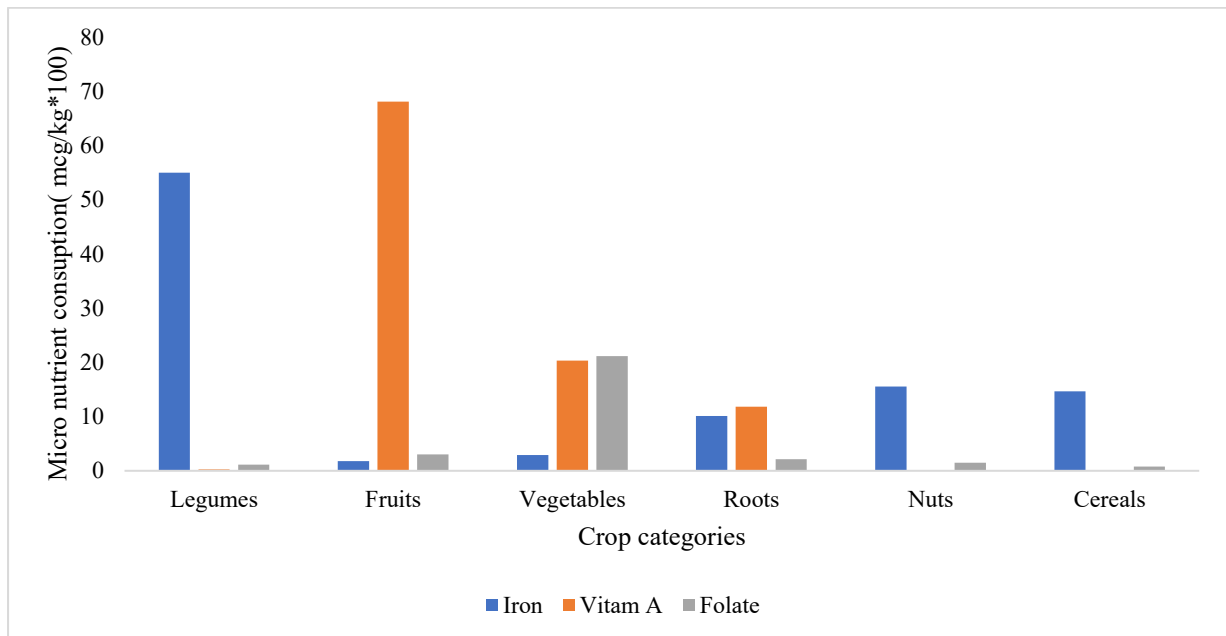


Figure 3: level of consumption of micro nutrients aggregated by food source

Following the quantification of dietary intake of the micronutrients, Pearson correlation analysis was performed to ascertain the association between household agricultural commercialization and micronutrient consumption. Results are presented in Table 11. There was a weak negative correlation ($p < 0.01$) between household agricultural commercialization and consumption of iron but no association was observed for consumption of vitamin A and folate.

Table11: Association between household agricultural commercialization and micronutrient consumption

	HCI	
	Pearson correlation	P-value
Iron	-0.220	0.000
Vitamin A	-0.056	0.261
Folate	0.030	0.544

The results of the 2SLS regression model depicting the influence of agricultural commercialization on household consumption of iron, vitamin A, and folate are presented in Tables 12, 13, 15, respectively. In the case of iron, agricultural commercialization had no influence on the level of iron consumed (Table 12). However, the level of iron consumption was influenced by other factors including main source of food ($p < 0.01$), use of ox-plough ($p < 0.05$), number of crops cultivated ($p < 0.01$) and phone ownership ($p < 0.01$) (Table 12). Specifically, households that relied on own production as their main source of food consumed more iron. Households that used ox-plough for land preparation and cultivated many different crops consumed more iron. Furthermore, households whose heads owned phones consumed more iron.

Table 12: Influence of agricultural commercialization on iron consumption

Explanatory variables	Coef.	Std. Err.	t	P>t
HCI	-0.00022	0.000208	-1.07	0.287
Primary occupation (1=farming)	-6.4E-05	0.000286	-0.22	0.824
Main Source of Food (1=own production)	0.000649	0.000166	3.91	0.000
Method used for land clearing (1=ox plough)	0.000447	0.000196	2.28	0.023
Distance to the market (km)	-7.49E-06	0.000101	-0.07	0.941
Distance to all weather roads (km)	6.22E-05	6.01E-05	1.04	0.301
Credit access (1=Yes)	0.000354	0.000186	1.90	0.058
Extension services (1=Yes)	0.000288	0.0002	1.44	0.15
Membership to farmer group (1=Yes)	-0.00018	0.00019	-0.92	0.357
Phone ownership (1=Yes)	0.000479	0.000152	3.15	0.002
Nutrition training (1=Yes)	4.32E-05	0.000224	0.19	0.847
Number of crops cultivated	0.00024	4.74E-05	5.06	0.000
Tropical livestock units	4.86E-05	6.35E-05	0.00 0.77	0.444
Location	0.000392	0.000209	1.88	0.061
Constant	-0.00052	0.000386	-1.36	0.176

In the case of vitamin A, agricultural commercialization also had no influence on consumption of the vitamin. As was the case with iron, the level of vitamin A consumption was influenced by other factors such as main source of food ($p<0.05$), distance to all-weather roads ($p<0.05$), and number of crops cultivated ($p<0.01$) (Table 13). Specifically, households that relied on own production as their main source of food and cultivated several different crops consumed more of the vitamin. On the other hand households that had easy access to all weather roads consumed less vitamin A.

Table 13: Influence of HCI on vitamin A consumption

Explanatory Variables	Coef.	Std. Err.	Z	P>z
HCI	2.55E-06	8.14E-06	0.31	0.754
Primary occupation (1=farming)	-2.80E-06	3.17E-06	-0.89	0.376
Main Source of Food (1=own production)	1.04E-05	4.85E-06	2.14	0.032
Distance to market (km)	-4.02E-06	1.78E-06	-2.26	0.024
Distance to all weather roads (km)	1.08E-06	1.78E-06	0.61	0.543
Credit access (1=yes)	3.07E-06	3.75E-06	0.82	0.413
Extension services (1=yes)	9.26E-06	5.92E-06	1.57	0.117
Membership to farmer groups (1=yes)	1.95E-06	4.81E-06	0.41	0.685
Phone ownership (1=yes)	-2.06E-06	3.14E-06	-0.65	0.513
Nutrition training (1=yes)	6.19E-06	6.22E-06	1.00	0.319
Number of crops cultivated	1.09E-05	3.99E-06	2.72	0.006
Tropical livestock unit	4.21E-06	3.37E-06	1.25	0.212
Location	-6.01E-06	3.13E-06	-1.92	0.055
Constant	-7.70E-06	9.27E-06	-0.83	0.406

It was only in the case of folate that agricultural commercialization influenced the level of consumption. Nonetheless, the level of folate consumption was also influenced by other factors including main source of food ($p<0.01$), phone ownership ($p<0.01$), and types of crops grown ($p<0.01$). Specifically, households that relied on own production as their main source of food and cultivated a number of different crops consumed more folate. Additionally, households whose heads owned phones consumed more folate.

