

**POTENTIAL OF UNDERUTILIZED DOLICHOS LABLAB (*Lablab purpureus*) SEEDS IN IMPROVING NUTRITIONAL QUALITY AND LIVELIHOOD IN TANZANIA**

**Josephine Joseph Minde**

**A Thesis Submitted in Fulfilment of the Requirements for the Degree of  
Doctor of Philosophy in Life Sciences of the Nelson Mandela African Institution of  
Science and Technology**

**Arusha, Tanzania**

**August, 2023**

## ABSTRACT

Lablab is a climate-smart legume that is underutilized despite its potential for food, and income. Less research attention is linked to its underutilization limiting its contribution to achieving Sustainable Development Goals (SDG) 1, 2 and 3. This calls to search for synergies to the further improve Lablab utilization in Tanzania. Both qualitative and quantitative methods were employed. A total of 344 Lablab farmers and 40 traders were interviewed to collect information on knowledge, attitude, and practices (KAPs), Lablab value chain and dietary diversity from the selected districts in Morogoro, Manyara, Arusha and Kilimanjaro regions of Tanzania. A total of 30 accessions were collected from the local farmers and NM-AIST Genebank. The accession collected were evaluated for nutritional quality using standard methods. The best nutrient dense four accessions (D-394, ELD K2, HA-4 and D-96) were further used to formulate Lablab cookies. The study revealed that KAPs vary among farmers in Babati (39.6%) and Arumeru (27.3%). Arumeru had a positive attitude toward black accessions (80.2%) for marketing, whereas non-black accessions were less well-known. Farmers were the primary actors, contributing for 70% of the natural assets for livelihood. Accession D-422 ranked higher in protein content by 28.3%. Sprouting significantly ( $p < 0.001$ ) reduced phytic acid in D-360 (64.6%), tannins in HA-4 (94.8%), and trypsin inhibitors (TIs). Fermentation significantly ( $p < 0.001$ ) decreases phytic acid by 75% in HA-4 and D-96, and tannin by 61% in HA-4 as well as trypsin TIs in ELD-K2, HA-4, and D-96 by over 90%. Furthermore, sprouted seeds had higher mineral concentrations in D-96 and HA-4, such as Mg (0.11-0.25%), (0.09-0.20%), and Zn (0.03-0.34%) and (0.23-0.32%), respectively, whereas fermented seeds increased Mg concentration in HA-4 from 0.09 to 0.23% and Zn content (0.23-0.35%). Lablab cookies made from HA-4 and D-96 fermented flours were highly preferred. HA-4 cookies scored the highest ( $> 8$ ) similar to control. On the other hand, black Lablab's revenue contributed less to dietary diversity than nonfood commodities as per the Principal Component Analysis. Farmers' diets were over 90% cereal-based, with less Lablab-eating foods. The study concluded that wise income allocation is essential for both non-food items and nutritive food. Furthermore, the best accessions represent a diverse supply of high-quality food that, when fermented, greatly reduces anti-nutrients, yielding healthier and convenient nutritious foods. As a result, among the recommendations, value-addition and promotion of underutilized seeds could increase consumption and revenue, particularly for smallholder farmers in Tanzania.

## DECLARATION

I, Josephine Joseph Minde, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.



Josephine Joseph Minde

21/08/2023

Date

The above declaration is confirmed by:



Prof. Athanasia O. Matemu

21/08/2023

Date



Dr. Pavithravani B. Venkataramana

21/8/2023

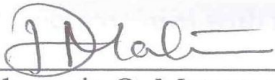
Date

## **COPYRIGHT**

This thesis is copyright material protected under the Berne Convention, the Copyright Act of 1999, and other international and national enactments, on that behalf, on intellectual property. It must not be reproduced by any means, in full or in part, except for short extracts in fair dealing; for researcher, private study, critical scholarly review, or discourse with an acknowledgment, without the written permission of the office of Deputy Vice Chancellor for Academic, Research, and Innovation on behalf of both the author and the Nelson Mandela African Institution of Science and Technology (NM-AIST).

## CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance for the thesis entitled "*Potentials of Underutilized Dolichos Lablab (Lablab purpureus) Seeds in Improving Nutritional Quality and Livelihood in Tanzania*". In fulfillment of the Award of Doctorate of Philosophy in Life Sciences at the Nelson Mandela African Institution of Science and Technology.



Prof. Athanasia O. Matemu

21/08/2023

Date



Dr. Pavithravani B. Venkataramana

21/8/2023

Date

## ACKNOWLEDGEMENTS

This thesis would have not been possible without Almighty God's blessing and power, and the humble supervision of Prof. Athanasia O. Matemu and Dr. Pavithravani B. Venkataramana, to whom I will be forever grateful for their invaluable advice, guidance criticisms, academic support, and patient understanding at every stage of this work.

The African center of excellence known as the Centre for Research, Agricultural Advancement, Teaching Excellence and Sustainability in Food and Nutrition Security (CREATES- FNS) and the Nelson Mandela African Institution of Science and Technology (NM-AIST) have jointly supported my PhD studies by awarding me the PhD partially scholarship for studies. Sincere gratitude goes to Prof. Hulda Swai, Ms. Rose Mosha, and Ms. Balbina Tenga for their various technical support during desperate times with regard to the implementation of the scholarship. Also, a special thanks to Prof. Patrick Ndakidemi for his fatherhood and moral and academic support.

I gratefully acknowledge the Kirk House Trust in the United Kingdom for financing the Stress Tolerant Orphan Legumes (STOL) project at NM-AIST for the collection and maintenance of the Dolichos Genebank, as well as for providing thorough information and seed materials used in this study.

I offer my profound gratitude to my employer the Open University of Tanzania (OUT) for the study leave under the Ministry of Education, Science and Technology of Tanzania. In addition, I gratefully acknowledge the support of all OUT staff, particularly those at the Kilimanjaro regional center.

I am thankful to the Tanzania Agricultural Research Institute (TARI), Selian branch in the Arusha region, for support prior to data collection under Mr. Wilson Mariki, and to the Tanzania Coffee Research Institute (TaCRI), Hai district, Kilimanjaro region, for technical support under Mr. Epafra Moss.

Special thanks to Mr. Sylivester Temba (Food laboratory specialist) and Mr. Emmanuel Lyimo (Molecular biology specialist) at NM-AIST for their technical support during laboratory activities. I am also very thankful to Dr. Sixbert Mkumbaye, a Senior Lab. Scientist and Research Scientist at KCMC/KCMUCo/KCRI, Dr. Protas M. Deogracious, a Manager Plant Pathology, Molecular Biology, and Tissue Culture Laboratory Facilities (Department, Crop Science, and Horticulture, Sokoine University of Agriculture, Morogoro) for their technical advice and laboratory data analysis support. I appreciate the Laboratory support from Aloyce Kinemelo of Tanzania Atomic Energy Commission (TAEC). Special recognition is given to high-quality scientific photographs

and graphics in this work assisted by Mr. Emmanuel Massaga and Mr. Joel Ephraim for technical advice and assistance on data analysis.

Many thanks to the staff of Babati, Arumeru, Same, and Mvomero District councils as well as Village Extension officers for the logistics support and cooperation. I acknowledge farmers from the mentioned Districts for their great concern and tireless time in making my study very easy during data collection and result dissemination.

Nobly, my work would not have been possible without the spiritual, moral, and financial support of my lovely husband, Dr. Gervas Mathias Machimu in this academic life. Special thanks to my loving boys Innocent G. Machimu and Joseph G. Machimu, whose endless smiles and enlightening inquiries pushed me forward and helped me to focus on my studies. I also like to thank Minde, Machimu family members and all our family friends for their ongoing prayers, love, and encouragement.

My thanks to the chairpersons and members of the NM-AIST School of Life Sciences and Bio-Engineering (LiSBE) committee for their efforts in ensuring the successful completion of this thesis defense, as well as to the entire NM-AIST staff. Appreciations go to Ms. Asha Mafita, Mr. Greyson Johnson, and Innocent Mrema. I gratefully thank my sister's family friend, Ms. Philipina Shayo, for her assistance during the study period, especially during difficult periods. Special thanks also to my Lablab Team: Mr. Letting Fanuel and Mr. Julius Misanga, colleagues: Dr. Difo Harouna, Mr. Frank Sangija, Mr. Dennis Mwalongo, and others, whose words of encouragement and support helped me get through the research period.

## **DEDICATION**

This work is dedicated to my almighty God who has given me life and strength to complete this work; to my parents Mr. Joseph Minde and Mrs. Germana Joseph Mombury who laid down the foundation of my education and to my lovely husband Dr. Gervas Mathias Machimu for his tireless support, love and immeasurable encouragement to make my dreams come true.



## TABLE OF CONTENTS

|   |       |
|---|-------|
| ABSTRACT.....                           | i     |
| DECLARATION .....                       | ii    |
| COPYRIGHT.....                          | iii   |
| CERTIFICATION .....                     | iv    |
| ACKNOWLEDGEMENTS.....                   | v     |
| DEDICATION.....                         | vii   |
| TABLE OF CONTENTS.....                  | viii  |
| LIST OF TABLES .....                    | xii   |
| LIST OF FIGURES .....                   | xiv   |
| LIST OF PLATES .....                    | xvi   |
| LIST OF APPENDICES.....                 | xvii  |
| LIST OF ABBREVIATIONS AND SYMBOLS ..... | xviii |
| CHAPTER ONE .....                       | 1     |
| INTRODUCTION .....                      | 1     |
| 1.1 Background of the Problem .....     | 1     |
| 1.2 Statement of the Problem .....      | 2     |
| 1.3 Rationale of the Study .....        | 3     |
| 1.4 Research Objectives .....           | 4     |
| 1.4.1 General Objective .....           | 4     |
| 1.4.2 Specific Objectives .....         | 4     |
| 1.5 Research Questions .....            | 4     |
| 1.6 Significance of the Study .....     | 5     |
| 1.7 Delineation of the Study.....       | 5     |
| CHAPTER TWO .....                       | 7     |
| LITERATURE REVIEW .....                 | 7     |
| 2.1 Introduction .....                  | 7     |

|       |   |    |
|-------|---|----|
| 2.2   | Research Framework.....   | 7  |
| 2.3   | A Brief Introduction of Lablab Crop .....                                   | 9  |
| 2.4   | Distribution of Lablab Crop .....   | 10 |
| 2.5   | Lablab Species Diversity.....   | 11 |
| 2.6   | Lablab Accessions.....  | 14 |
| 2.7   | Why Lablab Crop Production?.....  | 15 |
| 2.8   | Potentials of Underutilized Lablab Crop.....                                | 16 |
| 2.8.1 | Nutritional Potential.....  | 16 |
| 2.8.2 | Medicinal Potential .....   | 22 |
| 2.8.3 | Economic Potential .....  | 23 |
| 2.8.4 | Ornament Potentials.....  | 23 |
| 2.8.5 | Soil Conservation.....  | 24 |
| 2.8.6 | Lablab Crop for Livelihood .....  | 25 |
| 2.8.7 | Genetic Resources for Food and Agriculture Sustainability.....              | 27 |
| 2.9   | Why Lablab Crop is Underutilized? .....                                     | 29 |
| 2.9.1 | Little Attention by Researchers and Policymakers .....                      | 29 |
| 2.9.2 | Improperly Lablab Crop Documentation.....                                   | 29 |
| 2.9.3 | Little Traded as Commodities.....   | 30 |
| 2.9.4 | Confusion Regarding Phrases Usage .....                                     | 30 |
| 2.9.5 | Initiative for Bringing Back Underutilized Lablab Crop.....                 | 31 |
| 2.10  | Unravel Knowledge, Attitude, and Practice (KAP) for Lablab Consumption..... | 32 |
| 2.11  | Future Prospects of Lablab Crop.....  | 33 |
|       | CHAPTER THREE .....   | 34 |
|       | MATERIAL AND METHODS.....   | 34 |
| 3.1   | Study Area.....   | 34 |
| 3.2   | Study Design and Approach .....   | 34 |
| 3.3   | Sample Size Calculation .....   | 35 |

|       |   |    |
|-------|---|----|
| 3.4   | Sampling Procedure .....  | 35 |
| 3.5   | Questionnaire Designing, Pretesting, and Administration .....                                       | 35 |
| 3.6   | Ethical Clearance .....   | 36 |
| 3.7   | Materials.....  | 36 |
| 3.7.1 | Knowledge, Attitude and Practices Assessment .....  | 38 |
| 3.7.2 | Lablab Value Chain Analysis .....   | 40 |
| 3.7.3 | Physical and Nutritional Quality of Lablab .....  | 40 |
| 3.7.3 | Mineral Content .....   | 43 |
| 3.7.4 | Anti-Nutrients Determination .....  | 43 |
| 3.7.5 | Lablab Processing, Mineral, and Anti-Nutrients Determination of Sprouted and Fermented Lablab ..... | 45 |
| 3.7.6 | Lablab Products Formulation.....  | 46 |
| 3.7.7 | Consumer Acceptability Test.....  | 46 |
| 3.7.8 | Minimum Dietary Diversity Assessment.....   | 46 |
| 3.8   | Data Analysis .....   | 47 |
|       | CHAPTER FOUR.....   | 48 |
|       | RESULTS AND DISCUSSION .....  | 48 |
| 4.1   | Household Knowledge, Attitude, and Practices (KAPs) on Lablab* .....                                | 48 |
| 4.1.1 | Socio-Demographic Characteristics of the Respondents in the Study Sites .....                       | 48 |
| 4.1.2 | Farmers' Knowledge, Attitudes, and Practices .....  | 49 |
| 4.1.3 | Barriers to the Utilization of Lablab Crop .....  | 56 |
| 4.2   | Lablab Value Chain in Relation to Households' Livelihood* .....                                     | 57 |
| 4.2.1 | The Lablab Value Chain Systems .....  | 59 |
| 4.2.2 | The Lablab Value Chain Actors .....   | 62 |
| 4.2.3 | The Lablab Value Chain Activities.....  | 63 |
| 4.2.4 | Lablab Value Chain and Farmers' Household Livelihood .....  | 66 |
| 4.3   | Physicochemical Characteristics of Lablab Seeds .....   | 70 |

|                                      |  |     |
|--------------------------------------|--|-----|
| 4.3.1                                | Physical Characteristics .....   | 70  |
| 4.3.2                                | Proximate Compositions.....  | 71  |
| 4.3.3                                | Mineral Content .....  | 72  |
| 4.4                                  | Effects of Processing Methods on ANFs, Mineral Contents .....              | 73  |
| 4.4.1                                | Effects of Sprouting on ANFs.....  | 73  |
| 4.4.2                                | Effects of Fermentation on ANFs .....                                      | 74  |
| 4.4.3                                | Effect of Processing Methods on Trypsin Inhibitor.....                     | 75  |
| 4.4.4                                | Effects of Processing on Mineral Contents.....                             | 77  |
| 4.5                                  | Effect of processing on the Consumer Acceptability of Lablab Cookies ..... | 79  |
| 4.5.1                                | Consumer Acceptance of Sprouted Cookies.....                               | 79  |
| 4.5.2                                | Consumer Acceptance of Fermented Cookies .....                             | 80  |
| 4.5.3                                | Overall Acceptability .....  | 82  |
| 4.6                                  | Lablab Production and Dietary Diversity .....                              | 84  |
| 4.6.1                                | Dietary Diversity per District.....  | 84  |
| 4.6.2                                | Dietary Diversity in the Farmer's Household .....                          | 85  |
| 4.6.3                                | Lablab Production and Household Dietary Diversity .....                    | 86  |
| 4.6.4                                | Lablab Income Distributions.....   | 89  |
| CHAPTER FIVE .....                   |  | 92  |
| CONCLUSION AND RECOMMENDATIONS ..... |  | 92  |
| 5.1                                  | Conclusion .....   | 92  |
| 5.2                                  | Recommendations .....  | 93  |
| REFERENCES .....                     |  | 94  |
| APPENDICES .....                     |  | 115 |
| RESEARCH OUTPUTS.....                |  | 125 |

## LIST OF TABLES

|           |   |    |
|-----------|---|----|
| Table 1:  | Lablab Crop Names .....   | 10 |
| Table 2:  | Distribution of Lablab crop in the world .....  | 11 |
| Table 3:  | Some of the Lablab accessions in the Gene banks.....  | 15 |
| Table 4:  | Variation in major nutritional components of some Lablab accessions (g/100 g dry weight) .....                        | 17 |
| Table 5:  | Nutritional composition of selected legumes and cereals (g/100 g grain dry weight                                     | 18 |
| Table 6:  | Processing and cooking methods for dry legume seeds.....  | 21 |
| Table 7:  | Neglected and/or underutilized species used for FNS from around the world .....                                       | 30 |
| Table 8:  | Lablab accessions collected from the farmers in the study sites.....  | 37 |
| Table 9:  | Lablab accessions selected based on the farmers' observations/preferences (score parameters) at the NM-AIST farm..... | 37 |
| Table 10: | Socio-demographic characteristics of the Lablab farmers in the study districts respondents.....                       | 49 |
| Table 11: | Farmers' level of knowledge on Lablab crop across the study districts .....   | 50 |
| Table 12: | Factors determining farmers' level of knowledge of Lablab crop from an ordered probit regression analysis .....       | 52 |
| Table 13: | Farmers' attitudes toward Lablab crop .....   | 53 |
| Table 14: | Attributes that contributed to the acceptability of cooked black Lablab accession ...                                 | 56 |
| Table 15: | Inputs observed along the Lablab value chain in the study district .....  | 61 |
| Table 16: | Developed indicators (DI), with definitions and expected relationships .....  | 67 |
| Table 17: | Developed indicators from LVC used to measure farmers' household livelihood assets .....                              | 68 |
| Table 18: | Relationship between the livelihood index and social economic factors.....  | 69 |
| Table 19: | Physical properties of the seeds .....  | 71 |
| Table 20: | The proximate composition of Lablab accessions .....  | 72 |
| Table 21: | Mineral contents in Lablab accessions (mg/100 g).....   | 73 |

|   |    |
|---|----|
| Table 22: Anti-nutrient contents of raw, sprouted, and fermented Lablab accessions (mg/100 g) | 74 |
| Table 23: Effect of sprouting and fermentation on the mineral content in Lablab accessions .. | 78 |
| Table 24: Mean (S. D.) scores liking on the sensory attributes of sprouted cookies .....      | 79 |
| Table 25: Mean (S. D) scores liking on sensory attributes of fermented cookies.....           | 82 |
| Table 26: General comments.....   | 84 |
| Table 27: Lablab production determinants and MDD-W for household diet quality .....           | 88 |

## LIST OF FIGURES

|            |  |    |
|------------|--|----|
| Figure 1:  | Research framework of the potential of Lablab seeds in improving nutritional quality and livelihood (Rick de Satgé <i>et al.</i> , 2002) .....   | 8  |
| Figure 2:  | Lablab pods with diverse in colour and size (Singh & Abhilash, 2019) .....   | 13 |
| Figure 3:  | Lablab flowers of various colours (purple, yellow, and white) in full bloom and on a flower spike (Ambrose <i>et al.</i> , 2016; Grotelüschen, 2014).....  | 13 |
| Figure 4:  | Lablab (Hyacinth bean) vine with purple flowers planted as a fence and light tower decorator (Ambrose <i>et al.</i> , 2016; Adebisi & Bosch, 2004) .....   | 24 |
| Figure 5:  | Lablab a cover crop: (a) 4 weeks after planting, (b) 2 months after planting, (c) 3 months after planting, and (d) 4 months after planting (Shetto & Owenya, 2007; Bwalya, 2005).....                            | 24 |
| Figure 6:  | Lablab cropping systems: (a) Lablab crop can be cultivated as intercropping with cereals like maize, (b) rotated with other crops, (c) sole crop in conservation agriculture (Forsythe, 2019; Tefera, 2006)..... | 25 |
| Figure 7:  | Livelihood assets framework.....   | 26 |
| Figure 8:  | Farmers' level of knowledge on Lablab crop based on gender .....   | 50 |
| Figure 9:  | General farmers' attitudes on Lablab crop across the districts.....  | 53 |
| Figure 10: | Lablab consumption preference versus common bean consumption as determined by farmer choices in their districts .....  | 54 |
| Figure 11: | Farmers' preferences for Lablab crop cultivation versus common beans varied by study district .....  | 54 |
| Figure 12: | Frequency of consumption of foods made from Lablab in the farmers' households in the study districts .....   | 55 |
| Figure 13: | Based on the study district, farmers' responses to barriers to Lablab crop were identified.....  | 57 |
| Figure 14: | A map showing four agro-ecological zones for Lablab cultivation in Same, Mvomero, Arumeru, and Babati districts of Tanzania .....  | 58 |
| Figure 15: | The Lablab value chain mapping among Lablab growing districts in Tanzania.....   | 59 |
| Figure 16: | The Lablab value chain systems wheel and their subdivision magnitude in Lablab crop growing districts in Tanzania .....  | 60 |

|            |  |    |
|------------|--|----|
| Figure 17: | Lablab marketing destinations where Lablab seeds are sold observed per the study district .....  | 61 |
| Figure 18: | Demographic characteristics of the LVC actors; farmers (n=344) and buyers (n=40) .....   | 63 |
| Figure 19: | Buyers' market involvement at the study the sites (n=40).....  | 63 |
| Figure 20: | Varied Lablab farming systems were found across the study sites .....  | 64 |
| Figure 21: | Harvesting procedures for Lablab crop as observed across the study sites .....   | 64 |
| Figure 22: | Post-harvest handling of lablab seeds; pre-drying or not, threshing, winnowing, drying, and storage .....  | 65 |
| Figure 23: | Livelihood assets spider pentagon representing the average score per asset category: Calculated from the total scores (T. S.) of each developed indicator based on farmers' households' characteristics (Rick de Satgé <i>et al.</i> , 2002) .....   | 69 |
| Figure 24: | Constraints to the Lablab production as summarized across the Lablab producing districts in Tanzania.....  | 70 |
| Figure 25: | Dietary Diversity of Women Lablab farmers in the Study Districts: High dietary diversity score = 6 and above; Average = 4-5; Low = 3 or fewer .....  | 85 |
| Figure 26: | Food groups (%) consumed by women on the previous day per district .....   | 86 |
| Figure 27: | Household food security status: FS=food secure, FIWTH=food insecure without hunger, FIWHMH=food insecure with moderate hunger, and FIWHS=food insecure with severe hunger .....  | 87 |
| Figure 28: | Principal Component Analysis displaying the crop's resulting assets or services: 36(a) A biplot proxy of item variables presented as result of Lablab income gain in the household. Long arrows indicate an important contribution of the income in the acquired items. 36(b) A biplot showing items purchased using Lablab money by district (Arumeru, Babati, Mvomero, and Same) ..... | 90 |
| Figure 29: | Component loaded for patterns that retained in each of the item variables measured .....   | 91 |



## LIST OF PLATES

|           |  |    |
|-----------|--|----|
| Plate 1:  | Variability for seeds of some Lablab accessions at NM-AIST Genebank with different origins.....  | 12 |
| Plate 2:  | The map of Tanzania showing study sites in four districts in four regions with higher Lablab production .....  | 34 |
| Plate 3:  | The Lablab farmers visit at NM-AIST farm: (a) discussing on the assessment parameters, (b) at the assessment site and, (c) compilation of the results .....  | 38 |
| Plate 4:  | Data collection: Interviews with study participants at Majengo Kati village, Sakila village, and Mbauda local market in the study sites .....  | 40 |
| Plate 5:  | A tablet-like referred to as a pellet, labelled and stored for further analysis.....   | 43 |
| Plate 6:  | Lablab beans collection center at a local market in Ngaramtoni juu at Arusha region .....  | 65 |
| Plate 7:  | Lablab beans weighed, and packed ready for transportation to the local market.....   | 66 |
| Plate 8:  | SDS-PAGE for Lablab protein characterization for the presence of TI in the accessions .....  | 76 |
| Plate 9:  | Lablab cookies prepared from sprouted Lablab flour: 818:D-394 (1); 776:D-394 (2); 456:D-394 (3); 882:D-394 (4); 272:ELD K2 (1); 457:ELD K2 (2); 750:ELD K2 (3); 661:ELD K2 (4); 591:HA-4 (1); 150:HA-4 (2); 670:HA-4 (3); 114:HA-4 (4); 171:D-96 (1); 672:D-96 (2); 530:D-96 (3); 104:D-96 (4) and 238:Control.....    | 80 |
| Plate 10: | Fermented of Lablab accessions (a) fermentation with LAC at ambient temperature for 72 hours (b) fermented accessions .....  | 81 |
| Plate 11: | Lablab Cookies prepared from fermented Lablab flour: 842:D-394 (1); 615:D-394 (2); 727:D-394 (3); 601:D-394 (4); 138:ELD K2 (1); 721:ELD K2 (2); 475:ELD K2 (3); 299:ELD K2 (4);, 487:HA-4 (1);, 675:HA-4 (2); 649:HA-4 (3); 154:HA-4 (4); 249:D-96 (1); 620:D-96 (2); 825:D-96 (3); 522:D-96 (4) and 238:Control..... | 83 |

## **LIST OF APPENDICES**

|             |  |     |
|-------------|--|-----|
| Appendix 1: | Questionnaire for farmers and consumers at household level .....               | 115 |
| Appendix 2: | Questionnaire for trader/agents/middleman.....                                 | 122 |
| Appendix 3: | Questionnaire for sensory attributes and acceptability of the Lablab cookies.. | 124 |

## LIST OF ABBREVIATIONS AND SYMBOLS

|          |  |
|----------|--|
| ANFs     | Anti-Nutritional Factors                                     |
| ANOVA    | Analysis of Variance   |
| AOAC     | Association of Official Agricultural Chemists                |
| DFID     | British Department for International Development             |
| FAO      | Food and Agriculture Organization                            |
| FNS      | Food and Nutrition Security                                  |
| IFAD     | International Fund for Agricultural Development              |
| IITA     | International Institute of Tropical Agriculture Australian   |
| KAPS     | Knowledge, Attitude and Practices                            |
| LVC      | Lablab Value Chain   |
| MDD-W    | Minimum Dietary Diversity for Women of Reproductive Age      |
| ME       | Marginal Effect  |
| NM-AIST  | Nelson Mandela African Institution of Science and Technology |
| NUS      | Neglected and Underutilized Species                          |
| PCA      | Principal Component Analysis                                 |
| SDGS     | Sustainable Development Goals                                |
| SDS-PAGE | Sodium Disulfate Polyacrylamide Gel Electrophoresis          |
| Tis      | Trypsin Inhibitors   |
| UCS      | Underutilized Crops  |
| UN       | United Nation  |
| UNICEF   | United Nations Children's Fund                               |
| VCA      | Value Chain Analysis   |
| WFP      | World Food Program   |
| WHO      | World Health Organization                                    |

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background of the Problem

The State of Food and Nutrition Security (FNS) in the World 2020 reported that five years of ending hunger, food insecurity, and all forms of malnutrition are still off tracking to be achieved by 2030 (FAO, IFAD, UNICEF, 2020). The world is confronting challenges such as climate change and poverty which hinder efforts towards SDG target 2.1 and 2.2 of ensuring access to safe, nutritious, and sufficient food for all people all year round; as well eradicating all forms of malnutrition (FAO, IFAD, UNICEF, 2020; FAO, IFAD, UNICEF, WFP, & WHO, 2019). Since progress towards sustainably achieving SDGs 1 and 2 are not on track, then urgent spur synergy on crops that primarily can withstand climate change, conserve soil, reduce GHG emissions, and be affordable for food and nutritious diets are needful (FAO, IFAD, UNICEF, 2020). In a broad consideration, legume crop observed to have this multipurpose potential although regardless of being neglected and underutilized as a result of over-dependency on a few major staple crops (Popoola *et al.*, 2019; Padulosi *et al.*, 2013). On global distribution, species of legumes are endemic and underutilized or underexploited despite their great potential for nutritional quality, and income generation (FAO, 2018; Tyagi *et al.*, 2018; Mabhaudhi *et al.*, 2017).

Research on underutilized legumes which are of diversity has not yet provided solutions to their value chain nor developing adequate and attractive food preparation methods to meet broader customer satisfactoriness (Mayes *et al.*, 2012). The underutilized legumes still receive little attention from researchers and policymakers whose focus is on a few crop species that are in greater demand such as rice, wheat, maize, and potato (Baldermann *et al.*, 2016). According to Tyagi *et al.* (2018) and Padulosi *et al.* (2013) of 30 000 edible crop species, 7000 have been identified as human food resources but fewer than 30 species are used to feed the world. Therefore, with an exponentially growing world population estimated to reach 9.1 billion by 2050 reliance on few species as a food source poses an alarm to meet the demand for an adequate and nutritious diet (Greef *et al.*, 2015). Notably, records show that the global number of undernourished people has increased from 777 to 821 million (UNICEF, 2018) indicating a great challenge on ensuring access to nutritious diets by all people by 2030 (UNICEF, 2017). Thus, the SDGs focus on the search for alternative sources with attention on underutilized crops (UCs) to eradicate food and nutrition insecurity as well as poverty (Davari & Kasture, 2018; Kilonzi *et al.*, 2017).

Davari and Kasture (2018) and Maass *et al.* (2010) itemized that Dolichos Lablab (*Lablab purpureus*) is one among the potential UCs originating from Africa and Asia. Lablabs beans are

species of the family Fabaceae and existed since 1500 BC (Maass *et al.*, 2003). It is commonly known as Lablab or Hyacinth bean or Lablab bean or field bean which is a multipurpose crop, (Kilonzi *et al.*, 2017) drought tolerant legume is used as a relative source of cheap dietary proteins in comparison to animal sources especially in low-income communities (Davari & Kasture, 2018; Tyagi *et al.*, 2018). It is also used as forage, for soil improvement, protection, weed control, and medicinal purposes (Shetto & Owenya, 2007; Maass *et al.*, 2010; Soetan, 2012). Like other UCs, Lablab can play an important role in reducing poverty by increasing income in smallholder farmer households (FAO, 2018). Their diversity necessitates a better strategy for trait selection for nutritional and economic potentials. Therefore, Lablab can withstand environmental challenges; meet market demands. adequate macro- and micro-nutrients for human diets are of priority (Mayes *et al.*, 2012).

The Lablab is a native crop in Africa, neglected or a lost crop in several countries of Africa including Tanzania with the inaccessibility of researchers' facts as human nutritious food and economic value (Minde *et al.*, 2020; Nord *et al.*, 2020). In Central and South America, India, and Indonesia the Lablab crop is widely cultivated in large plantations as well as by smallholder farmers and is used as food for humans and animals (National Research Council, 2006). In Bangladesh, Lablab seed flour is used to improve malnourishment (Hossain *et al.*, 2016). In Kenya, accessions and varieties of Lablab seeds improve breast-milk production in lactating mothers, a great source of macro- and micro-nutrients in human diets, and being used in school feeding programs (Kilonzi *et al.*, 2017; Grotelüschen, 2014). Hence, this study aimed to investigate the potential of Lablab seeds in improving the nutritional quality of foods and livelihood in Tanzania.

## **1.2 Statement of the Problem**

Despite the diversity of Lablab accessions found globally of more than 3000 (Maass *et al.*, 2010), they are rarely used as a source of food especially in Sub-Saharan Africa (SSA), where malnutrition is prevalent (FAO *et al.*, 2020). The SSA has the highest rates of low-nutrition prevalence than other regions of the world, regardless of the huge potential of existing UCs including Lablab (UNICEF, 2018; WHO, 2017). In Tanzania, Lablab accessions are likewise less consumed (Nord *et al.*, 2020; Letting *et al.*, 2021). According to Mariki and Miller (2017), 70% of Lablab beans grown in Tanzania are exported, while 30% are used for food and feed under zero grazing. Furthermore, Forsythe (2019) reported that more than 80% of this crop is exported from Tanzania. Lablab is a native crop, domesticated by smallholder farmers in Tanzania for many years, mainly for livestock feed and soil conservation (Forsythe 2019; Morrison, 2019; Tefera, 2006). Factors such as the scarcity of information on the nutritional potential of its diverse seeds may contribute to its underutilization as a food crop. According to reports, Lablab accessions

contain little scientific information on nutrients and antinutritional factors (ANFs) (Nord *et al.*, 2020; Morrison, 2019; Arora, 2014; Padulosi *et al.*, 2013). Moreover, it is suggested to overshadow by a narrow number of edible crops (FAO, 2018). Only 30 of them produce world food (Arora, 2014), with 10 of them being in high demand, including wheat, maize, and rice, the most commonly used foods yet most vulnerable to climate change (Tyagi *et al.*, 2018). Nonetheless, researchers and policymakers are not making much progress toward expanding the nutritional and economic value of beans (Popoola *et al.*, 2019; Adhikari *et al.*, 2017). This may challenge the efforts of ensuring nutritious diets for all people, particularly in low-income and undernourished populations (Tyagi *et al.*, 2018; Padulosi *et al.*, 2013).

The investigation of Lablab seeds could have a considerable impact as a human nutritious food and a source of income, especially in low-income communities (Morrison, 2019; Davari & Kasture, 2018; Tyagi *et al.*, 2018; Sonali *et al.*, 2015; Grotelüschen, 2014). In low-income populations of sub-Saharan, Eastern Africa has a greater proportion of undernourished people (39%) than Western (20%), Middle Africa (18 %), and South Africa (2%) (FAO *et al.*, 2020). In Tanzania, chronic malnutrition is a public health issue, with 34% of children under five suffering from chronic malnutrition and anemia (FAO *et al.*, 2017; URT, 2015). Undernutrition has a negative impact on low-income households, which is worsened by poverty (Kilonzi *et al.*, 2017), and its impact is linked to declines in intellectual performance, employment capacity, reproductive outcomes, and overall health during adolescence and adulthood (UNICEF, 2018). This, therefore, calls for more research into the potential of underutilized Lablab seeds for improving nutrition quality and income for Tanzanian farmers' household livelihoods.

### **1.3 Rationale of the Study**

Lablab cultivation plays an important role in nutrition security and economic worth, although in Tanzania is mainly for commercial purposes and soil conservation (Forsythe, 2019; Morrison, 2019). In India, it is extensively used both for diet and commercial crop purposes (Venkatesha *et al.*, 2007). Similarly, in South Africa and Uganda, farmers use Lablab seeds and leaves as foodstuff for human nutrition and income generation (Grotelüschen, 2014; Maass *et al.*, 2010). Understanding potentials along the Lablab value chain (LVC), which includes key actors such as farmers, traders, and consumers, can improve sustainability contribution, especially for human food. In Tanzania Lablab has been less popular in food systems (Morrison, 2019; Popoola *et al.*, 2019) despite being a traditional diverse legume cultivated by smallholder farmers (Nord *et al.*, 2020; Forsythe, 2019; Morrison, 2019). Identifying accessions, investigating their nutritious potentials, and the opportunities of each actor in the LVC have a great contribution to long-term consumption and economic growth for smallholder farmers' livelihoods. Furthermore, the findings

of this study are vital for policymakers, stakeholders, and development agencies for improving nutrition quality and life in rural communities. Therefore, the study is significant since it investigated the potential of Lablab seeds found in Tanzania for human nutrition, health, improved livelihoods, and consumer acceptance of prepared bean cookies.

## **1.4 Research Objectives**

### **1.4.1 General Objective**

To investigate the potential of underutilized Dolichos Lablab (*Lablab purpureus*) accessions in improving the nutritional quality and livelihood of communities in the Northern (Manyara, Kilimanjaro, Arusha) and Eastern (Morogoro) zones of Tanzania.

### **1.4.2 Specific Objectives**

The study specifically intended to:

- (i) Assess the household's knowledge, attitude, and practices (KAPs) in relation to the Lablab crop as food.
- (ii) Assess the value chain of locally available Lablab seeds in relation to household livelihood.
- (iii) Determine physical characteristics, nutrient compositions, and anti-nutritional factors of collected Lablab seeds.
- (iv) Determine effects of different processing methods on nutrient retention of Lablab seed product and its consumer acceptance.
- (v) Examine the association between Lablab production and minimum dietary diversity for women of reproductive age (15-49) (MDD-W).

## **1.5 Research Questions**

- (i) What are the household knowledge, attitude, and practices (KAPs) related to the Lablab crop as human food in the study areas?
- (ii) What is the relationship between the value chain of available Lablab seeds and household livelihoods?
- (iii) What are the physical characteristics, nutrient compositions, and anti-nutritional factors of the collected Lablab seeds?

- (iv) What are the effects of different processing methods on nutrient retention of Lablab seed products and their consumer acceptance?
- (v) What is the association between Lablab production and minimum dietary diversity for women of reproductive age (15-49) (MDD-W)?

## **1.6 Significance of the Study**

This study had the aim of investigating on the potential of underutilized Dolichos lablab (*Lablab purpureus*) seeds to improve nutritional quality and livelihood among smallholder farmers. Important information generated on KAPs and the Lablab value chain will contribute to the long-term sustainability of viable options in agribusiness and agrifood systems, thereby improving the livelihoods of smallholder farmers in the future. Similarly, the detection of the seeds of good qualities and quantities, with the best methods for anti-nutrient reduction promise formulation of diverse nutritious products for enhancing nutrient quality and income, especially in low-income communities. Due to the socioeconomic and cultural relevance of Lablab accessions, several communities in Tanzania tend to underutilize these seeds as human food since they are unfamiliar with them and their nutritional potential. Therefore, a greater understanding of Lablab's diverse seeds in their entire potential is critical. This study focused on better exposing the potential of Lablab crop KAP, Lablab value chain, seeds' physical qualities, and nutrient composition in improving nutrition security and livelihoods of smallholder farmers in rural Tanzania.

## **1.7 Delineation of the Study**

In order to provide nutritional facts and a better approach for enhancing livelihoods, KAP research on underutilized Lablab legume, the entire production chain to consumers, including activities with different actors, physical and nutrient properties of the seeds, product formulation, and consumer acceptance must be researched. Research on these parameters was carried out using a cross-section survey and laboratory approaches. The collected results were compared to the benchmark accessible information for critical significance analysis of the specific attribute. Generally, this dissertation is divided into five (05) chapters. Chapter one presents background information, a statement of the research problem, the study's rationale, objectives, research questions, significance, and research framework. Chapter two presents the literature review which details the underutilized Lablab crop origination, distribution, diversity, and its various potentials. Chapter three presents the study sites, methods, and procedures used to investigate seeds' qualities, nutrient composition, processing effects, and customer acceptance of developed Lablab food products. Chapter four presents the results and discussions, which are detailed KAP, Lablab value chain, seeds physical, and nutrient composition. With the addition of anti-nutrient reduction processing



methods, product formulation, sensory acceptance evaluations, and determined income distribution provided by Lablab business for diet diversity and livelihood improvement. Chapter five is the conclusion and the recommendations of the conducted study.

This study further considers some aspects out of the study scope such as the morphology of the whole crop, protein, and carbohydrate digestibility. Moreover, minerals other than Mg, Fe, Si, Ca, Cu, and Zn were not included, phytic acid, tannins, and trypsin inhibitors were the only anti-nutrients investigated, and fat characterization, as well as soil parameters in connection to nutrient compositions were not investigated.

## CHAPTER TWO

### LITERATURE REVIEW\*

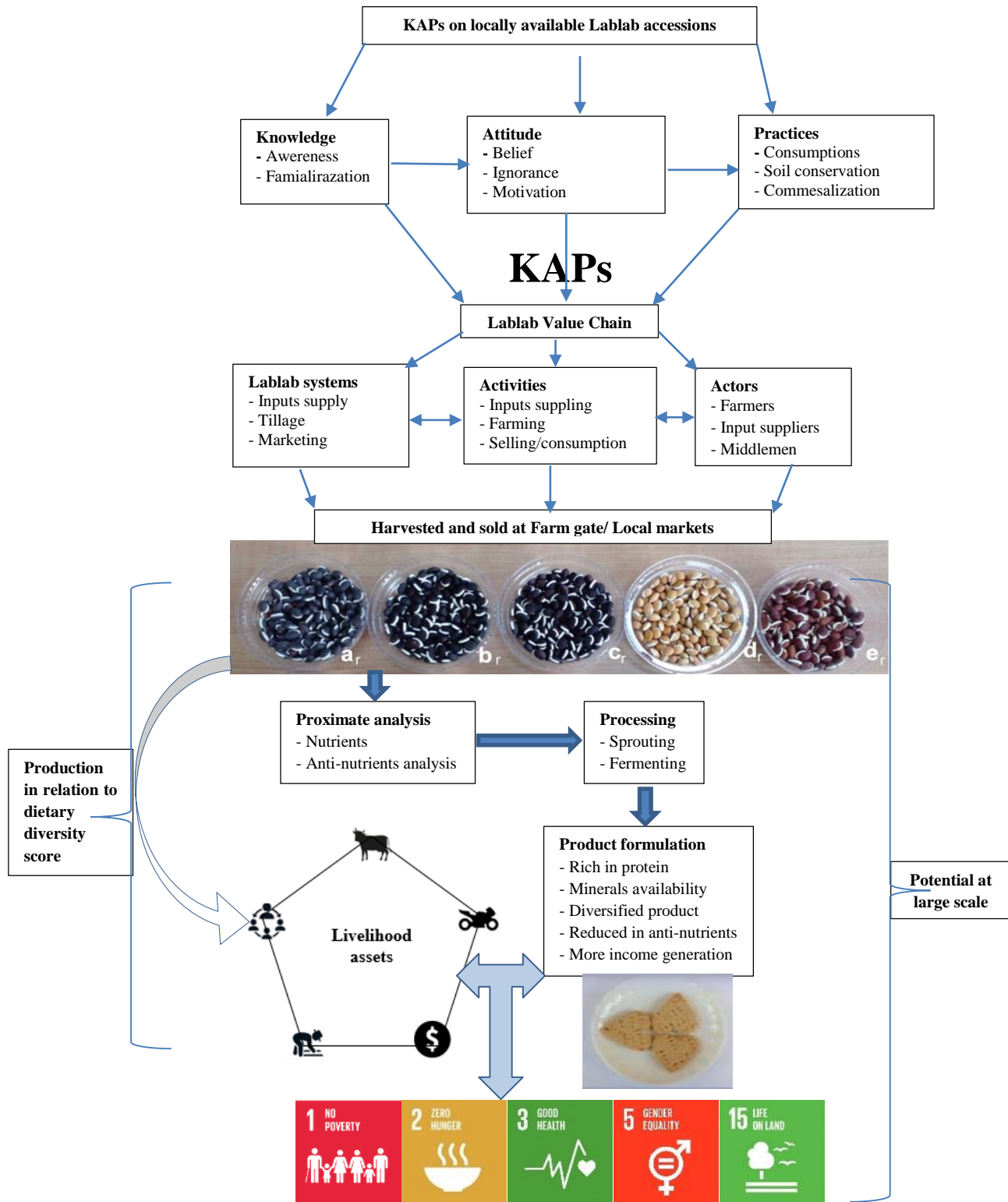
#### 2.1 Introduction

Lablab grows as a cover crop, a twining biennial or perennial crop, or both. In comparison to other members of the Fabaceae family, the legume is drought tolerant (Davari & Kasture, 2018). It's an African native crop by origination but a lost crop (Maass *et al.*, 2010). Its most well-known commercial accessions are Rongai and Highworth, which are remarkably similar in appearance and agronomic performance (Murphy & Colucci, 1999). Rongai, on the other hand, has a longer growing season (late), white flowers, and brown seeds. Highworth develops faster (earlier), flowering three to six weeks earlier than Rongai, with purple flowers, more upright growth, with smaller black seeds (Grotelüschen, 2014). This literature review focuses on the nutritional and economic potentials of underutilized Lablab seeds for nutritional quality and livelihood sustainability, to contribute to the achievement of realistic solutions by bringing possible information to the existing challenges and exposing knowledge gaps in this area.