Table 14: Influence of HCI on folate consumption

Explanatory variables	Coef.	Std. Err.	z	P>z
HCI	4.66E-05	1.73E-05	2.70	0.007
Main source of food	3.25E-05	6.28E-06	5.17	0.000
Method used for land clearing	-6.50E-06	7.76E-06	-0.84	0.402
Distance to the market	1.33E-06	3.79E-06	0.35	0.726
Distance to all weather roads	2.84E-06	2.39E-06	1.19	0.234
Extension services	2.62E-06	6.93E-06	0.38	0.705
Membership to farmer groups	6.92E-06	6.32E-06	1.09	0.274
Phone ownership	1.56E-05	5.43E-06	2.88	0.004
Nutrition training	5.87E-06	7.53E-06	0.78	0.436
Number of crops cultivated	2.93E-05	6.39E-06	4.59	0.000
Tropical livestock unit	9.49E-06	5.33E-06	1.78	0.075
Location	4.65E-06	6.65E-06	0.7	0.484
Constant	-5.1E-05	1.21E-05	-4.2	0.000

CHAPTER FIVE: DISCUSSION

5.1 Household Agricultural Commercialization and associated factors

This study examined the status and assessed factors that influenced household agricultural commercialization in Omoro and Otuke districts of northern Uganda. Across the two districts, agricultural commercialization 61% and varied from 58% - 54% respectively implying that households in Omoro and Otuke are at various levels of commercialization. The fact that most households did not sell all the food produced was expected given that smallholder farmers also rely on own production as a major source of food for the households (Nwafor & Westhuizen, 2020). Omoro district had a higher level of commercialization compared to Otuke district implying that households in Omoro sold more of their food compared to Otuke. The level of commercialization was influenced by several factors. For instance, gender of the household had a significant relationship with HCI, with male headed households selling significantly more of what was produced in the household. This finding suggests that, because women tend to prioritize household food before marketing decisions are made, they reserve more of the produced food compared to men (Lambrecht et al., 2017). These findings are in line with the study of Tavenner and Crane (2018) that reported that men dominated agricultural commercialization activities. This suggests differences in priorities with respect to consumption and marketing decisions in the household. Male farmers are more involved in decisions regarding income while female farmers are more involved in consumption decisions (Ater & Mutai, 2021). Additionally, Gebre et al. (2021) in their study showed that male headed households produced cash crops in large quantities compared to food crops. This further explains why male headed households had higher commercialization levels.

In the context of food acquisition pathway, results showed that reliance on own production as a source of food was associated with lower levels of household agricultural commercialization.

This was expected since relying on own production as a source of food requires that households reserve a large part of the produce for home consumption thus having a less marketable surplus. The number of households that relied on own production for food was higher in Omoro than Otuke districts. In order to promote agricultural commercialization among rural households, it is vital to promote home own production of food crops among households. This will increase food produced and thus surplus will be sold off to support household needs. These results are in agreement with the findings of Woldeyohanes et al. (2017) who reported that farmers used their off-farm income for other essential requirements. Subsequently less of it was channeled to buying food for home consumption thus those that cultivated their own crops managed food insecurity fairly. Additionally Chegere & Stage, (2020) reported that, households that did not produce any of the crops in the production year consumed less of that crop, if they consumed any at all. Furthermore, in the study on agriculture commercialization and nutrition in small farmer households, Ogutu et al. (2020), discovered that farmers that produced crops themselves had a better likelihood of consuming more of them than those who relied on market purchases.

Land area under agricultural production was also one of the factors that influenced household capability to produce diverse crops. This implies that households that had large land produced more crops as compared to those with small land. Results showed that Omoro district had more land under agricultural production compared to Otuke district even when the difference was minimal. Providing support to approaches that help households acquire more land for production (e.g providing credit to enable households hire more land for production) increases food production within households. This will not only increase agricultural commercialization but also provide households with enough food thus increasing food and nutrition security. These results agree with Bekele and Alemu, (2015) who reported that the amount of land used for production by a household dictated how much they could sell at the end of the season thus according to their study, farm size had a positive impact on commercialization of agriculture.

Additionally, Kabiti et al. (2016) concluded that a larger farm size implied greater room for production and, thus, higher commercialization of agriculture.

The study also discovered that households that had access to credit facilities engaged more in agricultural commercialization. This implies that, as farmers accessed credit, they produced more income generating crops, this in turn increased abundance of food crops which in turn encouraged commercialization of agriculture. Households in Omoro district had more access to credit services compared to households in Otuke district. In order to improve agricultural commercialization among rural households, it is vital for responsible organizations to develop policies that address provision of more credit services to rural households through offering interest free loans or reducing interest rates charged on loans offered to rural farmers. This will enable rural households' access funds and expand food production which in turn improves their income, food and nutrition security. These findings are in line with the research conducted by Sekyi et al. (2020) which in turn backs up Benjamin and Haruna (2017) study, which discovered that when more farmers had access to financing, they would purchase more inputs, which increased agricultural production yields. Further, Sher et al. (2021) discovered that offering farmers credit services with favorable terms, such as interest-free loans, relieved financial pressures and allowed farmers to hire more land for cultivation. This led to increased productivity, market engagement, and urban connections, which helped farmers produce more valuable products.

The study also discovered that households that used ox-plough for land preparation had better levels of household agricultural commercialization compared to farmers that used hand hoes. This implies that methods employed to clear the land influenced the amount of land prepared for cultivation at the beginning of the season. In turn, this determined the amount of produce that would be ready for harvest at the end of the season. On average, only 67% of the

households used oxploughs and varied from 71%-63%, respectively across districts. This implies that over 33% of households used hand hoes to prepare land which is a very slow method. This makes such households prepare less land for planting and thus produced less food. Supporting rural households with improved methods for land preparation such as oxploughs and tractors through government subsidies on the costs associated with acquiring such fast methods of land preparation will enable rural households prepare more land and produce more food. This in turn will promote agricultural commercialization among rural households. This research supports a study by Celliers et al. (2016) who found that techniques for preparing land had an impact on farmers' production. Additionally, Maertens & Vande Veld (2017) found that better land preparation technologies enabled fields to be ready for production on schedule and hence farmers would methodically follow the season.

On the other hand, farmers who were members of farmer groups were associated with significantly lower influence of agricultural commercialization. This implies that, although households can potentially work together, produce in large quantities, and increase potential for a turn on profit, the groups might restrict the amount to be sold which results in lower level of agricultural commercialization. Otuke district had more households under farmer groups as compared to Omoro district. Basing on the results, increase in agricultural commercialization will require approaches that support involvement of households in farmer groups but also address and emphasize individual agricultural production. These results are however not in tandem with the study conducted by Awotide et al. (2016) who found that farmer groups collaborated more readily with support staff to provide any form of assistance to individual farmers, which aided in the commercialization of agriculture. On the other hand, Dube and Guveya (2016) found no discernible influence of farmer groups on commercialization of agriculture thus farmers participated in the commercialization of agriculture.

5.2 Influence of agricultural commercialization on production of iron, folate and vitamin A

Despite the fact that legumes such as beans, soya beans and sesame produced higher levels of iron, other foods like cereals, nuts, roots and vegetables also contributed some percentage of the micronutrient. In the case of vitamin A produced, high levels were obtained from fruits, vegetables and some root crops. The fruits from which vitamin A was obtained are mangoes, pawpaws, guavas, tomatoes and lemons. The vegetables included amaranths, cowpeas leaves, roselle, and *alaju*, while the roots were orange flesh potatoes. Although these foods contributed high levels of vitamin A, they were produced in less quantities. In the case of household folate production, high levels were obtained from vegetables.

The vegetables from which folate was obtained included roselle, amaranths, garden eggs, eggplants, cow pea leaves, okra and *alaju*. Omoro district produced more of the micro-nutrient compared to Otuke district. As for the case with vitamin A sources, vegetables were also produced in small quantities. From the findings of this study, it is factual that for households to alleviate their micronutrient deficiencies, they should produce adequate quantities of these nutrients. This can be achieved through producing high quantities of legumes, fruits and vegetables. In order to ameliorate micronutrient intake, more emphasis should be put on increasing production of micronutrient rich foods such fruits, vegetables and orange flesh sweet potatoes. However, this study did not assess whether micronutrients produced was adequate for the households.

In relation to influence of agricultural commercialization on production of micronutrients, the results showed a higher association between agricultural commercialization and production levels of iron and folate, but not vitamin A among the households. This implies that agricultural commercialization promoted production of iron and folate. This finding suggests that

agricultural commercialization could have influenced farmer's choice of iron and folate rich crops such as legumes and vegetables at the expense of vitamin A rich crops. Crops such as beans, soya beans, sesame, amaranths, cowpeas leaves, okra that are rich in both iron and folate were highly produced while crops such orange flesh sweet potatoes, tomatoes, and paw paws that are rich vitamin A were only produced by a handful of households. The choice of which crops to produce has usually driven the farming goals. If farmers want to produce both for consumption and income, they would choose those crops whose combination would help them achieve the double goals (Chiputwa and Qaim, 2016; Carletto et al., 2015).

Results of this study has also shown that the level of iron, folate and vitamin A produced at household level was also associated with several other factors. For instance, farmers who used ox-plough for cultivation had a significantly higher levels of iron and folate produced than those who used only hand hoes but no significant relationship between use of ox-plough and quantity of vitamin A produced was apparent. Because use of ox-plough is associated with highly commercialized and diversified farmers who are more likely to produce crops for both home consumption and income, it was expected given that high levels of iron and folate was obtained from crops that were on demand for sale (legumes and vegetables). According to Chen et al. (2017), the tillage method used influences both the type of crop grown and size of land cultivated. Consequently, use of ox-plough is also associated with higher levels of production in terms of scale and productivity (Okello et al., 2019; Wambugu et al., 2018). Use of ox-plough for instance, favors relatively large-scale production of crops such as beans and soya beans which are rich sources of iron but also having huge potential for income.

Proximity to the market and market accessibility greatly influences household production decisions. This in turn is expected to have a significant relationship with production of micro-nutrients. From this study, production of iron and folate was highly associated with distance to

all-weather roads, which implies that farmers who stay near roads can produce more income generating crops as they easily access roads as well as traders. For example iron and folate was highly generated from legumes and vegetables, crops that were sold often.

According to a study by Banerjee et al. (2019), farmers who had farms adjacent to roads were more likely to engage in agriculture as a business than farmers who were far from roads. Additionally, farmers who were near good roads spent less on transportation of their produce, leading to increased trading of those products (Damania et al., 2017). Additionally, Khatiwada et al. (2017) found that the type of crops that farmers produced and the type of trade they engaged in were influenced by their geographic location. For instance, people who lived close to busy marketplaces or cities and towns, produced more vegetables and legumes due to their high demand. This was probably driven by the consumption habits of those who frequently access such locations. Furthermore, Martens et al. (2020) also discovered that farmers produced certain crops basing on favorable weather conditions of that location.

Findings of this study has also shown that households whose main source of food was own production had significantly higher levels of vitamin A produced than those who did not. In the case of iron and folate, there was no significant association. This implies that majority of the households obtained their vitamin A from fruits and vegetables they grew at home. In order to alleviate vitamin A deficiency, it is vital to develop approaches that promote fruit and vegetable production. According to Ochieng et al. (2020), farmers who planted their own food crops like indigenous legumes, cereals, vegetables, and beans were more food secure and could therefore more easily acquire micronutrients than those who relied on the market. Furthermore, El Bilali et al. (2019) found in another study that farmers who grew their own food had a higher capacity to eat healthy food and sustain it.

Basing on the results, farmers who possessed mobile phones were associated with higher levels of folate produced but not iron and vitamin A. Mobile phones are an important source of agricultural information and influences the choice of crops cultivated and scale of production (Atube et al., 2022). With ownership of mobile phones being significantly associated with levels of folate production, it is expected that information received by mobile phones are those that favor production of folate rich crops. Access to production information enables farmers to acquire specific inputs and boost their productivity (Tsiboe et al., 2018). Similarly, provision of nutrition knowledge using mobile phones has also been shown to increase production of foods rich in the nutrients being promoted (Isoto & Kraybill, 2017).