#### 2.2 Research Framework

A research framework is a narrative description of variables and their relationships to be examined. Figure 1 demonstrates the framework used in this study developed from a review of the literature. It establishes connections between Lablab knowledge, attitude, and practices (KAPs) among smallholder farmers (independent variables); Lablab value chain links in systems, actors, and activities from the farm to consumers (independent variables); and nutrients and anti-nutrients analysis, processing, product formulation, and sensory evaluation for food diversification (independent variables). Furthermore, Lablab production is linked to the Minimum Dietary Diversity for Women of Reproductive Age (15-49) (MDD-W), household food security, and dietary diversity (independent variables), all of which are approaches in nutrition-sensitive agriculture for improving nutritional quality and income while contributing to SDGs 1, 2, with more others as outlined in the Fig. 1. The dependent variable is nutritional quality and the assets that farmers can acquire from Lablab farming in both indirect and direct ways. In times of livelihood, the framework has been adapted from DFID (Rick de Satgé *et al.*, 2002). The variables derived from the five livelihood assets resulted in involvement in Lablab farming (Fig. 1). Capturing all the things in total scores generates data that could give the potential of Lablab production among smallholder farmers. As illustrated in the framework, the potential percipient of this study is wider use of large-scale, versatile, and convincing food items for smallholder farmers'

sustainable health attainment and better income generation for the global achievement of sustainable millennium goals as demonstrated in Fig. 1.



**Figure 1:** Research framework of the potential of Lablab seeds in improving nutritional quality and livelihood (Rick de Satgé *et al.*, 2002)

### 2.3 A Brief Introduction of Lablab Crop

Lablab is a monotypic genus widely known as *Lablab purpureus* (L.) Sweet, synonyms *Dolichos* Lablab. It belongs to the family Fabaceae like the common bean (*Phaseolus vulgaris*) and cowpea (*Vigna unguiculata*) (Maass *et al.*, 2010) but is less recognized as human food (Tefera, 2006). Lablab is an Arabic and Egyptian name that means dull rattle of seeds inside the dry pod (Sonali *et al.*, 2015). The genus Lablab is divided into three subspecies which are *Purpureus* spp., *Bangalensis* spp., and *Unicinatus* spp. (Dave, 2014). Amongst the subspecies, *Purpureus* spp is mostly cultivated as a pulse crop in Africa and Asia with large and long (100 mm x 400 mm) pods curved at the end (Sonali *et al.*, 2015). *Bangalensis* spp has linear-oblong-shaped pods (140 mm x 10–25 mm) and is largely spread in Asia (Dave, 2014). *Unicinatus* spp. is a wild form in tropical East Africa, its pods and seeds are similar to *Purpureus* spp but with smaller pods (40 mm x 15 mm) (Murphy & Colucci, 1999). *Purpureus* spp and *Bangalensis* spp show significant differences with respect to their pods' shape but they have similarities in genetics (Maass *et al.*, 2016; Shruthi, 2008).

The subspecies of the Lablab crop are documented to present great variability in many cultivars found across the world (Davari & Kasture, 2018; Kilonzi *et al.*, 2017). However, reported studies indicated limited qualitative and quantitative data on the nutritional quality of Lablab accessions (Popoola *et al.*, 2019). This may suggest the under-researched potential of Lablab varieties for sustainability improvement of nutritional quality and livelihood, particularly in developing countries. Moreover, studies also observed that limited presentation of nutritional information might be associated with frequent changes in its botanical name or the use of different synonyms (Table 1).

Maass *et al.* (2010) reported over 150 common names globally referred to Lablab crops that are scattered or unpublished. Likewise, Savitha (2008) also noted that Lablab is less known as a result of the frequency of changing names in scientific, English or domesticated names. A common understanding is therefore advocated by nutritionists and agronomists (Omondi, 2011) for better crop investigation for nutritional and livelihood purposes. Since it is a native crop in Africa (Maass, 2016) and a multi-purpose crop remarkable as a highly-recognized drought-tolerant legume adaptive to a range of climatic conditions with temperature variation of 22–35°C investing in it is of importance (Sherasia *et al.*, 2018). Likewise, it is a perennial crop that assures the annual availability of food and income (Grotelüschen, 2014). Therefore, it is time to act promptly and collectively to recognize Lablab species as a climate-resilient crop across diverse environments to optimize seeds for sustainable nutritional quality and livelihood.

**Table 1: Lablab Crop Names**

| Scientific name              | Example  | Reference  |
|------------------------------|--|--|
| <i>Lablab purpureus</i> (L.) | <i>Sweet; Lablab purpureus</i>   | Murphy and Colucci (1999), and Maass <i>et al.</i> (2010)                              |
| <b>Common names</b>          |  |  |
| Asia                         | Bian dou, Peng pi dou (China); Kerara (Indonesia); Mak thoua peb (Laos); Kachang kara, Kara-kara, kekara (Malaysia); Pe gyi (Myanmar); Batao, batau, Bataw, Beglau, Parda, Agaya, Itab (Philippines); Ihua nang (Thai); Dall van, Dầu van, Dầu móng chim (Vietnam) Avare, ballar, Chapparadavare, Chikkadikai chikkuda, Mochai numulu, Mochakotta sem, Pavta, Shim, Sin bean, Val, Wal, Urahi, Urchi, Uri (Assamese); Rajashimbi (Bengali); Bhatvas, Shimi, सेम sem (Hindi); Capparada-avare, Avare, avare Baele (Kannada); Amara, Avara (Malayalam); हवाई उबी hawai uri (Manipuri); Anvare, Kadavebaala, Pandhre pavate (Marathi); राज सिमी raaj simi (Nepali); Nispavah (Sanskrit); Ho-dhambala, Hodhambala, Kiri-dambala, Kos-ata-dambala, Ratu-peti-dambala (Sinhalese); Aavarai, Motchai (Tamil); Chikkudu, Adavichikkudu, Alsanda (Telugu) | Murphy and Colucci (1999), Maass <i>et al.</i> (2010), Savitha (2008) and Arora (2014) |
| Caribbean                    | Bunabis, Bannabees, Saeme (West Indies); Bonavis bean, Seeim bean (Trinidad)   | Murphy and Colucci (1999)  |
| English                      | Australian pea (South America); Bonavist bean, Bonavista pea, Field bean, Hyacinth bean, Lablab bean, Pig-ears, Poor man's bean, Rongai Dolichos, Tonga bean, Lablab   | Vidigal <i>et al.</i> (2018)   |
| Europe                       | Antaque (Réunion), Dolique d'Egypte, Dolique lab-lab, Pois boucoussou, Pois bourcoussou (Antilles); Pois nourrice (French); Laselbohne, Helmbohne, Lablabbohne (German); Dolico egiziano, Fagiolo d'egitto, Fagiolo del cairo, Fagiolo egiziano (Italian); Haricot cutilinho, Dólico do Egipto, Feijão cutelinho (Portuguese); Frijol de Egipto, Frijol jacinto, Quiquaqua, Caroata chwata, Poroto de Egipto, Chicarro, Frijol caballo, Gallinita, Frijol de adorno, Carmelita (Spanish)   | Murphy and Colucci (1999)<br>Pengelly and Maass (2001) and Maass <i>et al.</i> (2010)  |
| Latin America                | Cumandá, Cumandá aqú, Cumandatiá, Dólicos ervilha, Japonesa, Fava da India, Fava lablab, Feijoeiro bravo, Guar, Labelabe, Labe-labe, Lablab, Lab-lab, Mangalo (Brazil); Arbejón, Arroz con coco, Cabellero, Chaucha japonesa, Chicarro, Chicharo, Chimbolo verde, Chivata, cíceros, Dolichos, Dolichos rongai, Dolico Gigante, Dolicos, Fríjol caballero, Frijol caballo, Fríjol de adorno, Fríjol de enredadera, Frijol de tierra, Fríjol Jacinto, Fríjol punzada, Fríjol trepador, Frisol tropical, Gallinazo blanco, Gallinazo morado, Gallinita, Garbanzo indio, guaracaro, Indianella, Indianella, Judía do Egipto, Lablab, Lubía, Mulato, Poroto de Egipto, Poroto Japonés, Tapirusco (Spanish)  | Murphy and Colucci (1999)<br>Maass <i>et al.</i> (2003), and Grotelüschen (2014)       |
| Pacific                      | Chuchumeko (Chamorro); Ndralawa (Fiji); Pini'ae puaka (Tonga)  | Murphy and Colucci (1999)  |
| Africa                       | Amora-guaya, Lablab, Lupp, Guango abrua (Côte d'Ivoire); Njahi Kikuyu bean (Kenya); Wáákén dānfámí (Nigeria); Agni guango ahura, O-cala, Gerenga, Fiwi bean, Kashrengig, Lubia   | Murphy and Colucci (1999), Omondi (2011), and Grotelüschen (2014)                      |
| Swahili                      | Ngwara, Mfiwi, Mafuta (Tanzania)   | Morrison (2019).   |

## 2.4 Distribution of Lablab Crop

Lablab crop originated in Africa but widely cultivated in Asia since ancient times (Ewansiha *et al.*, 2017; Maass *et al.*, 2010). According to Fuller *et al.* (2004), Lablab is an ancient crop that originated in India before 3500 BC while Maass (2006) does not find any evidence from India rather than in Africa. However, some believe it originated in Asia and Africa (Sonali *et al.*, 2015; Kimani *et al.*, 2012; Bhuvaneshwari, 2008). The global distribution of the Lablab crop shows its existence in various parts (Table 2). However, the wild *unciantus* subspecies are primarily found

in East Africa in greater variety and they do occur naturally (Maass *et al.*, 2010). For more than 3500 years, the domesticated Lablab crop has been widely dispersed throughout Africa, India, and Southeast Asia (Maass *et al.*, 2010; Pengelly & Maass, 2001) although there is currently little information on the nutritional content of the accessions available (Sonali *et al.*, 2015).

The crop is widely distributed in the tropics and subtropics giving assurance of nutritional and livelihood sustainability (Kimani *et al.*, 2012). With nutritional deficiencies, especially in most African countries, investigating underutilized Lablab legumes can prevent existing malnutrition (Ewansiha *et al.*, 2017). Research on Lablab accessions would hold a promising future significantly for food-based solutions like supplements and substitutes for animal products which are expensive (Qamar *et al.*, 2019). To meet nutrient needs, particularly in low-income countries, exploration of both underutilized native and introduced Lablab legumes (Table 2) is needed to tap their potential as rich sources of nutrients to improve nutritional quality in a community (Grotelüschen, 2014). In addition, Lablab is extremely diversified with various accessions and yet its critical role in attaining both nutritional quality and livelihood has not been fully realized (Singh & Abhilash, 2019; Kimani *et al.*, 2012). Therefore, efforts are needed to bring back underutilized Lablab seeds for improving human food and increasing the source of income in the household.

**Table 2: Distribution of Lablab crop in the world**

| <b>Lablab type</b> | <b>Countries include</b>  | <b>References</b>   |
|--------------------|---|---|
| Native             | Africa: Egypt, Sudan, East, West, South Africa, and Indian subcontinent   | Singh and Abhilash (2019), Vidigal <i>et al.</i> (2018) and Maass <i>et al.</i> (2010)  |
| Introduced         | Australia: Northern New South Wales and Southern Queensland<br>Asia: Malaysia, Indonesia, Philippines, China, Papua New Guinea, and the Caribbean.<br>Europe: Italy<br>America: Central and South America | Singh and Abhilash (2019), Maass <i>et al.</i> (2016), Ade-Omowaye <i>et al.</i> (2015), Maass <i>et al.</i> (2010), Savitha (2008), Mahadevu and Gowda (2005). |

## 2.5 Lablab Species Diversity

The Lablab species is extremely varied, with three taxonomic subspecies (ssp.) recognized, based mostly on differences in pod and seed characteristics (Pengelly & Maass, 2001; Tefera, 2006). Similarly, Lablab genotypes are also distinguished based on differences in size, shape, and colours of pods, seeds, flowers, and leaves, respectively (Letting *et al.*, 2021). The diversity within Lablab crops such as seed size, colour, and shape provides useful information for nutritional significance (Fig. 2). Worldwide there are about 3000 Lablab accessions (Maass *et al.*, 2017), requiring further investigation (Baldermann *et al.*, 2016). The NM-AIST gene bank in Tanzania has almost 400 accessions collected throughout the world, and around 30 - 35 of them have been and evaluated

for their yield, farmer's choice, and agronomic qualities across three agro-ecological zones of main Lablab growing areas in Northern Tanzania (Morrison, 2019).



**Plate 1: Variability for seeds of some Lablab accessions at NM-AIST Genebank with different origins**

Referring to Plate 1: a= D-40 Bangladesh; b= D-140 Ethiopia; c= D-162 Tanzania; d= HA4 Kenya; e= D-125 Zambia; f= D-139 Australia; g= D-153 Tanzania; h= D-50 Bangladesh; i= D-82 Australia; j= D-26 Lao People's Democratic Republic; k= D-30 Bangladesh; l= D-79 Australia; m= D-39 Bangladesh; n= D-19 Thailand; o= D-63 Ethiopia; p= D-110 Myanmar; q= D-181 India; r= D-48 Bangladesh; s= D-155 Tanzania; t= D-76 Australia.

The Lablab crop's diversity shows that it has the potential to be a multipurpose legume for smallholder farmers in their farming systems. Similarly, Lablab is well-known for its high genetic diversity (Maass *et al.*, 2010; Tefera, 2006). A wide diversity of wild and cultivated Lablab genotypes can be crossed to produce genetically diverse viable hybrids in a breeding program to extend the genetic bank of this multipurpose crop. This assures the availability of Lablab beans to people for life and good health (FAO, 2018; Ngala, 2015) particularly rural societies primarily depend on farm produce as mainly a source of protein (Dobermann, 2018). According to Ruelle *et*



*al.* (2019), and Lenné and Wood (2011) understanding Lablab diversity has an advantage on trait selection for species that can fit in a certain environment, and serve nutritional needs, and income generations. However, while research on Lablab varieties has expanded in response to climate change, it has been less tied to nutritional research, particularly on human nutrition. Thus, the diverse accessions of wild and domesticated types, some of which are shown in Fig. 2 remain untapped in terms of eradicating malnutrition and its forms. Henceforth, this poses a challenge to their contribution to SDGs 1 and 2.

Research on diversity within the Lablab species and their sub-species would be beneficial such as for healthy diet recommendations (Purwanti *et al.*, 2019; Vidigal *et al.*, 2018) and useful for the future breeding of nutrient-rich varieties (Ojiewo *et al.*, 2018). Likewise, the diversity of morphological traits on qualitative characteristics such as flower colour, leaf vein colour, stem colour, and pod colour (Fig. 3, and 4) are potential parameters in agrifood studies. Likewise, quantitative characteristics such as length, width, and weight of pods and mature seeds are associated with nutrition potentials and consumer preferences (Singh & Abhilash, 2019; Ambrose *et al.*, 2016; Sarma *et al.*, 2010). Collectively, the legume varieties require considerable attention to optimize their health benefits for human diets (Davari & Kasture, 2018; Ojiewo *et al.*, 2018).



**Figure 2:** Lablab pods with diverse in colour and size (Singh & Abhilash, 2019)



**Figure 3:** Lablab flowers of various colours (purple, yellow, and white) in full bloom and on a flower spike (Ambrose *et al.*, 2016; Grotelüschen, 2014)



A deeper understanding of Lablab crop diversity is required for a better selection of nutritious legume seeds. Maass *et al.* (2017) reported that the worldwide dispersal of Lablab shows that wild germplasm accessions originated in eastern and southern Africa to have less comprehensive information. Hence, researchers and funding organizations are encouraged to investigate this crop (Maass *et al.*, 2017; Baldermann *et al.*, 2016). Although several studies have been focusing on Lablab crop diversity for instance in Australia, the Highworth variety (purple flowers and black seeds) is mostly cultivated as a forage crop in Northern New South Wales (Grotelüschen, 2014). Similarly, Rongai with white flowers, light brown seeds, and pods containing 2–4 seeds is a forage plant in Kenya (Kimani *et al.*, 2012). Koala cultivars with seeds of cream colour, and pale purple flowers are also used for forage purposes (Ewansiha *et al.*, 2007). Endurance was mainly developed for forage from Rongai and African wild parent with marked white coloured flowers and brown seeds (Sonali *et al.*, 2015; Partridge, 2003). Studies by Mabhaudhi *et al.* (2017), Sonali *et al.* (2015), Kimberly and Deepa (2014), and Mayes *et al.* (2012) are among the few detailed documented for Lablab accessions with nutritional information for human consumption. Therefore, a keen exploration of various accessions that could contribute to nutritional quality and the best income is a need. According to Karambu (2013) and Maass (2006), the Rongai type has more documentation than other Lablab varieties which may be good for the human diet. In Asia, several accessions have been well documented throughout as a significant pulse to human health (Mahadevu & Gowda 2005). In addition, the crop is also recognized as source of dietary protein in child feeding programs (Davari & Kasture, 2018). Indeed, it is important to understand Lablab varieties for better promotion of the beans to diet diversity (Foyer *et al.*, 2016). Researchers and nutritionists need to explore more on these accessions together with their suitable preparation methods for nutrient retention and consumer acceptability.

## **2.6 Lablab Accessions**

Seeds from plant material, also known as accessions, are unique, identifiable representations of a cultivar, breeding line, or species that are stored for further usage (Letting *et al.*, 2021; Maass *et al.*, 2010). Accessions are often produced from related single plant species collected from a single location at a time and usually are given a number. The accession number is a unique identifier in databases that allows tracking of data retrieved over time and never changes (Table 3). Lablab, a legume species in the flowering plant family with over 20 000 species (Maphosa & Jideani, 2017), has accessions with assigned numbers (Table 3) for both wild and domesticated species (Grotelüschen, 2014; Maass *et al.*, 2010). Notably, the terms "accessions," "seeds," and "beans" all have multiple interpretations, but they can all be used interchangeably (Fabbri & Crosby, 2016). In this study, these names are also used interchangeably. Lablab, an underutilized crop, its

accessions are of diverse significant quality in breeding programs, but nutritional information is scarce in African countries (Davari & Kasture, 2018). Besides breeding, the gathering pace for any underutilized nutrient rich accessions offers possibilities for feeding the world's ever-increasing population, particularly in Africa (Popoola *et al.*, 2019). Lablab accessions are diverse, with many improved varieties found across Asian countries (Popoola *et al.*, 2019). According to Letting *et al.* (2021), Asia has the largest (650) collection of Lablab accessions in the world at UAS Bengaluru, India, while Africa has 450 Lablab at NM-AIST, Tanzania, with other gene banks indicated in Table 3. Rekindling interest in diverse Lablab accessions has a promising future in agricultural, environmental, nutritional, and economic development for sustainable livelihoods.

**Table 3: Some of the Lablab accessions in the Gene banks**

| Country/Institution collected  | Accession number  | References                   |
|--|---|------------------------------|
| Australia  | CQ 3632, CQ3633, P5305, P5310, Q6879  | Murphy and Colucci (1999)    |
| South Africa   | CPI 29399, CPI 30701, CPI 52506B, CPI 81364, CPI 52437  | Murphy and Colucci (1999)    |
| Department of Agricultural Botany, Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra, India                         | DPLW10, DPLW11, DPLW12, DPLW13, DPLW15, DPLW17, DPLW18, DPLW29, DPLW30, DPLW31, DPLW32, DPLW33, DPLW35, DPLW41, DPLW43, DPLW44, DPLW45, DPLW46, DPLW48, DPLW51, DPLW54, DPLW57, DPLW58, DPLW61, DPLW63, | Davari and Kasture (2018)    |
| Tanzania Agriculture Research Institute (TARI)-Selian station in Arusha, Tanzania.   | DL 1002, ILRI 6536, KARAMOJA RED, Q6880B, ELDORET BLACK, DODOMA WHITE, ECHO CREAM   | Morrison (2019)              |
| Nelson Mandela African Institutions of Science & Technology (NM-AIST), Tanzania  | HA-4, NMD20, NMD21, D-1 to D-450  | Letting <i>et al.</i> (2021) |
| Kenyan National Gene Bank and Repository Centre at Kenya Agricultural and Livestock Research Organization (KALRO- Muguga, Kenya) | Q 6880B, 10706, Bahatiz, 11741, 10702, 10695, 13083, 11719, 8.26932, 13086, 12158, 27007, 11723, 28663, 11736, 12000, Njoroz, 10703, 10822, 12230, 13129, 11705, 12187, 11722, 13096,                   | Kimani <i>et al.</i> (2019)  |
| Kenya agricultural and livestock research organization (KALRO), Katumani dryland research station in Machakos.                   | KAT/DL-1, KAT/DL-2, KAT/DL-3  | Kilonzi (2020)               |

## 2.7 Why Lablab Crop Production?

Traditionally, Lablab is grown by smallholder farmers for marketing and is rarely consumed as a household protein source (Muoni, 2019; Snapp *et al.*, 2018). It is a multi-use and diverse crop that can be utilized as a pulse, and both the green pods and mature seeds can be consumed by humans

(Maass *et al.*, 2010). The leaf green of the legume can be used as a green vegetable, similar to spinach, and as animal fodder (Sonali *et al.*, 2015). It is known for being a significant producer of fodder biomass with a high crude protein content (Nord *et al.*, 2020). The crop can be cultivated as a stand-alone or in combination with other crops such as maize, sorghum, and sunflowers (Forsythe, 2019). It's also an organic green manure that boosts soil richness. Furthermore, in conservation agriculture, the crop is cultivated as a cover crop to suppress weeds, prevent soil erosion, and reduce water loss through evaporation (Shetto & Owenya, 2007). Similarly, crop rotations of Lablab legumes with cereals have also been observed among smallholder producers (Forsythe, 2019). Since the crop is drought resilient and perennial, it ensures food availability. Additionally, the Lablab crop has both early and late-maturing cultivars important for food and income generation (Grotelüschen, 2014). Noteworthy, the Lablab crop is versatile opens more opportunities in agribusiness and agrifood systems in enhancing sustainability in the global markets a key to smallholder farmers' livelihood (Grotelüschen, 2014).

## **2.8 Potentials of Underutilized Lablab Crop**

The Lablab crop is unremarkable in food systems and can significantly contribute to macro- and micronutrients in human diets as well as household income (Davari & Kasture, 2018; Cullis & Kunert, 2017). Less mainstreaming of research activity on this diverse crop is linked to its poor usage (Baldermann *et al.*, 2016; Maass *et al.*, 2017). Rethinking research on Lablab accessions to uncover attributes that make the beans less utilized could disclose the nutritional quality and quantity of seeds for agribusiness and agri-food systems (Lambein *et al.*, 2019). Furthermore, Lablab is a climate-smart crop since it is a tolerant legume to climate change and can live in drought conditions (Grotelüschen, 2014; Kalpanadevi & Mohan, 2013). These direct and indirect valuable resources further justify the potential uses of crop as detailed in the following subsections:

### **2.8.1 Nutritional Potential**

#### **(i) Nutrients in Lablab Seeds**

Lablab is indeed acknowledged as one of the possible sustainable crops to tackle malnutrition, particularly in low-income households (Kilonzi, 2020). The crop has a diverse range of wild, local, and developed accessions, some with information on the nutritional quality to demonstrate their potential as a good source of food for humans and animals (Table 4). Lablab species found in Asia and Africa offer a diverse range of seed accession choices for nutritional qualities, yet they are highly underutilized in Africa, particularly for human food (Singh & Abhilash, 2019; Grotelüschen, 2014). Nonetheless, only a few Lablab accessions are popular in low-income food systems (Popoola *et al.*, 2019) in comparison to soybean accessions (Giriraj *et al.*, 2016). Thus,

research on improving utilization of Lablab accessions is critical for establishing nutritional quality datasets of the crop.