In addition to using mobile phones as a source of knowledge, some farmers have been able to attend nutritional trainings. Such trainings are usually aimed at improving people's knowledge and skills with respect to household nutrition. In this study, results have shown that farmers who attended such training had significantly higher levels of vitamin A produced. This implies that nutrition training equipped households with nutrition knowledge and motivated them to produce more vitamin A. These findings are in agreement with Schreinemachers et al. (2018) who found that most households preferred to produce and eat particular foods once they realized their benefits. Additionally, Wuch et al. (2015) also found that farmers may easily adopt growing a particular crop if they were aware of the benefits of that crop in terms of nutrition and profitability.

5.3 Influence of agricultural commercialization on consumption of iron, folate and vitamin A

The findings of the study revealed that households consumed high levels of iron from legumes. Specifically, beans contributed the highest percentage of iron compared to other legumes. However, other food crops such as cereals, nuts, roots vegetables and fruits contributed some

percentage of the micronutrient consumed in the household. Following the contribution of food groups to vitamin A intake, fruits contributed the highest amount of the micronutrient followed by vegetables and roots. The fruits that were often consumed were mangoes and pawpaws. The vegetables were roselle (malakwang) and roots were orange flesh sweet potatoes. Regarding folate consumption, the highest amount was obtained from vegetables. Despite the fact that fruits and vegetables were main sources of vitamin A and folate, the food groups were consumed in less quantities. Consumption rates of the three micronutrients was higher in Omoro than Otuke districts.

For this reason, this study suggests that in order to alleviate micro nutrient deficiencies among rural households in Omoro and Otuke districts, households should increase their level of consumption of fruits, roots, legumes and vegetables in large quantities. This can be achieved through promoting production of these food categories. Specifically, households should increase production of fruits, vegetables and roots such as yams and orange flesh sweet potatoes. This study did not assess the adequacy of what was consumed to household annual needs. This is an important area for future studies.

Regarding the influence of agricultural commercialization on consumption of iron, vitamin A and folate, results from this study has shown that agricultural commercialization had a significant positive relationship with the level of folate in produce retained for home consumption, but not on Vitamin A and iron. This implies that to increase folate consumption among rural households, it is vital for the responsible programs in agriculture to promote agricultural commercialization especially for vegetables. This is because high levels of the folate was obtained from vegetables, which, while being marketed, are still the primary source that households rely on. This study also suggests that consumption of folate was dependent on what the household chose to sell and what they decided to consume and for this reason there is

a strong likelihood that households would consume vegetables throughout the week. For instance, majority of the households consumed a lot of vegetables regardless of whether they produced them or not. As a result, household agricultural commercialization was highly associated with consumption of folate. This findings are in agreement with Nakaziba et al. (2021) who showed that most of the households in Uganda consumed vegetables as accompaniment to high calorie foods which vegetables in turn were considered to be medicinal. Furthermore, Elliot (2021) in his research found that smallholder farmer households relied on a variety of plants as vegetables because it is the most affordable source they can get on a daily basis .

The study has also shown that crop diversity significantly influences the quantities of iron, folate and vitamin A retained for home consumption. This suggests that the likelihood of consumption increases with increase in the number of crops grown. For example, the fact that households in Omoro and Otuke districts grew more legumes and vegetables, and had plenty of mangoes in their homesteads, they were able to consume more of nutrients. This implies that the type of crops grown determine the nutrient intake among rural households. These findings are in agreement with a study by Khatiwada et al. (2017) who found that the crops households chose for agriculture production always dominated household nutrition. The study conducted by Kumar et al. (2015) observed a positive association between agriculture diversity and micro nutrient consumption.

Among other factors that influenced nutrient intake was main source of food. This was expected as most of the rural households depended on what was grown for consumption. This implies that nutrition of the household was dependent on agriculture production and thus households that produced less were affected by food and nutrition insecurity. These findings agree with the findings of Jones et al. (2019) which showed that farm level agriculture

biodiversity increased micronutrient consumption among rural households. Additionally, Lockyer et al. (2018) suggested that since rural farmers depend on farming as their main source of accessing food, it was vital to consider biodiversity and bio-fortification to increase the scope of micronutrient consumption.

Further, households whose family heads owned phones were associated with higher intake of iron and folate. This could have been because mobile phones increase dietary diversity through better access to information on which foods to produce, purchase and consume. These findings are in agreement with Parlasca et al. (2020) who discovered in their study that mobile phones improved household's dietary diversity as households gained more information on which foods to purchase to improve their nutrition. Additionally, Mwalupaso et al. (2020) showed that on average, households that owned phones accessed information on dietary diversity and nutritional significance which motivated them to increase their nutrient consumption by purchasing two more foods of different varieties weekly.

Household use of ox-plough for land preparation had a significant relationship with iron consumption. This is not surprising because ox-plough prepare land faster which can allow more land to produce crops that would generate more income as well as serve as food for consumption within the household. For example, legumes like beans and soybeans which are rich in iron were highly produced and consumed. This might explain why ox-plough usage had a significant influence on iron consumption as most of the iron was from legumes which is a good source of iron. These findings are in agreement with Pellegrini et al. (2017) who showed in their study about farm-level agricultural biodiversity in Peruvian Andes that the method farmers employed for land preparation influenced the size of land prepared for cultivation which in turn influenced the type of crops produced and consumed. Additionally, Mullins &

Arjmandi (2021) advised that most households employ improved methods for land preparation for crops that provide both income and food security.

Last but not least, distance to the market had a negative influence on vitamin A consumption. This was associated with the long distances to the markets. Since high levels of vitamin A was obtained from mangoes, households relied on the fruits at home for their vitamin A consumption. In this case, it became difficult for the households to purchase other varieties of fruits from the markets due to long distances. For this reason, in order to increase vitamin A consumption, households should be empowered to produce different varieties of fruits within homesteads. These findings are in agreement with Nabuuma et al. (2018) who showed in their study on dietary diversity among smallholder households that long distances to the markets limited rural households from purchasing various fruits that would have improved on their vitamin A intake. Additionally, Rasolofson et al. (2018) articulated that majority of the households near markets depended on market purchase for fruits which are a good source of vitamin A and thus for this reason households that were far from markets consumed less vitamin A.

CHAPTER SIX: LIMITATIONS CONCLUSION AND RECOMMENDATIONS

6.1 Limitations

This study considered production for the year 2021. From the list of produce provided by the households, the quantity sold was subtracted. The remaining quantity was considered as consumed. Therefore this study did not account for the produce lost during postharvest handling or that given out to relatives as a sign of good will. Additionally given that the quantity produced provided was dependent on memory for a full year, there is a possibility that some measurements were approximated, especially in the case of vegetables and fruits.