**Table 4: Variation in major nutritional components of some Lablab accessions (g/100 g dry weight)**

| Country          | Site of sample collection  | Common/cultivar name | Crude protein | Carbohydrate | Fat  | Fiber | Ash  | Reference                      |
|------------------|--|----------------------|---------------|--------------|------|-------|------|--------------------------------|
| Nigeria          | International Institute for Tropical Agriculture (I.I.T.A)                                   | Rongai brown         | 24.15         | 39.27        | 9.74 | 12.69 | 4.28 | Soetan and Oyewole (2009)      |
|                  |  | Rongai white         | 23.10         | 40.29        | 9.56 | 13.12 |      |                                |
|                  |  | Highworth black      | 22.75         | 40.39        | 9.63 | 12.98 | 3.97 |                                |
| South Africa     | South Africa   | Lablab               | 26.86         | 67.23        | 0.27 | -     | 4.12 | Mabhaudhi <i>et al.</i> (2017) |
|                  |  |                      |               |              |      |       | 3.96 |                                |
| Bangladesh       | Local market   | BARI Seam 1 black    | 23.95         | 61.86        | 1.02 | 1.21  | 3.50 | Hossain <i>et al.</i> (2016)   |
| North East India | Farmers' garden  | Landrace-A           | 32.2          | 30.4         | 1.93 | 12.82 | 5.99 | Sarma <i>et al.</i> (2010)     |
|                  |  | Landrace-B           | 31.2          | 32.1         | 1.06 | 12.05 | 9.17 |                                |
|                  |  | Landrace-C           | 32.7          | 33.30        | 1.08 | 16.77 | 6.58 |                                |
|                  |  | Landrace-D           | 35.51         | 28.18        | 0.88 | 13.47 | 6.54 |                                |
|                  |  | Landrace-E           | 28.6          | 37.60        | 0.91 | 12.03 | 8.62 |                                |
|                  |  | Landrace-F           | 23.99         | 48.41        | 0.82 | 10.52 | 7.78 |                                |
|                  |  | Landrace-G           | 34.42         | 39.73        | 1.12 | 11.52 | 6.21 |                                |
|                  |  | Landrace-H           | 26.81         | 29.59        | 1.23 | 11.25 | 6.20 |                                |
|                  |  | Landrace-I           | 29.0          | 33.33        | 0.76 | 14.52 | 5.13 |                                |
| Kenya            | Agricultural and Livestock Research Organization (KALRO), Katumani Dryland Research Station. | KAT/DL-1 Brown       | 25.4          | 59.8         | 2.6  | -     | 4.0  | Kilonzi <i>et al.</i> (2017)   |
|                  |  | KAT/DL-2 Black       | 24.4          | 60.8         | 2.6  | -     | 4.1  |                                |
|                  |  | KAT/DL-3 Cream white | 22.5          | 60.8         | 2.7  | -     | 4.4  |                                |
| India            | Tamil Nadu Agricultural University, Coimbatore,  | Co <sub>1</sub>      | 25.47         | 60.63        | 2.69 | 6.90  | 4.31 | Kamatchi <i>et al.</i> (2010)  |
|                  |  | Co <sub>2</sub>      | 24.98         | 60.86        | 3.87 | 6.32  | 3.97 |                                |
|                  |  | Co <sub>9</sub>      | 23.41         | 64.63        | 2.28 | 5.25  | 4.43 |                                |
|                  |  | Co <sub>11</sub>     | 23.02         | 62.73        | 4.17 | 5.80  | 4.28 |                                |
|                  |  | Co <sub>12</sub>     | 20.46         | 66.32        | 3.76 | 4.98  | 4.48 |                                |
| India            | Department of Agricultural Botany, Konkan Krishi Vidyapeeth, Dapoli at botany farm           | DPLW10               | 24.19         | 59.08        | 0.90 | 4.14  | 3.23 | Davari <i>et al.</i> (2018)    |
|                  |  | DPLW11               | 27.13         | 55.21        | 1.32 | 4.25  | 3.94 |                                |
|                  |  | DPLW15               | 28.70         | 54.16        | 1.22 | 4.16  | 3.96 |                                |
|                  |  | DPLW30               | 26.43         | 56.23        | 1.23 | 4.73  | 3.55 |                                |
|                  |  | DPLW45               | 25.55         | 57.70        | 0.97 | 3.98  | 3.52 |                                |
|                  |  | DPLW46               | 27.48         | 55.45        | 1.36 | 4.46  | 3.91 |                                |
|                  |  | DPLW48               | 26.25         | 56.29        | 1.29 | 4.56  | 4.11 |                                |
|                  |  | DPLW58               | 26.60         | 56.17        | 1.32 | 4.46  | 3.78 |                                |
|                  |  | DPLW61               | 25.20         | 58.21        | 1.28 | 3.68  | 3.72 |                                |

As a multipurpose crop found all over the world, it has the potential to feed both humans and animals (Davari & Kasture, 2018). The richness of varieties (Table 2) makes it an important underutilized crop with great dietary advantages (Sonali *et al.*, 2015). A varietal dataset study by Singh and Abhilash (2019), identified Lablab as a significant crop for nutritional qualities and income earns for livelihood. In addition, in Asia, the legume is known as a great source of traditional vegetables and pulse consumed as a green vegetable, green pods, and seeds (Ade-

Omowaye *et al.*, 2015; Abate *et al.*, 2012). In Bangladesh, Lablab is the most abundant crop in terms of genotypes that contribute to humans' diets (Hossain *et al.*, 2016). Considering its various accessions (Table 3), Lablab beans offer significant nutritional value (Sarma *et al.*, 2010) comparable to that of soybeans (Popoola *et al.*, 2019) and higher compared to common beans (Suárez-Martínez *et al.*, 2016) as well as cereals (Table 5). In comparison to Lablab, cowpea seeds have lower crude protein (15.62–17.91%) (Alayande, 2012) nonetheless their seeds are seldom documented as a source of human diets or dietary diversity (Siddique, 2016). Furthermore, data on the utilization of Lablab varieties in human nutrition is quite limited as compared to animal feed uses (Omondi, 2011). Table 5 shows a few examples of Lablab's nutritional value in comparison to other popular legumes and cereals.

**Table 5: Nutritional composition of selected legumes and cereals (g/100 g grain dry weight)**

| Legumes        | Proteins | Lipids | Fiber | Ash  | Carbohydrates | References                     |
|----------------|----------|--------|-------|------|---------------|--------------------------------|
| <b>Legumes</b> |          |        |       |      |               |                                |
| Lablab beans   | 35.51    | 0.88   | 13.47 | 6.54 | 28.18         | Sarma <i>et al.</i> (2010)     |
| Common beans   | 20.80    | 1.30   | 17.20 | 3.00 | 56.90         | Mutambuka (2013)               |
| Mung beans     | 27.60    | 1.85   | 4.63  | 3.76 | 62.90         | Mubarak (2005)                 |
| <b>Cereals</b> |          |        |       |      |               |                                |
| Wheat          | 14.30    | 2.80   | 2.80  | 2.20 | 78.40         | Mlyneková <i>et al.</i> (2004) |
| Maize          | 8.84     | 4.57   | 2.15  | 2.33 | 71.88         | Shah <i>et al.</i> (2016)      |
| Rice           | 6.81     | 0.55   | 2.80  | -    | 81.68         | Rohman <i>et al.</i> (2014)    |

As previously explained, Asian countries have a higher level of Lablab seeds utilization (Tyagi *et al.*, 2018; Sonali *et al.*, 2015; Arora, 2014; Mahadevu & Gowda, 2005). Further, Lablab is recognized as a good source of protein (*Dhal*) in human diets due to its balanced amino acid content, such as lysine 6 -7% (Omondi, 2011). Similarly, its leaves are high in protein (28%) and the best source of iron when compared to other legume leaves (National Research Council, 2006). Moreover, in developing countries, it is a less expensive protein source than animal protein (Davari & Kasture, 2018). Other rich minerals in this crop include calcium, phosphorus, sodium, potassium, magnesium, and iron, in addition to vitamins like vitamin A, and also carbohydrates (Davari & Kasture, 2018). Therefore, a critical analysis of the nutrient composition of the accessions is required to maximize their potential for nutritional quality and livelihood. Similarly, good accession recipe selection may improve the sensory qualities of Lablab meals hence increasing their intake.

## (ii) Anti-nutrients in Lablab Seeds

Nutritional quality is defined as the value of nutritional content in a diet. Primary, variations in nutrient content in seeds are mostly caused by inherent, environmental, and processing factors, raising concerns about their trustworthiness (Venkatesha *et al.*, 2007; Tefera, 2006). Concerns for

nutritional quality in Lablab seeds are notably important in determining nutrient concentrations and ANFs (Davari & Kasture, 2018; Kilonzi *et al.*, 2017; Karanja, 2016). Legume seeds contain bioactive compounds such as proteins (protease inhibitors,  $\alpha$ -amylases, lectins), glycosides ( $\alpha$ -galactosides), tannins, and saponins or alkaloids that, if consumed in large quantities, may limit the availability of some nutrients and in some cases might cause discomfort (Kilonzi *et al.*, 2020; Grotelüschen, 2014). Since plant nutrients are essential in obtaining sustainable diets, knowledge about them is important for food safety advice and guidance (Weingärtner, 2000). Moreover, nutrition quality is achieved when adequate food in terms of quantity, quality, safety, and socio-cultural acceptability is available and accessible for all individuals to use appropriately throughout their lives (Bokeloh *et al.*, 2009). On the other hand, better techniques such as organic farming in agricultural systems are critical in producing seeds of good quality and quantity for the stability of plant nutritional quality (Von, 2014).

Generally, legume seeds such as the Lablab seeds contain various amounts of ANFs like phytate, tannins, and TIs (Davari & Kasture, 2018). These ANFs reduce the absorption and bioavailability of nutrients from the crop during consumption (Kilonzi *et al.*, 2017). This means the nutritional quality is affected, hence restricting its availability from that particular food source. However, these ANFs vary in amounts considerably across genotypes and geographical zones (Guretzki & Papenbrock, 2013). Literature indicates that the seeds which are darker in colour are likely to contain higher amounts of cyanide (Grotelüschen, 2014) as well as being associated with a bitter taste (FAO, 2017).

Oligosaccharide is another ANFs responsible for flatulence due to the absence of  $\alpha$ -galactosidase enzyme produced in the human gastrointestinal tract (Jain & Kumar, 2015). Amounts of gases of carbon dioxide, hydrogen, and methane in high volume are given out during its metabolism. The consequence is bloats and gastric discomforts that need to be expelled out of the body.

Regardless its negativity awareness, oligosaccharides are prebiotics in nature that support growth of probiotics (*Bifidobacteria spp.*) hence a great player in colon health (Maphosa & Jideani, 2017). Also, in Japan, oligosaccharides have been pointed out to replace table sugar (Messina, 2016). Other compounds include tannins which also affect nutritional quality due to their formation of protein precipitates through binding with minerals (Chung *et al.*, 1998). The tannins present by 12.56 mg/g in seeds with red colour are higher (Omondi, 2011). So, to inactivate or reduce ANFs, various processing methods are needed.

Human beings started consuming legumes as food many years ago (Maphosa & Jideani, 2017). Although the presence of anti-nutrients on Legumes species has contributed in underutilization

(Kimani *et al.*, 2019). However, according to Kilonzi *et al.* (2017), well-processed Legume seeds are suitable for human consumption. Some beans, such as Lablab, are still regarded as unsuitable for human consumption due to the significant amount of the anti-nutrients (Mabhaudhi *et al.*, 2017; Arora, 2014; Padulosi *et al.*, 2013) despite their nutritional and health benefits (Foyer *et al.*, 2016; Bailey *et al.*, 2015; Gemede & Ratta, 2014). The ANFs found in Lablab beans include phytate and tannins in various amounts (Sonali *et al.*, 2015; Gemede & Ratta, 2014; Jain *et al.*, 2009) and TIs (Davari & Kasture, 2018). These compounds usually interfere with nutrient availability and utilization when consumed in significant amounts (Gemede & Ratta, 2014).

The presence of ANFs may affect maximum nutrient optimization and organoleptic properties (Kimani *et al.*, 2019; Davari & Kasture, 2018; John *et al.*, 2018; Kilonzi *et al.*, 2017; Hossain *et al.*, 2016; Grotelüschen, 2014; Kalpanadevi & Mohan, 2013). In Kenya, tannins were observed higher (12.56 mg/g) in seeds with red colour (Omondi, 2011). This sometimes is associated with a bitter taste that may affect the sensory quality of the beans leading to poor consumer acceptance (Omondi, 2011). So far, the intensity of colour among accessions is seldom described on the food label (Caldas & Blair 2009). Kimani *et al.* (2019), also observed that the bitter taste in beans is associated with factors such as cyanogenic glycosides, minerals (e.g., iron), and saponins.

### **(iii) Processing of Lablab Seeds for Value Addition**

Unprocessed legumes including Lablab are reported to contain high levels of ANFs (Kilonzi *et al.*, 2017; Sonali *et al.*, 2015) which differ with species diversity, cultivar, and geographical zones of cultivation (Guretzki & Papenbrock, 2013; Sridhar & Sahadevan, 2006). However, the combination of several processes in preparation and cooking removes or reduces them for safe use (Morrison, 2019). Guretzki and Papenbrock (2013), reported that the application of various treatments in combinations can result in a significant or total reduction of inhibitor activities. According to Fabbri and Crosby (2016), since each method is unique, a thorough understanding of the preparation and cooking procedures of various bean types can optimize their nutrients. Table 6 shows the most peculiar and commonly used methods for making seeds safe for human consumption. Importantly, it is advised that the methods used to ensure that food characteristics such as appearance, flavor, texture, and appetite are maintained at the best (Grotelüschen, 2014).

**Table 6: Processing and cooking methods for dry legume seeds**

| Processing methods  | References  |
|---|---|
| Washing, and then, boiling, or pressure-cooking, or stewing                 | Kilonzi (2020) and Morrison (2019)                |
| Soaking and boiling, or frying, or simmering steaming                       | Fabbri and Crosby (2016), and Grotelüschen (2014) |
| Fermentation and preparation for sauce or snacks                            | Kilonzi (2020) and Hooper <i>et al.</i> (2019)    |
| Germination and frying, or pressure-cooking, simmering steaming, or stewing | Fabbri and Crosby (2016), and Grotelüschen (2014) |

Value addition in Lablab accessions can benefit consumers and farmers across the production chain (Morrison, 2019). Lablab, like other legume seeds, is the best source of a consistent supply of nutrients that is higher than cereals (Kilonzi, 2020). However, the long processing time and the presence of antinutrients limit their usage (Grotelüschen, 2014). Although Soetan (2012) reported ANFs are bioactive substances that can reduce risks of noncommunicable diseases (NCDs) such as coronary heart disease and diabetes, studies are still needed to ensure the safety of nutraceuticals. The value-added seed products are safe with optimized time in preparation such as instant foods or fermented products (Avilés-Gaxiola *et al.*, 2018). The value-added products are versatility and convenience with good sensory qualities that promised the future of underutilized Lablab accessions (Hooper *et al.*, 2019). Resulting, in higher production, off-farm employment opportunities, and more diverse Lablab food products for healthy growth and income generation, particularly in developing countries. Lablab seeds are not consumed raw, therefore processing to improve eating and nutritional quality is important. As shown in Table 3, combining processing procedures has advantages in removing/reducing the ANFs and increasing mineral bioavailability.. Sprouting, for example, improve palatability, digestibility, and nutritive value such as vitamins B and C, and reduce flatulence factors (Murugkar, 2014). Whereas, the fermentation increases storage, safety, nutrients bioavailability, and improves sensory characteristics to increase consumer acceptability (Mukherjee *et al.*, 2016).

#### **(iv) Consumer Acceptance of Lablab Food Products**

Consumers' fast-paced lifestyles push them to demand high-quality, nutritious convenience, quick cooking time, and safe foods (Hooper *et al.*, 2019). To meet long-term demands, the search for underutilized crops has a future. In Nigeria, the use of non-wheat flour from Tigernut (*Cyperus esculentus*) and Pigeon pea (*Cajanus cajan*) increased protein content in baked products quality, and overcoming the high cost of wheat flour (Chinma *et al.*, 2011). Legume food products are inexpensive healthy foods that consumers can afford (Hossain *et al.*, 2016; Grotelüschen, 2014). However, limited diversity in bean products is related to less consumption (Hooper *et al.*, 2019).



In India, Lablab seeds can be used as a whole, decorticated, or dehusked into a wider variety of cuisines such as snacks, and vegetable stews, or processed into flour products (Dhaliwal, 2017; Grotelüschen, 2014). Like soybean which is acknowledged to have a wide range of processed foods, including beverages (soymilk) (Olagunju *et al.*, 2018). Processing seeds into flour, such as chickpea flour, increase consumer acceptance in the preparation of a variety of foods such as soups, and fortification of cereal flour (Zotor *et al.*, 2015). Hooper *et al.* (2019) enriched pasta with beans flour (*Phaseolus vulgaris L.*), which is a popular convenience dish among American customers due to its simplicity of preparation. Besides, bean products have gained consumer interest, as are gluten-free products ideal for persons suffering from celiac disease due to gluten intolerance around the world (Hooper *et al.*, 2019). Therefore, there is an option to make diverse food products from Lablab seeds which are nutritious.

Consumer acceptance is also related to wider products. In a bakery, Lablab flour could be turned into foods such as bread, cookies, and cookies for specific needs such as children, youth, the elderly, vegetarians, and athletes. Depending on consumer preferences, bakery products, and ready-to-eat foods could all benefit as convenient and nutritious food products for income and health growth.

### **2.8.2 Medicinal Potential**

The Lablab crop has been linked to healing properties in both modern and traditional ways (Arora, 2014). Sniffing crushed Lablab leaves are thought to treat stomach ailments in East Africa. In Rwanda, the leaves are mixed with other medicinal plants and used to treat heart ailments. Further, the leaves are used as a tea in Central African countries to treat tonsillitis while in South-East Asia are used to treat eczema, gonorrhea, and tumors (Adebisi & Bosch, 2004). Also, in Senegal, Lablab seeds treat cholera and sunstroke whereas in India, it is believed to be an effective anticholesterolemic, hypoglycemic, antihypertensive, and antispasmodic (Kilonzi, 2020; Adebisi, & Bosch, 2004). Moreover, flavonoids present in Lablab dry seeds may also play a role in cancer treatment, diabetes prevention, alcohol intoxication, and ear irritation (Kilonzi, 2020). In Kenya, the dried seeds are processed and used as a veterinary drug in the treatment of eye problems in sheep and lung problems in cattle (Grotelüschen, 2014). Furthermore, Lablab beans contain some substances that have been found to reduce the risk of certain diseases (Xiao & Bai, 2019; Soetan & Oyewole, 2009) hence they are considered medicinal resources in both modern and traditional medicine (Xiao & Bai, 2019; Ambrose *et al.*, 2016). In Nigeria, raw varieties of Rongai brown, Rongai white, and Highworth black from IITA were reported to contain a significant amount of trypsin inhibitors (TIs), cyanogenic glycosides, tannins, oxalates, phytates, alkaloids and saponins for phytomedicines applications (Soetan, 2012). Henceforth, the Lablab plant can be a potent raw

material for nutraceuticals and pharmaceutical industries however, more investigation is required for their biosafety.

### **2.8.3 Economic Potential**

Lablab is a fast and annually grown forage legume crop (Kilonzi *et al.*, 2017). It is among underutilized crops with economic importance (Grotelüschen, 2014; Weinberger & Msuya, 2004). Lablab legumes grow by covering the soil which in turn reduces weeding sessions, resulting in significant labor savings for farmers. According to Shetto and Owenya (2007), Lablab plants cover soil as a weed controller, saving work and providing an economic return to farmers by reducing weeding expenses and protecting the soil. Lablab's land also does not require artificial fertilizer serving money for purchasing industrial fertilizers. The legume is an organic fertilizer that allows smallholder farmers to improve their fields organically while also acquiring food/fodder and income despite having limited land area (Popoola *et al.*, 2019; Wijk *et al.*, 2018; Darnhofer & Vienna, 2016; Owenya *et al.*, 2011). Despite being a lost crop in Africa, it is highly valued as a commercial food for human and animal consumption (Maass *et al.*, 2010). Perhaps the fact that smallholder farmers are the primary producers of the Lablab crop in Africa may explain why researchers and policymakers have paid less attention to its production chain in terms of financial investment and global viability (Nájera, 2017; Maass *et al.*, 2010). According to Ahmed and Sallam (2020), in Africa, agricultural productivity analytics, stable market availability, and agricultural industry opportunities are linked to improved economies and rural livelihoods. That is why worldwide smallholder farm business is a public interest since it supports the livelihoods of about 2.2 billion people (FAO, 2019; Nájera, 2017). In Tanzania, a few Lablab smallholder farmers have been spotted in the northern zone with outside markets for the black Lablab beans as a cash crop (Same District Council, 2018). In addition, their Lablab business is primarily conducted through middlemen at the farm gate and a few well-known local markets which operate once or twice per week. Smallholder agricultural businesses typically function with less season cycle analysis on financial assessments that need to be modified for improving economic viability (Rojas *et al.*, 2021). Thus, empirical research on the Lablab crop production chain across countries could ensure its factual facts on the variety of the beans as economic drivers for smallholder farmers and the country.

### **2.8.4 Ornament Potentials**

Certain Lablab crop species are preferred for usage as ornaments due to their growth structures and colours. They can be grown along fence lines to form hedges making the home more visually appealing while also producing green vegetables and beans for the family food (Fig. 5). In the

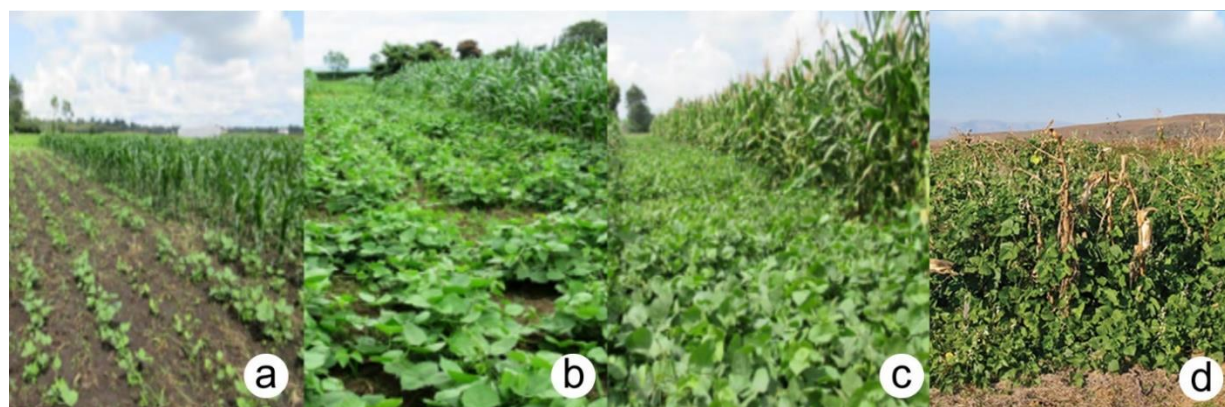
United States and Guyana, South America the crop has been observed being occasionally planted as an ornamental plant (Adebisi & Bosch, 2004). Further, Lablab pounded leaves are used to make green dye in Zanzibar (Adebisi & Bosch, 2004). Acknowledgment of flower crops, particularly breeding and promotion of traditional ornamental species capable of adapting to natural agro-environmental conditions, plays a key role in food security, employment, and income generation for livelihood enhancement (Ambrose *et al.*, 2016; Grotelüschen, 2014).



**Figure 4:** Lablab (Hyacinth bean) vine with purple flowers planted as a fence and light tower decorator (Ambrose *et al.*, 2016; Adebisi & Bosch, 2004)

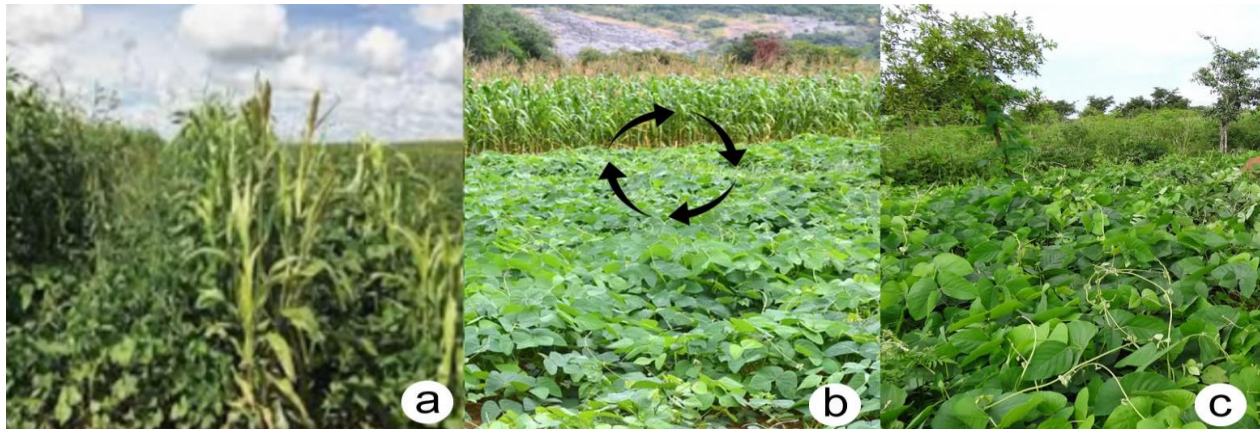
### 2.8.5 Soil Conservation

Today, Lablab is acknowledged as one of the promising climate-resilient crops for combating the effects of climate change in agriculture (Maass *et al.*, 2010). It can restore soil fertility through nitrogen fixation and produces a fast soil cover which ensures sustainable soil conservation in agriculture (Fig. 6) (Maass *et al.*, 2003). Lablab crops are sustainable and profitable in contributing to smallholder farmers' food and livelihoods based on three conservation agriculture principles: minimal soil disturbance, soil cover, and crop rotations (Fig. 6 and 7) (Shetto & Owenya, 2007; Bwalya, 2005).



**Figure 5:** Lablab a cover crop; a) 4 weeks after planting; b) 2 months after planting c) 3 months after planting d) 4 months after planting (Shetto & Owenya, 2007; Bwalya, 2005)

Lablab is a well-known soil cover crop in conservation agriculture, along with other cover crops like mucuna, pigeon pea, cowpea, and Canavalia introduced to smallholder farmers for addressing soil challenges such as inadequate soil fertility, poor soil structure, weed competition, and soil evaporation (Mthembu *et al.*, 2017; Shetto & Owenya, 2007; Bwalya, 2005). In many plantations like maize, coffee crops, and fruit orchards, Lablab makes a suitable cover. Farmers prefer it over other cover crops in conservation agriculture because of its drought tolerance, particularly in low-rainfall areas, and its capacity to flourish in a variety of environmental situations (Shetto & Owenya, 2007). Besides, it is widely used as green manure in a country like Australia, thus playing an important role in organic farming (Grotelüschen, 2014). It has also the ability to decrease soil erosion (Maass *et al.*, 2010) and can be grown along or intercropping with other crops, and can be used in crop rotations (Fig. 7) (Forsythe, 2019). In Africa, the Lablab legumes have been utilized for soil conservation in ensuring food security for the future, particularly in sub-Saharan Africa (Tefera, 2006).



**Figure 6: Lablab cropping systems; (a) Lablab crop can be cultivated as intercropping with cereals like maize, (b) rotated with other crops, (c) sole crop in conservation agriculture (Forsythe, 2019; Tefera, 2006)**

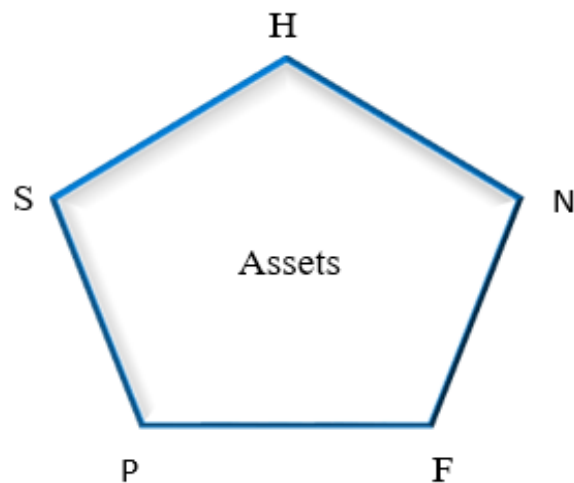
### 2.8.6 Lablab Crop for Livelihood

A livelihood can be explained as earnings in the making of a living, which may include people's competencies, resources, income, and activities such as agricultural practices to secure a means of living (Kimberly & Deepa, 2014). The livelihood concept is based on 'Sustainable Livelihoods' in building the distinct basis for 'Sustainable Livelihood Approaches,' which are the most widely utilized as livelihood frameworks in development practices (Rick de Satgé *et al.*, 2002). By the British Department for International Development (DFID's) definition of livelihoods, “A livelihood comprises the capabilities, assets, and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base (FAO & ILO, 2009).



Based on this definition, capabilities, and assets are made up of a variety of activities that, when included in the livelihoods framework, help in understanding how households improve their livelihoods. The capabilities and assets are closely related to the ability to support household livelihood. Assets or capital which are five can be employed in the framework to investigate the various activities/resources that influence household livelihood sustainability (Fig. 7) (Rick de Satgé *et al.*, 2002). Working with a livelihood framework, on the other hand, necessitates an understanding of its different features and the links between them, as people perceive resources and the connections between them differently in the world, albeit this may be refined accordingly.

The framework's arrows attempt to highlight the connections between various activities and their outcomes. Livelihood activities based on the agriculture sector have proven to provide more connection to sustainable living in terms of food and employment opportunities (Owenya *et al.*, 2011). The agriculture sector is documented to generate reasonable worth for living around the world (Kasolo *et al.*, 2019; Baldermann *et al.*, 2016). Approximately 90% of the world's farms are owned and operated by smallholders (FAO, 2020) and more than 85% of these farms primarily support the livelihood of the world population (Seville *et al.*, 2011). According to Nájera (2017), smallholder farming is a public interest for the main reason that it supports the livelihoods of about 2.2 billion people worldwide. Smallholder farmers' agricultural activities, such as legume cultivation, have shown promise of sustainability in terms of food and income source in developing nations.



**Figure 7: Livelihood assets framework**

Whereby, H = human capital: skills, knowledge, ability to labour, and good health to pursue various livelihood activities; S = social capital: Social resources (networks, membership of groups, relationships of trust, access to wider institutions of society) which people rely on to make a living; P = physical capital: basic infrastructure (transport, shelter, water, energy, and communications) and the producing equipment and means that allow people to earn a livelihood; F = financial

capital: financial resources which are available to people (whether savings, supplies of credit or regular remittances or pensions) and which give them with a variety of livelihood possibilities; and N = natural capital: natural resource stocks from which resource flows useful for livelihoods are derived (e.g. land, water, wildlife, biodiversity, environmental resources) (Rick de Satgé *et al.*, 2002).

However, there is a scarcity of data on underutilized legumes such as Lablab (Forsythe, 2019; Arora, 2014). In a country like Bangladesh, *Lablab purpureus* L. (*Sweet*) is commonly known as Country Bean and generates a significant income after Brinjal (English name is eggplant) and tomato. During summer, it plays a vital role to meet up off-season vegetable deficiency (Miah *et al.*, 2017). In India, Lablab promotes agricultural growth through its value chain in the marketing process. Its commercial value is visualized from short-season varieties of green-pods Lablab (Avarekai) as a vegetable that is available throughout the year (Arora, 2014; Venkatesha *et al.*, 2007). Because of the crop's agronomic and nutritional potential, it has promising opportunities for improving sustainable livelihoods in agribusiness and agrifood systems, particularly in rural areas. Empirical analysis of Lablab production to smallholder farmers' livelihood is crucial in understanding how it contributes to a living, how the world at large affects farmers, and how their livelihood activities affect the larger world (Rick de Satgé *et al.*, 2002).

### **2.8.7 Genetic Resources for Food and Agriculture Sustainability**

Plant genetic resources have the potential to help farmers and breeders assure a steady supply of various food crops (Mohan & Aghora, 2018) while also improving their nutritional quality (Clydesdale, 2004). Evaluating plant germplasm at the molecular level aids in decision-making on the removal of duplicate accessions and the preservation of accessions for future use (De Vicente *et al.*, 2006). Molecular characterization on a diverse crop like Lablab is of important to capture adaptive and productive genes to meet global challenges related to nutritional deficiencies and food security (Govindaraj *et al.*, 2015). According to Venkatesha *et al.* (2007), a considerable molecular variation in Lablab accessions across the world can be useful for plant breeding. Thus, the significance of molecular studies, particularly on underutilized crops, is to provide long-term benefits through genetic information required for increasing agro-morphological and nutritional quality for food and agriculture sustainability.

Among the underutilized crops, Lablab has piqued the interest of researchers due to its drought tolerance and nutritional qualities (Letting *et al.*, 2021; Kilonzi, 2020). Lablab possesses greater genetic variation than other legumes on drought tolerance (Cullis & Kunert, 2017; Kimani *et al.*, 2012) under a range of climate conditions which enhances its potential use for food and feed in

the future (Robotham & Chapman, 2017). Plant breeding systems make use of genetic resource information to come up with novel traits or improved varieties aiming for high crop yield, biotic and abiotic stress tolerance, and improved nutrient contents of food (Ariina, 2018; Maass *et al.*, 2017; Robotham & Chapman, 2017). Genetic resources are of great interest in crop breeding for improved quality and other characteristics (Halewood *et al.*, 2018). Collection and documentation of information on plant genetic resources are pivotal in creating global databases for future germplasm in food and agriculture (Singh & Abhilash, 2019). The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) promotes the collection of plant genetic resources, particularly on underutilized plants which are potential for food and agriculture (FAO, 2009).

For further plant improvement and exploitation, a range of actors needs a mutual understanding in preserving future discovery, conservation, and using new qualities from genetic resources (Halewood *et al.*, 2018). Genebanks are resources for sharing plant genetic materials such as the diversity of crops for global food sustainability (FAO, 2009). Poor sharing and inconsistent documentation may present incomplete genetic information (Day, 1996), especially on identical accessions for accession identifiers (Halewood *et al.*, 2018). Genotype information needs a better sequencing platform for documentation of germplasm accessions from various Lablab plants (Singh & Abhilash, 2019; Dave, 2014). Stone *et al.* (2011) and Tefera (2006) emphasized on well stewarding underutilized Lablab for economic and health benefits. Worldwide, Genebanks contain about 3000 accessions nevertheless, their uses for food and agriculture are yet to be explored (Ambrose *et al.*, 2016).

Moreover, neither the economic significance (Dansi *et al.*, 2012) nor the characterization for domestication and utilization of wild accession resources remains unknown (Ambrose *et al.*, 2016). Thus, genetic studies on underutilized crops, including Lablab varieties are important in this era of climate change and the ever-increasing global population. Furthermore, only a few studies have pointed out the significance of wild Lablab accessions compared to domesticated ones for food and agriculture (Ruelle *et al.*, 2019; Maass *et al.*, 2017). In Africa, where a significant number of wild species are found (Nord *et al.*, 2020; Ruelle *et al.*, 2019), there is limited genetic information on plant breeders (Mabhaudhi *et al.*, 2017; Rai *et al.*, 2010). Nevertheless, wild seed domestication will secure future nutritional traits by revealing novel varieties of germplasm.

In addition, the establishment of plant genetic resources needs to recognize farmers, plant breeders, geneticists, and nutritionists just to mention a few for linkages across the global Genebank (Singh & Abhilash, 2019; Halewood *et al.*, 2018; FAO, 2009). This can practically contribute to the global food demand of an exponentially growing population, which is projected to be over 9 billion by

2050 (UN, 2015). Lablab varieties, such as those shown in Table 4, are beneficial to nutrition security. Thus, the need for genetic information is critical in documenting the diversity of Lablab genotypes from farmer accessions. Since their scarcity can stymie improvements, resulting in underutilization.

## **2.9 Why Lablab Crop is Underutilized?**

### **2.9.1 Little Attention by Researchers and Policymakers**

Recalling from Padulosi *et al.* (2013) the neglected and/or underutilized species (NUS) are those to which little attention is paid and ignored by agricultural researchers, plant breeders, and policymakers. The Lablab crop, for instance, has a long tradition, tremendous diversity, and adaptation to a wide range of environmental circumstances, nevertheless, it has been designated as a marginal, underutilized, and/or neglected crop in most areas since the 1970s (Pengelly & Maass, 2001; Maass, 2006; Maass *et al.*, 2010; Kimani *et al.*, 2012). The Lablab crop is more robust to climate change, making agricultural production systems better off, and supporting traditional diets and cultures yet, Lablab is still classified as a minor crop in the legumes categorization (Snapp *et al.*, 2018; Kimani *et al.*, 2012; Pengelly & Maass, 2001). Although it is also a native crop with both wild and cultivated accessions, it has been promoted in many African countries for eliminating hunger and ending all forms of malnutrition (Davari & Kasture, 2018; Kilonzi *et al.*, 2017; Karanja, 2016; Siddique, 2016; Arora, 2014; Padulosi *et al.*, 2013; Mayes *et al.*, 2012). Therefore, it's time to recognize its diverse potential for agricultural development, nutrition, and sustainable livelihood for the world's overgrowing world population.

### **2.9.2 Improperly Lablab Crop Documentation**

Among the NUS (Table 7), the Lablab crop is primarily adapted to local environments, and smallholder farmers typically cultivate it in traditional systems (Padulosi *et al.*, 2013). According to Forsythe (2019), the sources of Lablab production information among farmers include internal sharing with other farms or inheritance from parents/grandparents, which in most cases uses word of mouth. Farmers' indigenous agricultural knowledge is described as an unwritten body of knowledge, and rarely documentation methods, putting it in danger of disappearing (Abioye *et al.*, 2011). Thus, a mechanism for preserving and perpetuating facts on underutilized crops to avoid them being lost forever to future generations is necessary.



**Table 7: Neglected and/or underutilized species used for FNS from around the world**

| Examples of NUS  | Common /scientific name   | Reference                      |
|------------------|---|--------------------------------|
| Roots and tubers | Yams ( <i>Dioscorea spp.</i> ), Maca ( <i>Lepidium meyenii</i> )                  | Padulosi <i>et al.</i> (2013), |
| Cereals          | Buckwheat ( <i>Fagopyrum spp.</i> ), Spelt ( <i>T. spelta</i> )                   | Mayes <i>et al.</i> (2012)     |
| Fruits and nuts  | Jackfruit ( <i>Artocarpus heterophyllus</i> ), Acacia ( <i>Acacia toritilis</i> ) |                                |
| Vegetables       | Black nightshade ( <i>Solanum nigrum</i> ), Celosia ( <i>Celosia argentea</i> )   |                                |
| Legumes          | Lablab ( <i>Lablab purpureus</i> ), Mungbean ( <i>Vigna radiata</i> )             |                                |
| Spice            | Nigella ( <i>Nigella sativa</i> ), Makoni ( <i>Fadogia ancylantha</i> )           |                                |

Maass *et al.* (2017) reported underutilization of Lablab crops as one of the challenges encountered in developing countries, with scarce statistics on the diversity potentials. This may likely affect awareness of Lablab beans in human diets, particularly in low-income populations where the majority cannot afford meat products to mitigate the risk of malnutrition (Snapp *et al.*, 2018; Bailey *et al.*, 2017). Likewise, farmers may likely be unaware of the potential of growing legume varieties to meet a range of dietary needs (Ruelle *et al.*, 2019; FAO, 2018).

### 2.9.3 Little Traded as Commodities

The underutilized crops (Tyagi *et al.*, 2018; Arora, 2014; Tadele, 2009) including Lablab has limited global market potential (Harouna *et al.*, 2018). Although Nord *et al.* (2020) and Hossain *et al.* (2016) described these crops to have the potential for livelihood yet they receive little attention in the market places. In general, the bean varieties are less traded in the national markets like rice, maize, and wheat (Oghbaei & Prakash, 2016). Another reason is a decrease in demand caused by the replacement of other leguminous species such as common beans and cowpea (Tefera, 2006). Furthermore, Lablab has diversified accessions that are unfamiliar to consumers, which may restrict its use and, as a result, has favored other legume species, particularly for human consumption (Pengelly & Maass, 2001; Maass *et al.*, 2010). In addition, Ngailo *et al.* (2003) indicate a significant market decline Lablab cultivation by the Lablab growers, with no interest in neither cultivation nor consumption due to market forces and farmers less depending on the crop for food security. Moreover, a market survey in eastern Africa had shown that the crop is needed back due to supply and demand forces (Nord, 2017; Ngailo *et al.*, 2003).

### 2.9.4 Confusion Regarding Phrases Usage

Changing its botanical name or common name or using various synonyms (Table 1) has led to consumer confusion (Dave, 2014; Maass *et al.*, 2010; Bhuvaneshwari, 2008). Furthermore, the underutilized Lablab crop has many synonyms (Maass *et al.*, 2017; Dave, 2014) such as underexploited (Ade-Omowaye *et al.*, 2015), an orphan (Lambein *et al.*, 2019), minor (Maphosa & Jideani, 2017), underused (FAO, 2018), a lost crop (Maass *et al.*, 2010), future promising

(Baldermann *et al.*, 2016), future smart food (Ertiro *et al.*, 2019) and a native crop (Shelef *et al.*, 2017). The context-specific observed in these terms are confusing and not interpreted the same way by everyone (Maass *et al.*, 2010). Depending on the context, a greater comprehension of words is required (Tadele, 2009). In this study, the term ‘underutilized’ has been used to capture the under-used status of Lablab crop in food, economic and social terms (Dansie *et al.*, 2012; Naylor *et al.*, 2004). Therefore, the greatest attention to underutilized Lablab legume requires strategic frameworks in enhancing the use of accessions as they owe multiple benefits in sustainable food systems, and livelihood, and are well adapted to climate challenges.

### **2.9.5 Initiative for Bringing Back Underutilized Lablab Crop**

Underutilized crops like Lablab need mutual coordination systems with farmers, consumers, and researchers for global availability and utilization (Østerberg *et al.*, 2017). The perceptions and preferences of individuals have a significant influence on the acceptability and consumption of underutilized crops (FAO, 2018; Nyende & Delve, 2004). A study by Tefere (2006) reported that northeastern farmers in Tanzania were unfamiliar with developed accessions and associated them with snap bean (*Phaseolus vulgaris*). On the other hand, Nord (2017) reported that various Lablab accessions had been introduced in northern Tanzania. Therefore, promoting them for the improvement of agricultural, nutritional quality, and livelihood is necessary (Halewood *et al.*, 2018; Østerberg *et al.*, 2017; Maass *et al.*, 2017).

More studies focused on evaluating agronomical performance (Ambrose *et al.*, 2016) with limited information on the nutrient qualities and livelihood income gain (Kilonzi *et al.*, 2017). Therefore, extra efforts are still needed to further tap the potential of Lablab and its widespread varieties for human diets and dietary diversity as well as consumer acceptance (Karanja, 2016; Siddique, 2016; Grotelüschen, 2014). Noteworthy, varieties developed in India had shown to possess good nutrient composition (Table 4). Indeed, in India, a substantial range of different genotypes of Lablab have been documented with significant nutrition variation in nutrition value, acceptability, and consumption (Ariina, 2018; Hadavani *et al.*, 2018; Sonali *et al.*, 2015). Thus, both wild and domesticated accessions require better mainstreaming of nutritional and agricultural programs as a worthy policy agenda in eliminating all forms of malnutrition. Keep in mind that the acceptance of Lablab crops is also linked to traditional knowledge in the areas where they are grown (Dhaliwal, 2017). For example, green pod varieties are more popular for vegetables in Southern and Northern India than white pod varieties, which are popular in Eastern India (Dhaliwal, 2017). This could provide information about the crop's acceptance, use, exports, and commercial potential (Gopi *et al.*, 2017; Shruthi, 2008), nevertheless, the crop still highly is underutilized as a nutritious crop (Maass *et al.*, 2017).