6.2 Conclusions

This study has revealed the following; First, agricultural commercialization in Omoro and Otuoke districts varies from 58% to 54% with an average of 4% of commercialization higher in Omoro than in Otuoke district and is influenced by land area under production, method used for land preparation, access to credit, gender of household head, main source of food and membership to farmer groups; secondly, agricultural commercialization has a potential to boost production of certain micronutrients but not all. This is illustrated by its positive influence on production of iron and folate but not vitamin A; thirdly, agricultural commercialization has the potential to boost consumption of folate among households. Considerations for the influence of agricultural commercialization on micronutrient production and consumption should take into consideration other factors such as main source of food, methods used for land preparation, access to credit, number of crops cultivated, ownership of phones, nutrition training, distance to the markets, distance to all weather roads, and location. These issues are necessary in motivating household production and consumption of micronutrient dense foods to contribute in ameliorating micronutrient deficiencies in Omoro and Otuoke districts.

6.3 Recommendations

6.3.1 Recommendations for practice

On the basis of the results of the study, the following recommendations are advanced to inform practice in the country:

- i. As agricultural extension offices promote commercialization, they should put into consideration promoting production of nutrition sensitive crops in order to increase production of micronutrients of public health importance.
- ii. Households should be encouraged to prioritize to produce and consume legumes to increase their iron levels, vegetables for folate enhancement, fruits and root crops for vitamin A improvement in order to amelioration of micronutrient deficiencies in Otuke and Omoro districts.

6.3.2 Recommendations for further studies

Basing on the information generated on production and consumption, to produce better insights on contribution of commercialization, future studies should examine the adequacy of production and consumption to households micronutrient needs. Results provided valuable information on food groups that contribute significantly to intake of the three micronutrients. Further studies should delineate factors that motivate household to produce these food crops. This information would be important for promoting production of these food groups.

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APPENDIX

Appendix I: survey data collection tool

Gulu University

Faculty of Agriculture and Environment

Department of food science and post-harvest technology

HOUSEHOLD COMMERCIALIZATION AND MICRO-NUTRIENT NUTRITION OF RURAL HOUSEHOLDS IN OMORO AND OTUKE DISTRICTS OF NORTHERN UGANDA

Introduction

My name is Kisebe Lilian, a student from Gulu University, pursuing a master's degree in food security and community nutrition. I am conducting a study in your district to assess the effect of agriculture commercialization on your micro nutrient nutrition. I am therefore requesting for your time and active participation. I will ensure total confidentiality of the information you will provide, and you are at liberty to pull out of the interview in case you do not feel comfortable. Thank you so much for your time.

SECTION A: SOCIAL DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

S/N	QUESTION	RESPONSE
1	District	1=Omoror.....2=Otuke.....
2a	Sub-county	1=Lalogi..... 2=Koro..... 3=Adwari..... 4=Okwang.....
b	Village	
3. a	Age of respondent	years
B	Age of household head	years
4. a	Gender of respondent	1=Male.....2=Female.....
. b	Gender of household Head	1=Male.....2=Female.....
5a	Are you a family household head?	1=yes.....2=No.....
b	Number of dependants in a household	
6a	Primary occupation of a household head	farming..... civil servant.....cobla... bodaboda.....firewood sales..... petty trade..... carpentry.....
b	Secondary occupation of a household head	farming.....civil servant.... cobla..... bodaboda.....firewood.... Petty trade.... carpentry.....
7	Education level of the household head in years of formal education	years
8	Main source of food	1=Own production..... 2=Market purchase.....
9.a	Land size in acres	Owned.....acre; Hired.....acres
b	Land under agricultural production	Owned.....acre; Hired.....acres
10 a	Did you use agro-chemicals on your garden last year?	1=Yes 2=No.....
b	Did you use fertilizer on your garden last production year?	1=Yes 2=No.....

c	Did you use a tractor in the last production year?	1=Yes.....2=No.....
d	Did you use ox plough last production year?	1=Yes.....2=No.....
11.a	Nearest road to the input market in km	km
b	Distance to nearest output market	km
c	Distance to nearest all weather road (km)	km
12a	Do you have access to credit	1=Yes 2=No.....
b	If yes, How do you always obtain your credit?	Banks..... Saving groups..... Money lenders..... Friends Others (specify).....
14a	Do you always have agriculture trainings from extension workers?	1=Yes 2=No.....
b	If yes, how many times in a season?	
15	Membership to a farmers group	1=Yes 2=No.....
16a	Ownership to mobile phone	1=yes.....2=No.....
b	If yes, what do you use it for in relation to farming	Receiving extension training..... Access information on inputs prices..... Access information on produce prices..... weather update..... connecting with other farmers..... Connecting with buyers..... Others (specify).....
17a	Access to agricultural information	1=Yes 2=No.....
b	Information source	Radio..... TV..... Newspapers..... Extension Agents Friends/fellow farmers Others.....
18a	Attendance of nutrition training by household head	1=Yes 2=No.....
b	If yes how often in a year	

SECTION B: AGRICULTURAL PRODUCTION

In this section, please specify the crops you grow, the quantities harvested, sold, and consumed within the last 1 production year.

			Season A						Season B					
	Crops	Prod uced (Yes /NO)	Acr eage	Qua ntity harv este d	U ni t	Qua ntit y Sold	Pr ic e pe r U ni t	Qua ntity cons ume d	Acr eage	Qua ntity harv este d	U ni t	Qua ntit y Sold	Pr ic e pe r U ni t	Qua ntity cons ume d
1i	Beans Local													
1i i	Iron- enrich ed													
2	Soybe ans													
3	Sesam e													
4	Peas													
5i	Gnuts shelle d													
5i i	Gnuts unshel led													
6	Maize													
7	Millet													
8	Sorgh um													
9i	Cassa va fresh													
9i i	Cassa va dry													
1 0i	Sweet potato Local													
1 0i i	Orang e flesh													
1 1	Mang oes													
1 2	Orang es													
1 3	Lemo n													
1 4	Paw paws													
1 5	Guava s													
1 6	Tomat oes													
1 7	Egg plants													
1 8	Entula													

			Season A						Season B					
	Crops	Prod uced (Yes /NO)	Acr eag e	Qua ntity harv este d	U ni t	Qua ntit y Sold	Pr ic e pe r U ni t	Qua ntity cons ume d	Acr eag e	Qua ntity harv este d	U ni t	Qua ntit y Sold	Pr ic e pe r U ni t	Qua ntity cons ume d
19	Malakwang													
20	Boo													
21	Dodo													
22	Okra													
23	Green gram/soroko													
24	Yams													
25	Dekngo													
28	Alaju													
	Other s ...													