Further, reconsidering the abandoned Lablab traditional recipes due to a rise in western eating habits focused on starch and sugar is anticipated as a technique to bring back the crop (Baldermann *et al.*, 2016; Padulosi *et al.*, 2013). Besides that, in Africa, Lablab a traditional legume is eclipsed by popular cousin of the common bean (*Phaseolus vulgaris*) and soybean (*Glycine max*) which are less drought-tolerant compared to Lablab beans (Nord, 2017; Stone *et al.*, 2011; Mabhaudhi *et al.*, 2017; Ewansiha *et al.*, 2017; Guretzki & Papenbrock, 2013). In addition, the weak value chain of the Lablab crop from farm to consumer contributes to a poor attitude toward its cultivation and consumption (Hossain *et al.*, 2016; Arora, 2014). In Africa, fewer studies have been conducted on Lablab varieties than in Asian countries, due to a lack of financial support for nutritional research (Ambrose *et al.*, 2016; Tefera, 2006). According to Davari and Kasture (2018), Kilonzi *et al.* (2017), Karanja (2016), Foyer *et al.* (2016), and Ade-Omowaye *et al.* (2015) Lablab accessions have less information on nutritional potential to human's health.

Besides, Lablab beans contain ANFs hence regarded as unsuitable for human consumption, which demoralizes consumers' choices (Davari & Kasture, 2018; Kilonzi *et al.*, 2017). Thus, nutritional understanding is necessary for exerting greater influence on Lablab accessions for nutritional diets. Moreover, programs to promote Lablab varieties require multidisciplinary collaboration, financial support, plus holistic and innovative approaches across agriculture and food systems.

## **2.10 Unravel Knowledge, Attitude, and Practice (KAP) for Lablab Consumption**

Unravelling personal/peoples' behavior towards food, particularly underutilized foods are of worthy exploration to guarantee their acceptance (Adhikari *et al.*, 2017). With Lablab beans one of the most underutilized crops for human consumption, the necessity for research that strives to provide insights and understanding of what was previously clouded or unknown is critical for sustainability. The KAP studies are acknowledged to be an excellent approach for comprehending as well as a measured technique for revealing consumer preferences for various foods based on their choices (Jin *et al.*, 2019). In addition, the study that includes the KAP survey of underutilized crops is beneficial for improving and sustainably managing its value chain from farm to consumer, hence increasing food and nutrition security, and better livelihood. The KAP may assist agricultural value chain players make informed decisions and implement successful measures. Besides, because KAP are related, they may disclose truths about food choices that influence dietary consumption. According to Román *et al.* (2017), human innate perception use of KAP techniques may greatly contribute to Lablab diet acceptance. In view of farmers' dietary preferences, gathering information on existing Lablab accessions in relation to their food systems may reawaken opportunities for the consumption of these abandoned differed beans.

## 2.11 Future Prospects of Lablab Crop

Lablab has the potential to provide a substantial amount of macro- and micro-nutrients (Vidigal *et al.*, 2018; Nord, 2017; Ertiro *et al.*, 2019; Cullis & Kunert, 2017). Scientists and politicians from Africa and beyond are interested in tapping into the legume's nutritional value (Ruelle *et al.*, 2019). Since it has the potential to address nutrition insecurity and poverty in low-income parts of Africa due to its great diversity and drought tolerance (Ertiro *et al.*, 2019). Furthermore, in Africa, both wild and domesticated varieties are found (Maass *et al.*, 2017). Exploration of their nutritional potential can fight against the existence of malnutrition in developing countries particularly in sub-Saharan Africa (FAO, 2019). Likewise, nutrient content strength can be analyzed and used in food-to-food approach recipe formulations (Botelho *et al.*, 2018; Mabhaudhi *et al.*, 2017).

Further investigation to establish nutritional profiles of Lablab varieties is key for future food systems. More understanding of Lablab varieties with their nutritive strengths and contents in comparison with referred nutrient intake per person would make a useful for food-to-food fortification approach for recipe development (Zotor *et al.*, 2015; Hillenbrand & Waid, 2014). Further research particularly on the wild for useful traits like drought/saline tolerance, nutritional and sensory quality, high yield, and domestication would highly contribute to nutritional qualities and livelihood. In this view, accessions with good nutritional quality can be collected and harnessed with other locally available foods like cereals for recipe development based on nutritional requirements (FAO, 2019; Zotor & Amuna, 2017). Therefore, researchers can provide food recipes that meet nutrient requirements, especially for needy people.

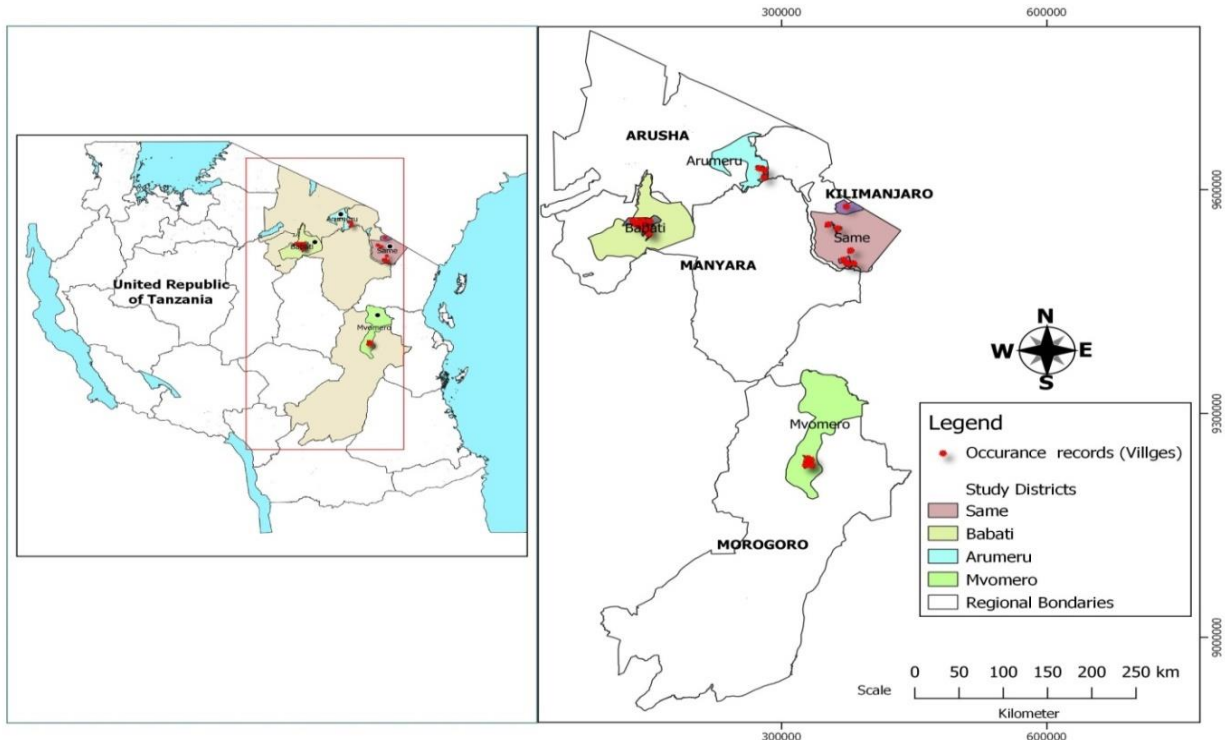
Studies on Lablab seed varieties from diverse habitats have been observed to significantly contribute toward national and global food security (Singh & Abhilash, 2019). Vidigal *et al.* (2018) reported there is scanty information on edible accessions for food-to-food-based fortification approaches at the community level. Mainstreaming this crop into food systems may require an integrated research approach among multi actors on its value chain to reach crop availability, accessibility, affordability, and sustainability (Ojiewo *et al.*, 2018). The mainstreaming process needs to complement customers' willingness on diet selections (Adhikari *et al.*, 2017) to capture their selection criteria for Lablab meal varieties. This will provide wider choices in product formulation, hence dietary diversification (Ade-Omowaye *et al.*, 2015). To achieve this, researchers need to explore the potential of underutilized Lablab varieties for food preferably for different socio-economic strata. Furthermore, uncovering accessions with high nutritional quality may pick the interest of market value for underutilized Lablab as a commercial product and this is critical to farmers' economic advantages for livelihood improvement.

## CHAPTER THREE

### MATERIAL AND METHODS

#### 3.1 Study Area

The study was conducted in northern (Manyara, Arusha, Kilimanjaro regions) and eastern (Morogoro region) zones of Tanzania (Plate 2) covering main Lablab-producing areas (Babati District Council, 2020; Meru District Council, 2017; Same District Council, 2018; Mvomero District Council, 2018).



**Plate 2:** The map of Tanzania showing study sites in four districts in four regions with higher Lablab production

#### 3.2 Study Design and Approach

The study adopted a cross-sectional and experimental study. Data on variables of interest was collected more or less concurrently, assessed once, and the relationship between variables determined (Bryman & Bell, 2011). Also, laboratory analyses with product formulation were conducted. Qualitative and quantitative data were collected using a structured and semi-structured questionnaire. Collected information included knowledge, attitude, and practices (KAPs) on Lablab crop, Lablab value chain (LVC) in relation to Farmer's livelihood, and the contribution of Lablab production to farmers' dietary diversity.

### 3.3 Sample Size Calculation

A total of 384 adult (18 years and above) respondents was estimated as a sample size (n). The sample size was calculated using the formula of:

$$n = \frac{Z^2 Pq}{e^2} \text{ for unknown population (Smith, 2013)}$$

Whereby, n = sample size, Z= the value on the Z table at 95% confidence level =1.96, confidence level P= maximum variability of the population at 50% (0.5), e = sampling error at 5% and q= 1-p = 0.5. The total sample of 384 was then divided into four study districts and each district had a sample size of 96 respondents consisting of 10 buyers/middlemen and 86 were Lablab farmers/consumers at the household level. Since the targeted population was unknown, the prevalence of 0.5 was used by this study to ensure sufficient statistical power to detect (Smith, 2013).

### 3.4 Sampling Procedure

The survey was conducted from April 2019 to February 2020 in the four main Lablab growing districts of Arumeru in Arusha, Babati in Manyara, Same in Kilimanjaro, and Mvomero in Morogoro region (Plate 2). The districts were purposively selected due to the high cultivation of Lablab. A total of 14 wards were selected from the four districts. Four wards (Kikatiti, Makiba, King'ori, and Majengo) with nine villages were selected from the Arumeru district. In the Babati district, four wards (Magugu, Mamire, Kiru, and Gallapo) with five villages were selected. In Kilimanjaro, four wards (Makanya, Hedaru, Stesheni, and Kisima) with seven villages were selected and two wards (Melela, and Mlali) with six villages were selected from the Mvomero district. Farmers' households were identified with the help of Agricultural Extension Officers (AEO). The participants were randomly selected from the record lists of Lablab farmers. The household data on socio-economic characteristics, Lablab crop cultivation, processing, storage, consumers' acceptance, utilization, as well as constraints, were collected using a structured and semi-structured questionnaire adapted from Macías and Glasauer (2014), and Grotelüschen (2014) (Appendices 1 and 2).

### 3.5 Questionnaire Designing, Pretesting, and Administration

The survey data was collected using a modified structured questionnaire that comprised both closed and open-ended questions (Macías & Glasauer, 2014; Grotelüschen, 2014). Before the final developed questionnaire, the questionnaire was pre-tested among 20 respondents in Arumeru. This

was done to ensure that the questionnaire was valid before collecting data. Notably, the 20 interviewees were not counted in the sample size. The developed questionnaire included information from farmers on knowledge, attitude, and uses of the crop. A smallholder farmer of adult age (above 18 years) with at least more than one Lablab harvesting season was interviewed. All data were collected through face-to-face interviews with the researcher and three trained enumerators. Notably, the developed questionnaire was translated into Swahili, the country's common language, to facilitate communication and understanding with respondents, but the collected data was recorded in English. The questionnaires were checked for quality control at the end of the day. Moreover, households involved in growing Lablab were identified with the assistance of Agricultural Extension Officers from the study areas, who also participated as key informants in this study.

### **3.6 Ethical Clearance**

The request to conduct the study in the four study areas was approved and permission was provided by the Northern Zone Health Research Ethics Committee (Ref no. KNCHREC00028). All respondents gave their consent before participating in the study. Moreover, permission to conduct surveys in the four regions was requested from the district and regional government authorities.

### **3.7 Materials**

Thirty Lablab accessions were collected from farmers and the NM-AIST Gene bank, respectively. In each study site, Lablab accessions widely known and cultivated by farmers were collected (Table 8). In total, fourteen farmers' accessions were collected; however, based on their similarity in colour across the study sites, black accessions D-922 (Arumeru), D-397 (Babati), D-394 (Same), and D-419 (Mvomero) were selected (Table 8). The collected accessions were from the 2018 harvest season. The accessions of about 2 kg were stored in zip bags (Zhejiang Jiahe Plastic Co., Ltd., China) and transferred to the laboratory for further analysis. From the NM-AIST Gene bank, Lablab accessions were selected based on farmers' preferences during a farm visit (Plate 3). Fourteen parameters namely high yielding, seed colour, pest resistant, pod size, early maturity, disease resistant, animal feed, soil conservation, drought intolerant, food, market, seed quality, seed shape, and intercropping potential were used as the selection criteria (Table 9). The parameters were derived from literature documentation presented by various scholars (Letting *et al.*, 2021; Davari & Kasture, 2018; Kilonzi *et al.*, 2017; Grotelüschen, 2014).

A total of 31 Lablab growers from the study sites (Plate 3) were involved in the assessment of farmers' preferences. Six of the sixteen accessions were selected because they scored four or higher parameters than the others (Table 9). Therefore, a total of ten accessions (four from farmers, D-

360, D-96, ELD K2, D-287, D-104, and HA-4 in Table 8) were selected and six from the NM-AIST Gene bank (Table 9) were analyzed further.

**Table 8: Lablab accessions collected from the farmers in the study sites**

| Study Site | Seed/accession colour | NM-AIST Gene bank (Given name) |
|------------|-----------------------|--------------------------------|
| Arumeru    | Brown                 | D-421                          |
|            | Black                 | D-422                          |
|            | Khaki                 | D-423                          |
| Babati     | Khaki                 | D-393                          |
|            | Red                   | D-406                          |
|            | Black                 | D-397                          |
|            | Brown                 | D-398                          |
| Same       | White                 | D-418                          |
|            | Black                 | D-394                          |
|            | Brown                 | D-305                          |
|            | Red                   | D-396                          |
| Mvomero    | Black                 | D-419                          |
|            | Cream                 | D-420                          |
|            | Khaki                 | D-415                          |

**Table 9: Lablab accessions selected based on the farmers' observations/preferences (score parameters) at the NM-AIST farm**

|                 |                    | Lablab Accessions |      |        |       |       |      |       | Total per parameter |       |
|-----------------|--------------------|-------------------|------|--------|-------|-------|------|-------|---------------------|-------|
|                 |                    | D-360             | D-96 | ELD-K2 | D-287 | D-104 | HA-4 | D-391 |                     | D-152 |
| 1               | High yielding      | √                 | -    | -      | √     | √     | -    | -     | √                   | 4     |
| 2               | Seed colour        | √                 | -    | √      | -     | √     | √    | -     | -                   | 4     |
| 3               | Pest resistant     | √                 | √    | -      | -     | √     | -    | √     | -                   | 4     |
| 4               | Pod size           | √                 | -    | -      | -     | -     | √    | -     | √                   | 3     |
| 5               | Early maturity     | √                 | -    | -      | √     | -     | -    | -     | -                   | 2     |
| 6               | Disease resistant  | -                 | √    | √      | √     | √     | -    | √     | -                   | 5     |
| 7               | Animal feed        | -                 | √    | √      | -     | √     | √    | √     | -                   | 5     |
| 8               | Soil conservation  | √                 | √    | -      | -     | -     | -    | -     | -                   | 2     |
| 9               | Drought intolerant | -                 | √    | -      | -     | -     | -    | -     | -                   | 1     |
| 10              | Food               | √                 | √    | √      | -     | -     | √    | -     | -                   | 4     |
| 11              | Market             | -                 | -    | √      | -     | -     | -    | -     | √                   | 2     |
| 12              | Seed quality       | -                 | √    | -      | -     | -     | -    | -     | -                   | 1     |
| 13              | Seed shape         | -                 | √    | √      | -     | -     | √    | -     | -                   | 3     |
| 14              | Intercropping      | -                 | -    | -      | √     | -     | -    | -     | -                   | 1     |
| Total parameter |                    | 7                 | 8    | 6      | 4     | 5     | 5    | 3     | 3                   |       |





**Plate 3: The Lablab farmers visit at NM-AIST farm: (a) discussing on the assessment parameters, (b) at the assessment site, and (c) compilation of the results**

### **3.7.1 Knowledge, Attitude and Practices Assessment**

The KAPs were determined as per Macías and Glasauer (2014) whereby farmers' level of knowledge on Lablab Crop was assessed using 17 items which were in four categories. The category with items on food and nutrition potentials were six, medicinal plant for health benefits (two), agronomic advantages (six) and household income generation (three) (Plate 3 and 4). The questions to assess knowledge in all four categories had a response of "True" or "False" or "Don't know" for each item. These responses were not assigned any score during the interview to avoid pre-empting farmers' response. During data entry, farmers' who responded "False" or "Don't know" were assigned a score of zero and one for those who responded "True". All 17 tested items were true and this is why a farmer who opted for "False" or "Don't know" scored zero meaning they had no knowledge and one score denote knowledge of a farmer on Lablab. In order to obtain the knowledge level, responses which were "True=1" were summed on each respondent in each category through STATA version number 14.0. The sum from each category generated a total score for each respondent. Then, total scores for all respondents used to compute a median score for the purpose of establishing a decision criterion to generate the knowledge group levels. The descriptive results indicated that the median score was 10, 15 being the maximum score and two (2) the minimum score. The median score necessitated establishment of three group levels of farmers' Lablab knowledge; farmers who scored between one (1) and nine (9) were placed under low knowledge category, farmers who had 10 scores placed under the medium group level of knowledge and those who score 10 and above were considered to have high level of knowledge.

A cross-tabulation between knowledge group levels based on districts was employed to establish percentage knowledge levels. Also, farmer's knowledge levels were compared based on their gender across the districts.

Thereafter, the knowledge level score was used as a dependent variable in determining the factors that influence farmers' level of knowledge on Lablab Crop. An ordered probit regression was employed to determine the important (significant) factors. Since, the dependent variable in this study has ordering nature as low, medium and high. Using STATA software of version 14.0, the ordinal knowledge score as dependent variable was determined across ten independent variables which were age (in years), level of education (in years), location (districts), sex (male or female), advice (number of counseling sources with regard to Lablab farming), production (in kilogram), income (total kilograms of Lablab beans sold), farm size (hectares), farming experience (years in Lablab crop farming), and household size (total number of household members). Furthermore, marginal effect (ME) was used after an ordered probit regression to determine the influence of the independent variables across each knowledge levels. Tamás (2005) explained that ME enables to show how a dependent variable changes when a specific independent variable changes while the other covariates (regressors) are kept fixed. The ME also describes average effect of changes in independent variables on the change in probability of outcomes in a regression applied model on the effect of each factor (Tamás, 2005).

To determine farmers' attitude on the crop, eleven statements portraying attitude on Lablab crop were tested to each respondent. The statements were describing positive attitudes. Farmers had five options (Likert scale) (Macías & Glasauer, 2014) to respond to the statements. The options include strongly disagree (SD), disagree (D), neutral (N), agree (A) and strongly agree (SA). With respect to neutral responses, in this study 'neural' response meant undecided that is neither a positive response nor a negative response (Thiessen & Blasius, 2001). During data entry, the responses were assigned values as follow as: SA=5, A=4, N=3, D=2 and SD=1. Finally, respondents who answered the statements SA and A reflected a favorite attitude while respondents who opted for SD and D reflected a unfavorite attitude. The statements were all added to get a total score as a new variable. The median score was then computed to be used as a decision criterion to establish the attitude levels. Thereafter, a transformation was done to establish the attitude groups. In addition, the data generated were split district wise for comparison purpose. Likely, the mean differences of farmers' attitude or preferences were compared across the districts using one-way ANOVA at five percent (5%) confidence level.

Farmers' practices were assessed using four statements. Statement one and two assessed Lablab meals preference and cultivation of Lablab in comparison to common beans respectively. Five

options (Likert scale) (Macías & Glasauer, 2014) was employed and neutral responses were respected (Thiessen & Blasius, 2001). The results were transformed as: SA and A responses were considered to agree on the given statements while SD and D were considered to disagree. The third statement evaluated the frequency of Lablab consumption in the household by giving a farmer four options to choose; the options included never (N), seldom (S), sometimes (ST) and often (O). The responses were computed and presented as percentages. In the fourth statement, attributes that contribute to the acceptance of black Lablab accessions as food were evaluated. A farmer had to respond on one of the following options “Extremely unacceptable (EU)”, “Unacceptable (U)”, “Neutral (N)”, “Acceptable (A)” and “Extremely acceptable (EA)” on the given attributes. Previous procedures for statement one and two were employed. Then, the results of the food attributes were determined across the districts using one-way ANOVA at five percent (5%) confidence level.

### 3.7.2 Lablab Value Chain Analysis

The LCA was conceptualized by adapting the structure value chain map proposed by Tadesse and Bakala (2018). The LCA was developed based on three components namely systems, actors, and activities. The LVC relationships within farmers’ household livelihood were determined following an approach by Rick de Satgé *et al.* (2002) where household assets resulting from Lablab production used as a dependent variable and independent variables included production data (Plate 4).



**Plate 4: Data collection: interviews with study participants at Majengo Kati village, Sakila village, and Mbauda local market in the study sites**

### 3.7.3 Physical and Nutritional Quality of Lablab

#### (i) Physical Characterization

The accessions were sorted and cleaned to remove dirt, damaged seeds, stones, and other undesired materials before being measured for weight, length, width, and thickness (Plate 5). Seed weight in each sample, a hundred randomly selected accessions were weighed in triplicate, and the average

was recorded as the 100 seed weight. The weights of the seeds were determined using a precise electronic balance that read with 0.01 gm accuracy (Kilonzi *et al.*, 2017). Then, an individual seed was chosen at random from each type, and three principal parameters, of length (L), width (W), and thickness (T) were measured using a Vernier caliper (India Tools & Instruments Co., India) with a 0.01 mm precision (Palilo *et al.*, 2018; Kilonzi *et al.*, 2017). Three seeds were measured per type, and the average was recorded.

## **(ii) Nutritional Characterization**

Each Lablab accession was ground (Beijing Zhongxingweiye Instrument Co., Ltd. China) into flour then sieved through a 60-mesh size (1.67 mm) (Shanghai sieves/ China), packaged into a zip bag (Zhejiang Jiahe Plastic Co., Ltd., China) and stored at ambient temperature for further analysis.

### ***Moisture Content***

The moisture content was determined by the gravimetric method as per ISTA (2008). Lablab seed flour 5 g was weighed into a pre-weighed crucible for moisture estimation. The sample was oven-dried (Tritec®, Germany) at  $103 \pm 1^\circ\text{C}$  for 17 hours, then cooled in a desiccator and weighed. Then, the percentage of moisture content was calculated as per the formula given below:

$$\text{Moisture content (\%)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where  $M_1$  = Weight of container without seed

$M_2$  = container weight + seed (dried before)

$M_3$  = Weight of container + seed (dried after).

### ***Crude Protein***

Crude protein was estimated using the Kjeldahl method (AOAC, 2005) method 920.152.A. A Lablab flour 5 g was boiled in conc.  $\text{H}_2\text{SO}_4$  (LOBA Chemie, India) at 350 to 380°C together with  $\text{K}_2\text{SO}_4$  (LOBA Chemie, India) to speed up boiling point and the reaction. The nitrogen in Lablab flour was converted into ammonium ions ( $\text{NH}_4^+$ ). The  $\text{NH}_4^+$  was converted into ammonia gas ( $\text{NH}_3$ ) by adding alkali ( $\text{NaOH}$ ) (LOBA Chemie, India), and then transferred into the receiver vessel through steam distillation. The distillate ammonium nitrate ( $\text{NH}_3$ ) was mixed with aqueous  $\text{B}(\text{OH})_3$  (LOBA Chemie, India) to form  $(\text{NH}_4)_3\text{BO}_3$ . Then, it was titrated with  $\text{HCl}$  (LOBA Chemie, India) until the solution was a slightly bluish-purple. Thereafter, the number of moles was calculated from nitrogen atoms by using the volume and concentration of the acid, and the

percentage of protein in the seed flour was multiplied by 6.25 nitrogen conversion factor (AOAC, 2005).

$$\% \text{ Protein} = \frac{(A-B) * M * 14.007 * 1.00 * 6.25}{W} * 100$$

Where:

A = volume (ml) of 0.2 N HCl used in sample titration

B = volume (ml) of 0.2 N HCl used in blank titration

M = molarity of the acid

W = weight (g) of sample

14.007 = atomic weight of nitrogen

MCF = moisture correction factor = 100/(100 - Moisture (%))

6.25 = factor used to convert percent N to percent crude protein. Most proteins contain 16% N, so the conversion factor is 6.25 (100/16 = 6.25).

### ***Ash Content***

Ash content was determined by incinerating the sample in a Muffle furnace (Nabertherm B180, Germany) (AOAC, 2000) Method 923.03. Lablab seed flour, 5 g was accurately weighed in preconditioned crucibles. First, the sample was charred by a flame to eliminate smoking before being incinerated at 550°C for 12 hours in a Muffle furnace, to the point of white ash. The residue was cooled in a desiccator and the weights were taken.

$$\% \text{ Crude ash} = \frac{\text{weight of ash}}{\text{weight of sample}} * 100$$

### ***Crude Fat***

Crude fat was determined by Soxhlet's apparatus (Bio Technics BTI-41, India) using the AOAC (2005) method number 945.87 (AOAC, 2005). The Lablab seed flour of 5 g was put in extraction thimbles and oil was extracted using 60 mL C<sub>6</sub>H<sub>14</sub> (Mallinckrodt, USA) for 12 hours at 40 - 60 °C. The (solvent) was removed by a rotating vacuum evaporator (Acmas Technologies INC. India), and the crude fat was dried at 70°C for 30 minutes and weighed. Percentage fat was calculated by using the formula:

$$\text{Crude fat (\%)} = (W_2 - W_1) \times \frac{100}{S}$$

Where:

Weight of empty flask (g) = W<sub>1</sub>

Weight of flask and extracted fat (g) = W<sub>2</sub>

Weight of sample = S



### ***Total Carbohydrate***

The total carbohydrate was calculated to be as per AOAC (2005) method, that is a difference of the sum of protein, fat, moisture, and ash subtracted from the total weight of the food. This is referred to a total of carbohydrate (g/100 g) =  $100 - \{\text{protein (g)} + \text{fat (g)} + \text{ash (g)} + \text{moisture content (g)}\}$ .

#### **3.7.3 Mineral Content**

The minerals (Mg, Si, Ca, Cu and Zn) were determined according to Croffie *et al.* (2020). The samples were oven-dried at 65°C until they attained a consistent weight. Each sample's dry weight of 4 g was subsampled and mixed with a cellulose binder of 0.9 g (Hoechstwax) (Cereox fluxana-BM- 0002-1/Germany). The mixture was placed in a bowl, and spherical balls with a 3 mm radius were prepared and inserted into a pulverize for additional grinding and homogenization. The pulverize was set to run at 150 rpm for 5 minutes. The mixture was placed in a polished hydraulic pressing machine (Vaneox Fluxana PP25, Germany) at 15 psi (pounds per square inch). A tablet-like known as a pellet was formed (Plate 7) and then kept in a clean petri dish, labelled, and then placed in a holder, and inserted into Energy-dispersive X-ray fluorescence (EDXRF) spectrometry, a Spectro Xepos, serial No. 4R0138 to quantify the mineral content (Campbell *et al.*, 2000).



**Plate 5:** A tablet-like referred to as a pellet, labelled and stored for further analysis

#### **3.7.4 Anti-Nutrients Determination**

##### **(i) Phytic Acid**

The phytic acid was determined as per Hossain *et al.* (2016) with modification. Two grams of Lablab seed flour was weighed into a glass beaker and 10 mL of 0.2 N HCl (LOBA Chemie, India)

was added. The mixture was placed on the horizontal shaker at ambient temperature for 24 hours. Two milliliters of  $\text{NH}_4\text{Fe}(\text{SO}_4)_2$  solution was added to the 1 mL of each aliquot of the extract. Then, the mixture was boiled at  $100^\circ\text{C}$  for 30 minutes and left to cool at ambient temperature. Followed by centrifuging at 5000 rpm at  $4^\circ\text{C}$  for 10 minutes (Eppendorf Centrifuge 5810, Germany). Two milliliters of the supernatant were mixed with 3 mL of  $\text{C}_{10}\text{H}_8\text{N}_2$  solution (2,2'-bipyridine - Thermo Scientific™) vortexed and incubated at  $40^\circ\text{C}$  for 30 minutes. The light absorbance was measured with a Spectrophotometer at 530 nm (Heidolph, Germany).

## **(ii) Tannins**

The tannin content was determined according to the method of Morrison (2019) with some modifications. Each seed flour extract was dispersed in a 100 mL volumetric flask containing 50 mL of distilled water and shaken after every 10 minutes for 30 minutes at ambient temperature. After that, the solution was filtered with Whatman filter paper (Cytiva™, India). A 2 mL extract was transferred to a 50 mL volumetric flask, separately. Each flask was diluted with 35 mL of distilled water before adding 0.5 mL of Follin-Dennis reagent and 2.5 mL of 35%  $\text{Na}_2\text{CO}_3$  (LOBA Chemie, India). Then, distilled water was added up to the 50 mL mark, thoroughly mixed, and incubated at ambient temperature for 90 minutes. The wavelength of the developed colour was read at 700 nm on a UV-Visible Spectrophotometer (UV-Vis Spectrophotometer, U-1800, 5 930 482, High Technology Corporation, Tokyo, Japan) as well as a blank solution (distilled water).

## **(iii) Trypsin Inhibitor**

### ***Protein Extraction***

Lablab seed flour 10 mg from each accession was suspended in a 200  $\mu\text{L}$  of extraction solution (0.5 M NaCl, pH 2.4) and vortexed (Eppendorf MixMate®, Germany) for complete dissolving as described by Osborn *et al.* (1986) with some modification. The mixture was left to settle at ambient temperature for 30 minutes and centrifuged at 12 000 rpm for 5 minutes. Supernatant 12  $\mu\text{L}$  was mixed with 6  $\mu\text{L}$  of 0.5 M NaCl (LOBA Chemie, India) pH 2.4 and 6  $\mu\text{L}$  of 2x protein-based sample buffer (65.8 mM Tris HCl pH 6.8, 26.3% (w/v) glycerol, 2.1% SDS, 0.5% 2-Mercaptoethanol, 0.01% Bromophenol blue). The mixture was vortexed and then heated at  $95^\circ\text{C}$  for 5 min followed by centrifugation at 16 000 rpm for minutes at  $4^\circ\text{C}$ , and then the supernatant was collected.

The two-dimensional SDS-PAGE method was used (Maro *et al.*, 2022; Osborn *et al.*, 1986) with some modifications. The supernatant of 8 µL from each sample was immediately loaded onto a 12% Tris-glycine SDS-PAGE running gels in running buffer (0.5 M Tris-HCL (15 mL) (TRIS AMINO™ HCl, USA), Glycine 100 mL, 10% SDS (5 mL) (SDS Sigma-Aldrich L3771-100G, Germany) and distilled water) and 5 µL of standard molecular weight (MW) marker of 10 - 225 kDa (Promega V8491, USA). The electrophoresis gel was run for 3 hours with a constant voltage of 200 power supply. After electrophoresis, the gels were stained with Coomassie brilliant blue R-250® for 1 hour while shaking at low speed. Then the gels were de-stained using 40% methanol, and 10% acetic acid solution for 2 hours. Thereafter, washed three times with deionized water with gentle shaking and left in deionized water for 48 hours. The clear blue bands on a clear background were visualized using a ChemiDoc MV gel documentation system (Bio-Rad, Hercules, CA, USA) and photographed with image Lab 4.1 software as needed. The gels were scored against a reference to a 10 – 250 kDa MW marker subunits from electrophoretic mobility of size standard proteins.

### **3.7.5 Lablab Processing, Mineral, and Anti-Nutrients Determination of Sprouted and Fermented Lablab**

#### **(i) Sprouting**

Sprouting of the Lablab accessions was done according to Hassan *et al.* (2006) with modifications. The seeds of 200 g were washed twice and soaked in 1000 mL of potable (drinking) water, at 25°C for 12 hours, with a change of water twice. The beans were drained before being spread thinly on a moist jute bag in ambient conditions to enable sprouting to occur. Sprouting was halted when the rootlets reached a length of about 2.50 cm (2 days). The bean sprouts were dried in an (air-oven) dryer (Tritec®, Germany) at 60 - 70°C for 8 hours and the drying was stopped after obtaining a constant moisture content using the gravimetric method (ISTA, 2008). The dried sprouted Lablab seeds were ground by a grinder machine (Beijing Zhongxingweiye Instrument Co. Ltd., China) and sieved through a 60 mesh (1.67 mm) sieve (Shanghai sieves, China). The flour was stored separately in airtight containers for further analysis of minerals and ANFs analysis as described in sections 3.7.4 and 3.7.5.

#### **(ii) Fermentation**

Fermentation of Lablab seeds was done according to Adeyemo and Onilude (2013) with slight modifications. For each one, 200 g of Lablab was immersed in 1000 mL of distilled water. About



0.5 g of Lactic acid bacteria (LAB) was added, covered, and allowed to ferment for 3 days at 25°C. Fermented accessions were then washed with distilled water and dried in a dehydrator (Hakka Stainless Steel Food Dehydrator, US) at 60°C for about 5 hours following the method (ISTA (2008). The dried accessions were ground using a grinder machine (Moongiantgo Electric Grain Mill Grinder, Germany). The flour was sieved through a 60 mesh (1.67 mm) sieve, and each flour was stored separately in airtight containers for further analysis of minerals and ANFs as described in sections 3.7.4 and as described in section 3.7.5.

### **3.7.6 Lablab Products Formulation**

#### **(i) Lablab Cookies Preparation**

The primary ingredient in the cookie formulation was Lablab flour, with addition of other ingredients in small amounts to enhance flavor and texture (Violalita *et al.*, 2019). Different ratios of Lablab flours (fermented, sprouted, unfermented/unsprouted and control wheat flour) were used to prepare the cookies. All ingredients were measured such as flour, butter, and sugar and mixed to make a smooth cookie dough. The dough was cut into desired portions and lined into baking tray. The cookies were baked in an oven at 180°C at different times, cooled, and packaged in airtight clear containers for later ranking by consumers.

### **3.7.7 Consumer Acceptability Test**

Participants included NM-AIST students, staff, and visitors were selected randomly and assessed for eligibility such as no food allergies, willingness, and availability (Chinma *et al.*, 2011). A total of 80 untrained consumers participated in the consumer acceptability test. As suggested by Gacula and Reutenbeck (2006) for sample size in consumer acceptability tests that involve a large number of products to be examined. Similarly, Kerth (2013) stated that in order to satisfy consumer acceptance of new products, large numbers of participants are required to qualify demographic and product liking on various statistical measures to provide estimates with more generalized validity results. The affective approach of 9 points Hedonic scale was used to assess customer like and disliking, preference for one product over another, and the overall consumer acceptability of the products (Chinma *et al.*, 2011; Gacula & Reutenbeck, 2006; Singh-Akbar & Maharaj, 2014).

### **3.7.8 Minimum Dietary Diversity Assessment**

The contribution of the Lablab crop towards dietary diversity among the growers' households was determined using a 24-hour recall method by FAO and FHI 360 (2016). Foods and drinks consumed by the respondents on the previous day were converted into ten food groups which were

later categorized into 6 or more groups (High), 4 – 5 (Minimum), and 3 or fewer food groups (Low) (Custodio *et al.*, 2020; Adubra *et al.*, 2019). The responses were added to establish the dietary diversity scores (dependent variable) (Kennedy *et al.*, 2010) which were then used to measure the association between crop productivity and household quality diet. Although the MDD-W dietary diversity score is presented at the individual level, the data obtained were useful in describing the diet quality of Lablab growers and their households, as well as recommending any future interventions if required (FAO & FHI 360, 2016).

Furthermore, household assets (Naveed *et al.*, 2021) acquired as a result of involvement in Lablab production were assessed (Adubra *et al.*, 2019). Also, Food and Nutrition Technical Assistance (FANTA) guide for monitoring household food access, which employs the Household Food Insecurity Access Scale (HFIAS) was used to determine household food security (Adubra *et al.*, 2019). The association between household food security, MDD-W dietary diversity, and Lablab production was investigated to provide a promising context for nutrition-sensitive agriculture aimed at improving nutritional quality as well as livelihood among smallholder Lablab farmers.

### **3.8 Data Analysis**

Data were cleaned, coded, and entered in Statistical Package for Social Sciences (SPSS) version 21. Descriptive statistics such as means, frequencies, and percentages were calculated. The mean differences were compared across the districts at 5% confidence level by using a one-way analysis of variance (ANOVA). For physical characteristics, nutrient compositions, and sensory characteristics the mean differences observed were further subjected to Post hoc test Tukey's Honest Significant Difference test (Tukey's HSD) at a 5% confidence level. Moreover, the Poisson regression model was used to examine the association between Lablab production and dietary diversity whereas the Lablab income expenditure data were analysed by the Principal Component Analysis to optimize the variance using STATA Version 14.

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Household Knowledge, Attitude, and Practices (KAPs) on Lablab\*

##### 4.1.1 Socio-Demographic Characteristics of the Respondents in the Study Sites

The socio-demographic characteristics of the participating Lablab farmers are presented in Table 10. Lablab cultivation, was dominated by males, similar to the findings of Letting *et al.* (2022). Farmers' ages ranged from 31 to 40 in Arumeru, Babati, and Same districts, and 41 to 50 in Mvomero, which corresponded to Letting *et al.* (2022) results. Regarding education, over 70% had primary education, the majority were married, and households consisted of 6 to 13 individuals, a characteristic of farmers' households which is consistent with Minja *et al.* (2021).

On Land ownership, the majority owned over 70% of able land and cultivate about two to five hectares of Lablab. Due to their economic potential, black Lablab seeds was primarily grown across the study areas, with 93.5% grown in Arumeru (Table 10). According to Grotelüschen (2014), black Lablab seeds have predominantly markets in Eastern Kenya. Farmers in northern Tanzania's are being encouraged to regrow the crop for commercial purposes as a result of demand (Nord *et al.*, 2020; Ngailo *et al.*, 2003). In the Same district, the Lablab is a cash crop (Same District Council, 2018). The majority of farmers had 13 to 49 years of experience in Lablab farming for agribusiness in contrast to Letting *et al.* (2022) reported having < 10 years' experience in Lablab cultivation. Further to that, the non-black Lablab was less than 35% cultivated. The fact that the brown, khaki and red accessions fetched no market value, resulting in low production. According to Morrison (2019), farmers usually tend to grow crops with high market value. Also, it was noted that some accessions such as the white color (1.1%), were unfamiliar which were only found in the Same district and used for food. According to Maass *et al.* (2010), Lablab accessions are diverse but underdocumented in Africa, where they originated.

\*Minde *et al.* (2021). Dolichos lablab (*Lablab purpureus*): Smallholder Farmers Knowledge, Attitude and Practices in relation to Food and Nutrition Security in Tanzania. *International Journal of Biosciences*, 19(5),122-136. DOI: <http://dx.doi.org/10.12692/ijb/19.5.122-136>

**Table 10: Socio-demographic characteristics of the Lablab farmers in the study districts respondents**

| Variable                                    | District /number of farmers (%, n=344) |           |           |           | F-test              |
|---|--|-----------|-----------|-----------|---------------------|
|   | Arumeru                                | Babati    | Same      | Mvomero   |                     |
| <b>Gender</b>                               |  |           |           |           | 4.072**             |
| Male  | 44 (51.2)                              | 44 (51.2) | 59 (68.6) | 44 (51.2) |                     |
| Female                                      | 42 (48.8)                              | 42 (48.8) | 27 (31.4) | 42 (48.8) |                     |
| <b>Age (years)</b>                          |  |           |           |           | 24.509**            |
| 21-30                                       | 16 (18.6)                              | 9 (10.5)  | 32 (37.2) | 2 (2.3)   |                     |
| 31-40                                       | 36 (41.9)                              | 34 (39.5) | 33 (38.4) | 20 (23.3) |                     |
| 41-50                                       | 16 (18.6)                              | 27 (31.4) | 12 (14.0) | 29 (33.7) |                     |
| 51-60                                       | 14 (16.3)                              | 16 (18.6) | 8 (9.3)   | 27 (31.4) |                     |
| 61-70                                       | 4 (4.7)                                | 0.0       | 1 (1.2)   | 8 (9.3)   |                     |
| <b>Level of education</b>                   |  |           |           |           | 39.226***           |
| Informal education                          | 2 (2.3)                                | 3 (3.5)   | 0.0       | 18 (20.9) |                     |
| Primary                                     | 62 (72.1)                              | 72 (83.7) | 40 (46.5) | 62 (72.1) |                     |
| Secondary                                   | 20 (23.3)                              | 11 (12.8) | 33 (38.4) | 4 (4.7)   |                     |
| Tertiary                                    | 2 (2.3)                                | 0.0       | 13 (15.1) | 2 (2.3)   |                     |
| <b>Marital status</b>                       |  |           |           |           | 3.7*                |
| Separated                                   | 5 (5.8)                                | 2 (2.3)   | 11 (12.8) | 2 (2.3)   |                     |
| Single                                      | 9 (10.5)                               | 4 (4.7)   | 8 (9.8)   | 2 (2.3)   |                     |
| Widow/widowed                               | 1 (1.2)                                | 5 (5.8)   | 4 (4.7)   | 10 (11.6) |                     |
| Married                                     | 71 (82.6)                              | 75 (87.2) | 63 (73.3) | 72 (83.7) |                     |
| <b>Household size</b>                       |  |           |           |           | 1.773 <sup>ns</sup> |
| 1-4   | 19 (22.1)                              | 13 (15.1) | 13 (15.1) | 15 (17.4) |                     |
| 5   | 33 (38.4)                              | 26 (30.2) | 27 (31.4) | 32 (37.2) |                     |
| 6-13  | 34 (39.5)                              | 47 (54.7) | 46 (53.5) | 39 (45.3) |                     |
| <b>Land tenure status</b>                   |  |           |           |           | 3.936**             |
| Land owned                                  | 68 (79.1)                              | 80 (93.0) | 63 (73.3) | 66 (76.7) |                     |
| Land rented                                 | 13 (15.1)                              | 5 (5.8)   | 23 (26.7) | 16 (18.6) |                     |
| Owned and rented                            | 5 (5.8)                                | 1 (1.2)   | 0.0       | 2 (2.3)   |                     |
| Gift  | 0.0                                    | 0.0       | 0.0       | 2 (2.3)   |                     |
| <b>Land area under crop production (ha)</b> |  |           |           |           | 8.644***            |
| <5  | 8 (9.3)                                | 7 (9.4)   | 5 (5.2)   | 11 (11.5) |                     |
| ≥ 2 <5                                      | 56 (64.2)                              | 49 (51.0) | 24 (27.1) | 61 (66.6) |                     |
| ≥ 1 >2                                      | 22 (25.6)                              | 32 (39.6) | 59 (66.7) | 16 (21.8) |                     |
| > 1   | 4 (4.7)                                | 7 (9.4)   | 10 (12.5) | 11 (13.5) |                     |
| <b>Lablab accessions available</b>          | <b>Percentage (%)</b>                  |           |           |           | <b>Average</b>      |
| Black                                       | 93.5                                   | 53.8      | 55.9      | 45.9      | 62.3                |
| Red   | 1.1                                    | 11        | 17        | 0         | 7.3                 |
| Brown                                       | 0.0                                    | 2.1       | 9.4       | 22.8      | 34.3                |
| Khaki /Cream yellowish                      | 5.4                                    | 33.2      | 16.5      | 31.4      | 21.6                |
| White                                       | 0.0                                    | 0.0       | 1.1       | 0.0       | 0.3                 |
| <b>Lablab farming experience</b>            |  |           |           |           |                     |
| 2-11  | 48.8                                   | 11.6      | 57.0      | 48.8      | 41.6                |
| 12  | 2.3                                    | 0.0       | 0.0       | 0.0       | 0.6                 |
| 13-49                                       | 48.8                                   | 88.4      | 43.0      | 51.2      | 57.9                |