SECTION C: LIVESTOCK PRODUCTION

SECTION C-1: Livestock Production and Commercialization

S/N	Livestock/Product	Produced (Y/N)	Total number/quantity available in the last 1 year	Units	Quantity sold in the last 1 years
1	Goats				
2	cattle				
3	milk				
4	Chicken				
5	eggs				
6	Pigs				
7	Others (specify)				

Section C-2: Consumption of Livestock products from own production

*Of the livestock products that your household produces, what quantities were consumed
(Only focus on livestock products from own production)*

S/N	Livestock Product	Own produced and consumed (Y/N)	Quantity Consumed in the last 1 years (two cropping seasons)	Units	Price per unit
1	Goats meat				
2	Beef				
3	Pork				
4	Chicken				
5	Eggs				
6	Milk				
	Others (Specify)				

Appendix II: consent form

Informed consent form

Title of the study: household agriculture commercialization and micronutrient nutrition of rural households in Omoro and Otuke district (Northern Uganda)

Introduction:

My name is Kisebe Lilian, a student pursuing a Master of science in Food Security and Community Nutrition in Gulu University. I am conducting research on “household agriculture commercialization and micronutrient nutrition of rural households. ”

The study is approved by the Gulu University Research Ethics Committee (GUREC). During the study you will be asked question that will require your response. The questions will ensure to protect your sensitivity and confidentiality and incase of need of withdrawal from the interview, you will have the free will to do so. After the study has been explained, you will be asked to sign a consent, which you will be given a copy to keep. Please feel free to ask about anything you would like to understand in depth about the study at any given time before signing the consent form.

Sponsors of the research:

This study is sponsored by MasterCard Foundation and Regional Universities' Forum for Capacity Building in Agriculture (RUFORUM).

Purpose:

The study seeks to gain an understanding the influence of agriculture commercialization on vitamin A, folate and iron food production and intake among the rural households. This finding will enable the policy makers to direct the right policies sand interventions that support micro nutrient food production and consumption among rural households to promote a healthy lifestyle and improve livelihoods.

Benefits to the respondent;

The respondent gets to ask any questions in agriculture and nutrition, they also get to get a copy of the results upon request that will guide them into making production decisions basing on the knowledge they have acquired.

Procedures:

Your participation in this study will involve filling in a questionnaire together with the researcher.

Who will participate in the study?

You have been chosen to participate in this study because you are among the rural household heads in Omoro or Otuke districts. The interview will not last longer than 30 minutes. Approximately 400 participants will take part in this study.

Risks/discomforts:

There is no foreseeable risk of harm or discomfort that will arise from your participation in this study. The only risk or discomfort will be the inconvenience in terms of time spent during the interview.

Benefits:

You will be allowed to ask any nutrition related questions and seek the researcher's nutrition education and guidance during the study. After the report is compiled, you can ask to have a hard copy to read through our findings. The researcher shall share the report with the concerned bodies that may guide them react appropriately.

Confidentiality:

Your identity will not be revealed to any one as we shall only use codes to identify participants. Information obtained will only be accessible by the research team. Confidential information will only be accessed by the principal investigator.

Alternatives:

You do not have to participate in this study if you are not interested. You will not lose any benefit in case of no participation.

Cost:

There will be no additional cost incurred as a result of participating in this study.

Questions:

If you have any questions related to the study, or your rights as a research participant, you can contact the principal investigator, Kisebe Lilian on telephone number 0780763523 or via email on liliankisebe9@gmail.com

Statement of voluntariness:

Participation in the research study is voluntary and you may join on your own free will. You have a right to withdraw from the study at any time without penalty.

If you have any issues pertaining to your rights and participation in the study, please contact the Chairperson, Gulu University Research Ethics Committee, Dr. Gerald Obai Tel: No., 0772305621; email: lekobai@yahoo.com/lekobai@gmail.com; or the Uganda National Council for Science and Technology, on plot 6 Kimera road, Ntinda, Kampala on Tel 0414705500.

Statement of consent

The research team has described to me what is going to be done, the risks, the benefits involved and my rights as a participant in this study. I understand that my decision to participate in this study will not affect me in any way. In the use of this information, my identity will be concealed. I am aware that I may withdraw at any time. I understand that by signing this form, I do not waive any of my legal rights but merely indicate that I have been informed about the research study in which I am voluntarily agreeing to participate. A copy of this form will be provided to me.

Name.....signature/thumb print of the participant.....date.....

Name signature of witness.....date.....

Name signature of the interviewer.....date.....

Appendix III: Translated consent form

Karatac mi yee

Wii pwony madongo me kwan man;

Pur me gangmeacataki cam matinoma kom mito wekkom wa kubed yot igangi ma icaro onyo ikin gang iyi Omoro karacel ki Otuke districk (ikumalo me Uganda)

Lakweda; Kisebe Lilian

Garg kwan; Gulu University

Langut

An nyinya Kisebe Lilian, latin kwan matye ka kwano rwom maloyo digiree goko cam ki ka bedo maorumo I moc can ma kom wan daro mito I Gulu University. Atye ka bedo ikom pur ma kipuru ki gang me acata bot lwak wek kinong cente ki dong moc cam matino ma kom wa mito igangi ma tye icaro.

Ka cedong dong pwonye Pwonye enidul matye Gulu University maloyo lokmkom kwedama munu lwongo ni Gulu University Research Committee (GUREC) gu ye.

Lapeny ma tye piri ni obi gwokongec ni ki gin ma pe imito ni ki ngee nil ok oa ki bot in. ka ce mitimo tye me aa woko wek pe wa kwed-lok man ki boti,ci imono weko wa nge ci labongo dik, wa weko in wako.

ma kitoto,wabi legi ni iket cingi I karatc me yee ma wa bi weko bot karatac acel ma meggi wek igwoki. Bed agonya me penyo kit lapenyi mo keken ikom pwonye man icawa moo keken

Lacul kwed man

Pwonye eni mastercard foundation kara cel ki Regional Forum and Capacity building in Agriculture

Tic pa kwed man

Pwonye man neon yoomeniang kit ma pur me ata tye kwede cam ma vitamin A, folate ki iron food production kit ma lukia gang camo kwede. Nango lok man obi konyo lumok cik me como enoni ikin gang wek yot kom ki bit kwo wa kuloke.

Yoo me tic

Tye ma megI I pwanye eni obi in ipongo lapeny ma tyer ikara tac karacel ki tiko yero in me bedo ipwonnye man pien in itye kin dano ma I yi omono maloyo wi gangi ma pun pur .Lapeny ki lagam eni pe obiton dakiga pyeradek. Dano marono miya angen obibedo tye I pwonge man.

Lworo

Pe tye gin moo onyo neno moo marac ikwan man. Keken ni gwok cawa moni manok ma ijalo pi gamo lapeny magi.

Mugoba

Mugoba bibino iyonge lukwed man coyo lok dogi(report) bot dul maneno lokka kikweda I Gulu University. Dano weny ma ojalo kare gi pi kwed man binongo ngec ki lok malube ki kwed man tye kawot kwede.

Kano mwung

Nyingi ki lok komi moo keken pe obinen kamoo keken pi-en kibitiyo ki nama mapatpat pi ngat acel. Kwed weng ma wabitimo ne kikany, bibedo atyera bot lukwed keken. Medo ikom mano, ladit maloyo dul kwed me Gulu University keken eni bibedo kikare me ngiyo kwed man.

Ka gwok ipe ki mitti me gamo lapeny malupe ki kweda man, ngat mo peke ma obidiyo in.

Acara

Kit acara moo keken peke ma ibinongo malupe ki jaleni pi kwed man. Kono do cawa manok keken.

Lapeny

Ka itye ki lapeny moo madok ii kum kwan man, no madok i kum twero ma meg ii bedo tye i kwan ma, i room nongo la kwed madit, Lilian Kisebe ii namba cim 0780763523 ono ki ii yamo pa munu liliankisebe9@gmail.

Lok medyere

Dano ducu ma I kwan man tye pi mitti gi labongo dic dok bene nono. Itye ki twero me aa labongo dic moo dok labongo kit pwod moo bene. Ka itye ki gin moo ma kwakko twero ni ikwan man, ribbe ki won kom me Gulu University Research Ethics Committee, Dakta Gerald Obai I namba 0772305621 onyo I mel: lekobai@yahoo.com/lekobai@gmail.com; onyo Uganda National council for Science and Technology I pulot namba 6 kimera road Ntinda, Kampala in namba: 0414705500

Yee

Joo me kwed man gi owacca gin ma mito atima, acara, mugoba ki twero na ikwan man. Atye ki ngec maber ni kwan man pe twero kelo kit lok moo keken ikoma. I kwed man, lok koma moo peke ma kibiyaroo kamaleng dok aromo aa ki I kwan man cawa moo keken. Aniang ni keto cinga I karatac man pediyo twerona iyoo moo keken, ento nyutu ni aye kwanyo kare na me gamo lapeny malupe ki kwed man. Kara tac kwed man ki bi miyo mogo botta.

Nying: Sigineca: /thumb print of the participant..... Nino
dwe:.....

Name signature of witness.....date.....

Name signature of the interviewer.....date.....

Ngec atut ikom ikweda man

**Wie Malo: Pur irwom me biacara iwi ot acel acel kede mot cem apat pat iwi wudi me
calo iyi Omoro Kede Otuke District (Tumalo me Uganda)**

Nying Akwed ping: Kisebe Lilian

Cukul: Gulu University

Jami amyero inge

An nyinga Kisebe Lilian. Abedo atin kwan me Gulu University, ame atye amedo kwan na irwom me Masters i food security and community nutrition. Atye atimo ikweda ikom **“Pur irwom me biacara iwi ot acel acel kede mot cem apat pat iwi wudi me calo ”**

Ikweda man Gulu University Research Ethics Committee (GUREC) otyeko yee ni myero timere. Icawa me ikweda man, openyi kede apenyoro anonok ame nwo omino ni igami wa. Apeny wa ni ducu bino gwoko jami akwaki ducu acalo imung, ento ka iwinyo ni pe itwero bedo iyi ikweda ni, itwero bedo agonya me weko. Iyonge kobi jami ducu akwako ikweda man, okwayi me coyo cingi me nyuto ni iye bedo iyi ikweda man ame nwo oweki kede pote acel me megii. Bed agonya me penyo peny ikom ginoro keken ape iniang iye icawa moro keken. Bed dang agonya me penyo peny ikom ginoro keken ame imito niango atat akwako ikweda man icawa moro keken apwod pe i keto cingi me yee bedo iye.

Jo oculo pi ikweda man:

Ikweda man jo oculo pire obedo MasterCard Foundation and Regional Universities’ Forum for Capacity Building in Agriculture (RUFORUM)

Pingo myero otim ikweda ni?

Ikweda man atye atimo me nyayo ngec kede niang adwong ikom jami adongo nyo balo timo pur calo biacara ikom kayo mot cem acalo vitamin A, folate, iron kede kero me camo iwi wudi atye i calo. Ripot aya ikom ikweda man bino konyo otela irwom apat pat me kato kede moka ame konyo dongo puro cem ame kelo mot cem apat pat kede camo ikin wi wudi acel acel icalo, me dongo rwom me yotkom kede kwo ajo.

Kit ame ikweda man awot kede

Iyi ikweda man, in ibino tiyo tic me gamo apeny ame wan obino penyi kede ite gamo kede kony atim ikweda man.

Nga atwero bedo iyi ikweda man?

Wan oyeri me bedo iyi ikweda ni pyen ibedo dano ame tye atelo wi paco acel ikin paci/ wudi ame tye icalo iyi Omoro nyo Otuke district. Ikweda ni pe atero dakika akato pyero adek (30). Jo aromo mia angwen (400) aye bino bedo igum me bedo iyi ikweda man.

Angola ngola/ Ayela yela

Pe tye angola ngola nyo ayela yela moro ame oneno ni bino kato ikom bedo ni iyi ikweda man. Kar angola ngola nyo ayela yela ame twero timere obedo balo cawa ame gamo peny iyi ikweda ni bino bedo kede.

Gum/ Ber a bedo iyi ikweda man

Ibino bedo kede gum me penyo peny ikom jami ducu ape iniang ikom kite me gwoko yotkom ni beo icamo cem atye kede mot cem amite ikomi ducu; me miyi nwongo pwonyere, kede anyut aber me aluba. Ka ikweda man otum, itwero penyo wek omi adwogi me ikweda man ame ocoo ping wek yin dang inge adwogi me ikweda man. Atin kwan man bino cwalo adwogi me ikweda man bot jo ame twero konyo inyuto yo aber me aluba kede jami abeco amyero itim.

Imung

Kop akwaki ducu obino gwoko calo imung kede dang obino tic kede namba me ngeyo jo atye iyi ikweda ni ducu. Obino gwoko agami duc kan ame dul me ikweda man keken aye twero mako. Imung atutere won ikweda man kene aye bino bedo kede kare me bedo kede.

Itwero dang timo kiti:

Ka cunyi winyo ni pe myero ibed iyi ikweda man, itwero miyo wa ngeyo wek ogonyi oko calo dic pe iye. Pe tye mot moro ame ibino keng pyen pe ibedo iyi ikweda man.

Cul

Pe tye cul moro keken ame ibino culo me wek ibed iyi ikweda man.

Apeny

Ka itye kede apeny moro keken akwako ikweda man, onyo akwako twero ni me bedo iyi ikweda man, itwero penyo akwed kwed man (Kisebe Lilian) nibeo igoyo cim i namba 0780763523, onyo icwal balo inyonyo amuno bot liliankisebe9@gmail.com

Ngec ikom jalo cawa ni me bedo iyi ikweda man

Bedo iyi ikweda man tye imiti ni, dang itwero bedo iye ka tek cunyi winyo. Itwero weko bedo iyi ikweda man icawa moro keken acunyi winyo. Pwod moro keken pe iweko timo ikweda man.

Ka itye kede koporo keken akwako ikweda man, onyo akwako twero ni me bedo iyi ikweda man, itwero penyo atel wi ikweda i Gulu University, Dr. Gerald Obai, nibeo igoyo cim namba 0772305621; onyo icwal waraga inyonyo amuno i lekobai@yahoo.com onyo lekobai@gmail.com; onyo dang Uganda National Council for Science and Technology, plot 6 Kimera road, Ntinda, Kampala inamba cim 0414705500

Kop anyuto ni iye bedo iyi ikweda man

Jo ame tye aloyo ikweda man okoba jami ducu ame atimere iyi ikweda man, angola ngola atimere, gum atye iye bedo iyi ikweda man, kede twero na ducu alubere kede bedo na iyi ikweda man. Aniang ni moko tama me bedo iyi ikweda man pe abedo kede ayela moro keken ikoma iyore moro keken. Itic kede ngec ame amiyo, ngec ikoma bino bedo imung, dang pe obino poko kanoro keken. Angeo ni atwero weko bedo iyi ikweda ni icawa moro keken. Aniang ni keto cinga i papara ni pe mia arwenyo twero na moro keken iyore moro keken, ento nyuto ka ni aniang ikom ikweda man ame aye bedo iye imiti na ni. Pot papara ni acel obino miyo bota.

Nyingi: Cingi: /thumb print of the participant..... Nino dwe:.....

Name signature of witness.....date.....

Name signature of the interviewer.....date.....

Appendix iv

Appendix V: Approval Letters from the CAO

GULU UNIVERSITY
P. O. BOX 166
Gulu-Uganda
-256 471 432518
FAX. +256 471 432094
Email: fac@gu.ac.ug
URL: www.gu.ac.ug

FACULTY OF AGRICULTURE & ENVIRONMENT

The District agriculture officer,
Omoro District

19th April 2022

Dear Sir/Madam

RE: INTRODUCTION OF MS. LILIAN KISEBE

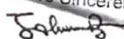
I hereby introduce to you, Ms. Lilian Kisebe, who is a student of Master of Science in Food Security and Community Nutrition, Department of Food Science and Postharvest Technology, Gulu University. Her registration number is 20/U/2842/MFN/PS.

Lilian is conducting an academic research to understand the effect of agriculture commercialization on micro nutrient nutrition in Lalogi and Koro sub-counties. Your district has been selected for this study because of the nutrition status basing on the country's statistics. The study will involve talking to rural household heads to under the influence of agriculture commercialization on micro nutrient nutrition. During the study, all the standard operating procedures against the spread of Covid 19 will be observed.

I therefore request you to allow her to conduct the study in these sub-counties.

Any assistance rendered to her will be appreciated

Yours Sincerely,



Dr. Solomon Olum (PhD) Head, department of Food Science and Postharvest Technology s.olum@gu.ac.ug, 0779 486193

Appendix v

GULU

P. O. BOX 166
Gulu-Uganda



UNIVERSITY

256 471 432518

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Email: fac@gu.ac.ug

URL: www.gu.ac.ug

FACULTY OF AGRICULTURE & ENVIRONMENT



The District agriculture officer,
Otuoke District

Dear Sir/Madam

RE: INTRODUCTION OF MS. LILIAN KISEBE

I hereby introduce to you, Ms. Lilian Kisebe, who is a student of Master of Science in Food Security and Community Nutrition, Department of Food Science and Postharvest Technology, Gulu University. Her registration number is 20/U/2842/MFN/PS.

Lilian is conducting an academic research to understand the effect of agriculture commercialization on micro nutrient nutrition in Adwari and Okwang sub-counties. Your district has been selected for this study because of the nutrition status basing on the country's statistics. The study will involve talking to rural household heads to under the influence of agriculture commercialization on micro nutrient nutrition. During the study, all the standard operating procedures against the spread of Covid 19 will be observed.

I therefore request you to allow her to conduct the study in these sub-counties.

Any assistance rendered to her will be appreciated

Yours Sincerely,

Dr. Solomon Olum (PhD) Head, department of Food Science and Postharvest Technology, solom@gu.ac.ug, 0779 486193

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PLAGIARISM CHECK

Declaration of Originality Form

This form must be completed and signed for all scholarly work produced.

Name: Ms Lilian Kisebe
Personal File No.(staff) Reg. (student). 20/U/2842/MFN/PS
Faculty/Institute: AGRICULTURE AND ENVIRONMENT
Department: FOOD SCIENCE & POST HARVEST TECHNOLOGY
Title and bibliographic description of the work
INFLUENCE OF AGRICULTURAL COMMERCIALIZATION ON MICRONUTRIENT NUTRITION
AMONG RURAL HOUSEHOLDS IN OMORO AND OTUKE DISTRICTS OF NORTHERN UGANDA

Declaration.

1. I understand what plagiarism is and I am aware of the University policy on this regard,
2. I declare that this ...**Master Thesis**... (thesis, dissertation, essay, assignment, paper, report etc.) is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work or my work has been used, this has been properly acknowledged and referenced in accordance with Gulu University requirements,
3. I have not sought or used the services of any professional agency to produce this work,
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own,
5. I understand that any false claim of this work shall result in disciplinary action in accordance with University Policy on Plagiarism.

Signature [Signature]

Date 11/05/2023

Originality Report

The article/thesis/document titled above have been subjected to plagiarism check and the level was found to be.....**15%** (percent) this is classified as:

- ☒ Minor
☐ Moderate
☐ Serious

Yours sincerely,

[Signature]
Dr. Ongaya Kizito (PhD)
AG. UNIVERSITY LIBRARIAN