Statistically significant level: \*\*\*P ≤ 0.001; \*\*P ≤ 0.01; \*P ≤ 0.05

#### 4.1.2 Farmers' Knowledge, Attitudes, and Practices

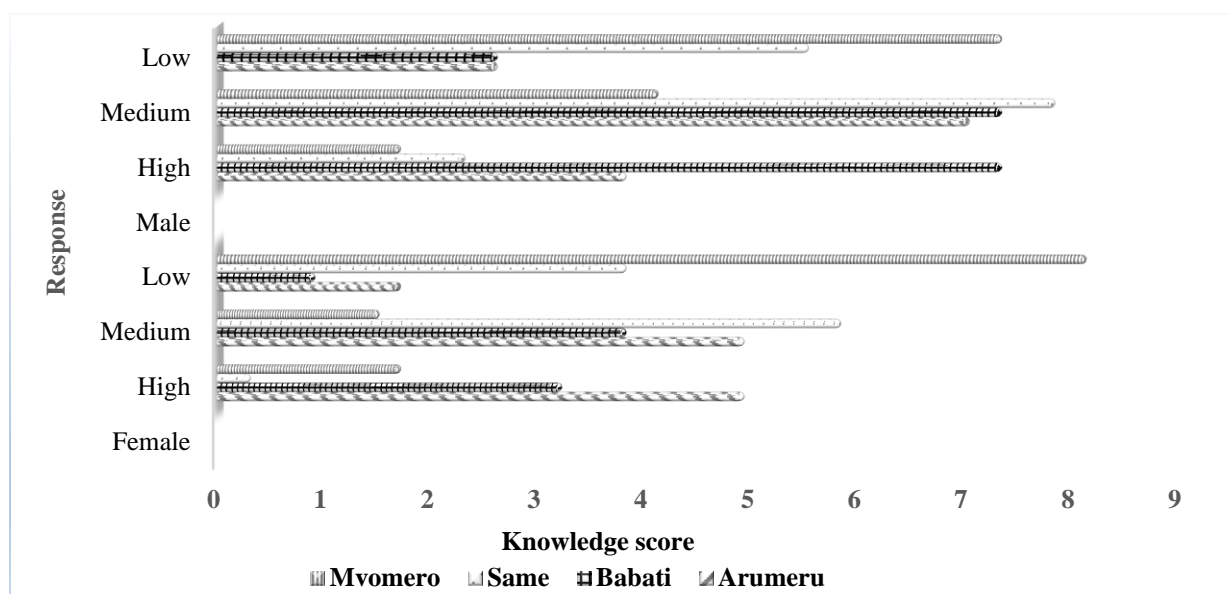
##### (i) Farmer's Knowledge

Farmers' knowledge of Lablab, despite being the oldest cultivated crop, ranged from low to medium to high (Table 11). Determination of farmers' understanding of a particular product is most important to know the level of informedness. Grotelüschen (2014) reported that farmers' awareness is crucial when introducing underutilized, new, or developed crops into their food

systems. As factors such as location significantly affected the level of understanding (0.142) ( $p \leq 0.05$ ) (Table 12). This implies that the probability of farmers' understanding of Lablab crop was based on the place where they lived. Nord *et al.* (2020) and Forsythe (2019) reported that farmers were more exposed to the Lablab crop, a cash crop for export. In this study, Lablab farmers had higher knowledge of the beans in relation to other cash crops as observed in Same (36.6%) and Arumeru (27.3%) (Table 11). Furthermore, the knowledge by genderwise revealed that males in Babati and females in Arumeru knew more about the Lablab crop (Fig. 8).

**Table 11: Farmers' level of knowledge on Lablab crop across the study districts**

| Study Districts | Farmers' Level of Knowledge (%; n=344) |              |              |
|-----------------|--|--------------|--------------|
|                 | Low                                    | Medium       | High         |
| Arumeru         | 19.0                                   | 38.3         | 27.3         |
| Babati          | 36.1                                   | 4.3          | 19.4         |
| Same            | 13.3                                   | 21.3         | 39.6         |
| Mvomero         | 31.6                                   | 36.1         | 13.7         |
| <b>Total</b>    | <b>100.0</b>                           | <b>100.0</b> | <b>100.0</b> |



**Figure 8: Farmers' level of knowledge on Lablab crop based on gender**

Farmers with low and medium knowledge levels were less exposed to crop potential rather than cash crop. Factors such as location ( $-0.041$ ) ( $p \leq 0.05$ ) and advice ( $-0.077$ ) ( $p \leq 0.001$ ) were of importance, but negatively contributed to their knowledge levels (Table 12). The place where farmers lived and what they were informed had an inverse influence on their understanding. The majority obtained the information from their parents/relatives, fellow farmers, or neighbors. A similar report by Forsythe (2019) explained the same scenario and linked it to farmers' lack of awareness and up-to-date information.

Furthermore, the study results showed farmers with a high understanding of Lablab crop was due to places they lived with good access to advice, but not influenced by age or formal education.

Farmers' formal education had a negative (-0.041) ( $p \leq 0.001$ ) effect on their knowledge about the crop (Table 12). It was expected that the formal education they had could promote positive understanding. Kasolo *et al.* (2019) argue that the wider perception of education has to reflect changes and also inspire someone's interest in various development aspects of living. The farmer's education less contributed to their understanding of the underutilized crop in this study. Nonetheless, farmers who were more knowledgeable about the crop were associated with the areas in which they live (0.055) ( $p \leq 0.05$ ) and advice (0.096) ( $p \leq 0.01$ ) (Table 12). This observation was confirmed by farmers from the northern zones of Arumeru (93.5%), Babati (53.8%), and Same (55.9%) who cultivated black Lablab seeds (Table 10). These seeds were marketed outside the country and the growers were familiar with them. High demand for the Lablab crop outside the county induced farmers' interest to understand more about black Lablab accessions to fulfill the market needs (Grotelüschen, 2014). Black Lablab accession are well known in Kenya due to the higher potentials in mixed farming systems, livestock feeds, and human diets.

Factors such as production, income, farm size, farming experiences, and household size did not display a significant ( $p \leq 0.001$ ,  $p \leq 0.01$ ,  $p \leq 0.05$ ) effect on farmers' levels of knowledge (Table 12). Although, production and household size showed a positive influence on farmers' knowledge, but income, farm size, and agricultural experience showed a negative impact. In general, based on, the location influenced farmers' knowledge of Lablab (Table 12). Macías and Glasauer (2014) argued that what is known in a specific population in a particular location is more likely to be believed and adopted.

**Table 12: Factors determining farmers' level of knowledge of Lablab crop from an ordered probit regression analysis**

| Variable           | Coefficient Standard Error |           | Marginal effects on different knowledge levels |           |                  |           |                |           |
|--------------------|----------------------------|-----------|--|-----------|------------------|-----------|----------------|-----------|
|                    | Coef.                      | Std. Err. | Low knowledge                                  |           | Medium knowledge |           | High knowledge |           |
|                    |                            |           | dy/dx  | Std. Err. | dy/dx            | Std. Err. | dy/dx          | Std. Err. |
| Age                | -0.014*                    | 0.067     | 0.004*   | 0.002     | 0.001            | 0.001     | -0.006*        | 0.003     |
| Education          | -0.105***                  | 0.025     | 0.037***                                       | 0.008     | 0.008**          | 0.003     | -              | 0.010     |
| Location           | 0.142*                     | 0.063     | -0.044*  | 0.020     | -0.011           | 0.006     | 0.055*         | 0.025     |
| Sex                | -0.103                     | 0.129     | 0.032  | 0.040     | 0.008            | 0.010     | -0.040         | 0.051     |
| Advice             | 0.247**                    | 0.095     | -0.077**                                       | 0.296     | -0.019*          | 0.009     | 0.096**        | 0.037     |
| Production         | 0.001                      | 0.000     | -0.000   | 0.000     | -0.000           | 0.000     | 0.000          | 0.000     |
| Income             | -0.020                     | 0.039     | 0.006  | 0.012     | 0.002            | 0.003     | -0.008         | 0.015     |
| Farm size          | -0.014                     | 0.016     | 0.004  | 0.005     | 0.001            | 0.001     | -0.005         | 0.006     |
| Farming experience | -0.004                     | 0.005     | 0.001  | 0.000     | 0.000            | 0.000     | -0.002         | 0.002     |
| Household size     | 0.043                      | 0.032     | -0.013   | -0.010    | -0.003           | 0.003     | 0.017          | 0.013     |
| /cut1              | -1.457                     | 0.550     |  |           |                  |           |                |           |
| /cut2              | -0.537                     | 0.546     |  |           |                  |           |                |           |
| Log likelihood     | -354.529                   |           |  |           |                  |           |                |           |
| Number of obs      | 344                        |           |  |           |                  |           |                |           |
| LR chi2 (10)       | 32.00                      |           |  |           |                  |           |                |           |
| Prob> chi2         | 0.004                      |           |  |           |                  |           |                |           |
| Pseudo R2          | 0.0432                     |           |  |           |                  |           |                |           |

Statistically significant level: \*\*\* $P \leq 0.001$ ; \*\* $P \leq 0.01$ ; \* $P \leq 0.05$  Note: dy/dx for factor levels is the discrete change from the base level

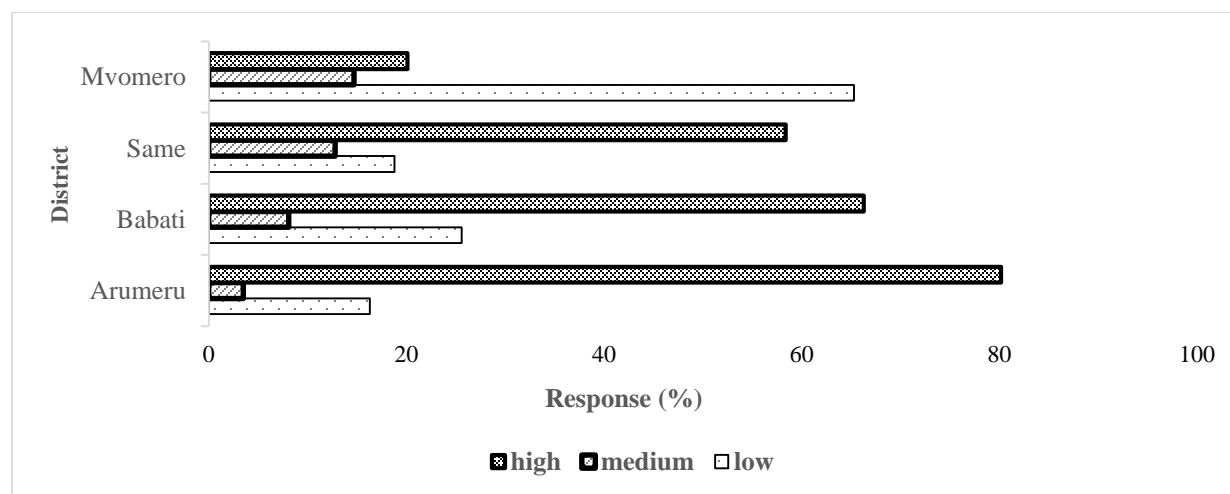
## (ii) Farmers' Attitudes

The findings in Table 13 present farmer's attitudes towards the underutilized Lablab. Variations across in terms of attitude were observed, with Arumeru district (80.2%) ranked higher followed by Babati (66.3%) and Same (58.4%), respectively (Fig. 9). This is due to the economic potential of Lablab (Nord *et al.*, 2020; Ngailo *et al.*, 2003). Low favorite towards the crop was observed in Mvomero with only 20.1% (Fig. 9), despite a higher Lablab consumption rate (93.7%) (Table 13). This phenomenon prompts more explanations from farmers' which revealed that the low cost of Lablab, and the absence of reliable markets in the Mvomero district contributed to the less preference for the crop (Fig. 9). This alert rethink smallholder farming products in terms of income generation rather than food contribution. Farmers tend to value their products, and economical potential, but less important if contribute more directly to household diets. Implying crops that directly serve as food in the household, farmers do preserve them with unfavorable attitudes to their living which may hinder achieving nutritional qualities for healthy living (Grosso *et al.*, 2020).

**Table 13: Farmers' attitudes toward Lablab crop**

| Statements  | District (%, n=344) |      |      |        |      |      |      |      |      |         |      |      | F-test     |
|---|---------------------|------|------|--------|------|------|------|------|------|---------|------|------|------------|
|   | Arumeru             |      |      | Babati |      |      | Same |      |      | Mvomero |      |      |            |
|   | D                   | N    | A    | D      | N    | A    | D    | N    | A    | D       | N    | A    |            |
| Lablab farming is a beneficial activity           | 0.0                 | 1.2  | 98.9 | 0.0    | 9.4  | 90.6 | 0.0  | 1.0  | 98.9 | 20.8    | 11.5 | 67.7 | 56.480***  |
| Lablab farming add nutrients to the soil          | 8.1                 | 3.5  | 88.4 | 2.0    | 4.2  | 93.8 | 1.0  | 19.8 | 79.2 | 4.2     | 5.2  | 90.6 | 16.563***  |
| Preference of Lablab as cash a crop               | 3.5                 | 4.7  | 91.9 | 2.1    | 14.6 | 83.3 | 8.4  | 25.0 | 66.6 | 68.8    | 17.7 | 13.6 | 115.423*** |
| Lablab remains after harvest as feeds             | 20.9                | 14   | 65.2 | 18.8   | 25.0 | 56.3 | 16.7 | 58.3 | 25.0 | 91.7    | 2.1  | 6.3  | 54.923***  |
| Lablab are consumed by human                      | 40.7                | 7.0  | 52.3 | 29.2   | 28.1 | 42.7 | 14.6 | 9.4  | 76.0 | 3.1     | 3.1  | 93.7 | 54.923***  |
| Some Lablab accessions take short time in cooking | 25.6                | 27.0 | 47.5 | 25.0   | 35.2 | 41.0 | 32.2 | 37.5 | 30.2 | 79.2    | 1.0  | 19.8 | 46.598***  |
| We usual consume Lablab                           | 67.4                | 11.6 | 20.9 | 33.7   | 14.6 | 51.7 | 36.0 | 23.0 | 41.0 | 7.3     | 3.1  | 89.6 | 4.060**    |
| Consumption of Lablab accessions                  | 38.4                | 46.5 | 15.1 | 24.7   | 29.1 | 46.3 | 3.5  | 31.4 | 65.1 | 11.6    | 10.5 | 77.9 | 3.452*     |
| Lablab is a nutritious food                       | 13.5                | 33.5 | 53.0 | 20.9   | 35.4 | 43.7 | 10.4 | 46.3 | 43.3 | 22.9    | 17.7 | 59.4 | 25.771***  |
| Lablab local dishes are known in my village       | 12.8                | 5.8  | 81.4 | 7.3    | 23.3 | 69.4 | 11.5 | 16.3 | 72.3 | 4.7     | 7.0  | 88.3 | 35.434***  |
| Lablab farming is economically profitable         | 7.3                 | 3.1  | 89.6 | 0.0    | 9.4  | 90.6 | 3.5  | 4.7  | 91.9 | 64.4    | 11.1 | 24.5 | 55.470***  |

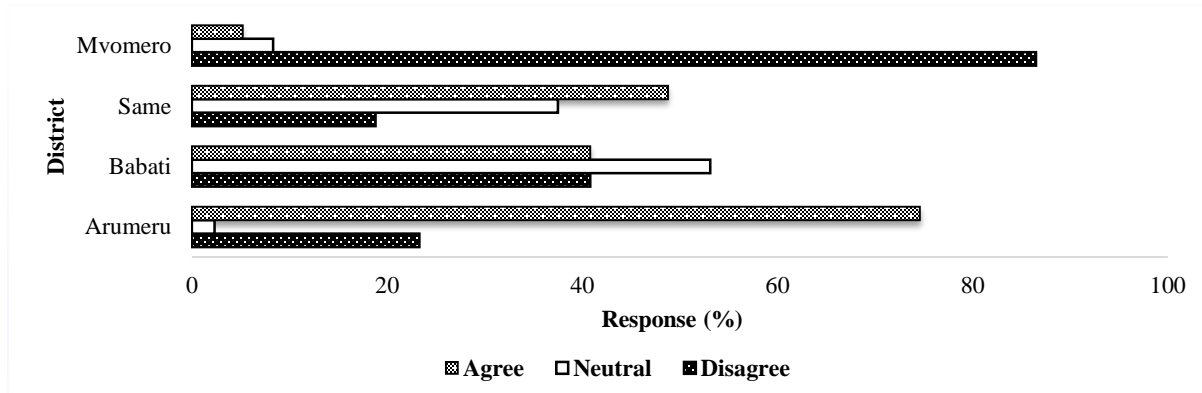
statistically significant level: \*\*\*  $p \leq 0.001$ ; \*\*  $p \leq 0.01$ ; \*  $p \leq 0.05$ , d=disagree; n =neutral; a = agree

**Figure 9: General farmers' attitudes on Lablab crop across the districts**



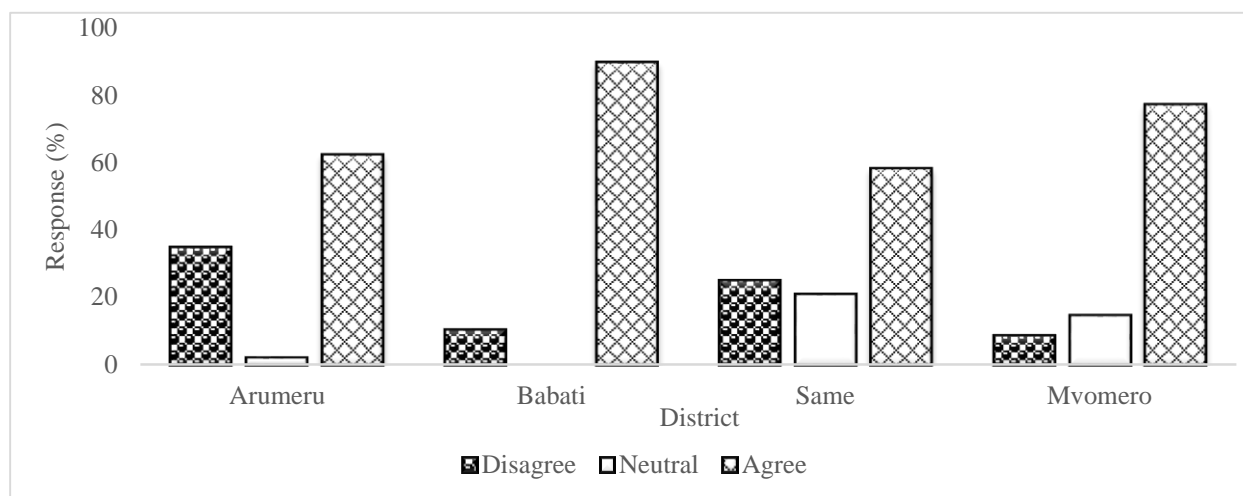
### (iii) Farmers' Practices

In comparison to Lablab beans consumptions, common beans were vehemently opposed (86.5%) in Mvomero, but preferred (74.8%) in Arumeru (Fig. 10). As shown in Table 10, black Lablab seeds are commonly cultivated (93.5%) in Arumeru compared to the non black seeds. The presence of characteristics such as black Lablab seeds taking a long time to prepare and cook, darkening food, and having a bitter taste is associated to their underutilization (Grotelüschen, 2014).



**Figure 10: Lablab consumption preference versus common bean consumption as determined by farmer choices in their districts**

On the other hand, findings revealed great preference in Lablab farming in comparison to common beans (Fig. 11). This is because the legume is drought resilient, and cultivation requires just one wedding, with no fertilizer application, and irrigation. In comparison to other legumes, the Lablab crop is the most drought-tolerant and green manure crop (Maass *et al.*, 2010). The crop root nodules can form a symbiotic connection with nitrogen-fixing soil bacteria (rhizobia) to convert atmospheric nitrogen into ammonia plants fertilizer (Grotelüschen, 2014; Maass *et al.*, 2010).



**Figure 11: Farmers' preferences for Lablab crop cultivation versus common beans varied by study district**

The agronomic potentials indicated that preference on Lablab's cultivation over common beans was of great interest (Fig. 11). Nord *et al.* (2020) and Same District Council (2018) reports

confirmed this, adding that Lablab beans generate more income. This implies that Lablab is more for agribusiness than agrifood, posing a challenge to their direct contribution to ending malnutrition (Shelef *et al.*, 2017) despite being among UNC that can enrich food systems (Kasolo *et al.*, 2019). Furthermore, traditional Lablab recipe identified by farmers such as *Loshoro* from Arumeru is becoming less popular (Mbise, 2020). Whereas *Kivuge/Chibote* from Mvomero was more popular consumed (Fig. 12).



**Figure 12: Frequency of consumption of foods made from Lablab in the farmers' households in the study districts**

This prompted an investigation into the reasons for variations in Lablab meal preference across the other study sites. The results on Table 14 show that black seeds have a darker color, a bitter taste, and take longer to cook than red, brown, cream, khaki, and white seeds. However, proper preparation and cooking make the beans edible (Raja *et al.*, 2014). Soaking beans overnight, then discarding the water and cooking the beans in fresh water reduces/removes the amount of anti-nutrient compounds and improves flavor (Grotelüschen, 2014). However, these practices were found to be tedious and unfavorable to farmers, contributing to a lower acceptance of black beans (Mbise, 2020). Regardless of the crop grown by smallholder farmers, Asians make up the majority of Lablab consumers in Tanzania (Pengelly & Maass, 2001).

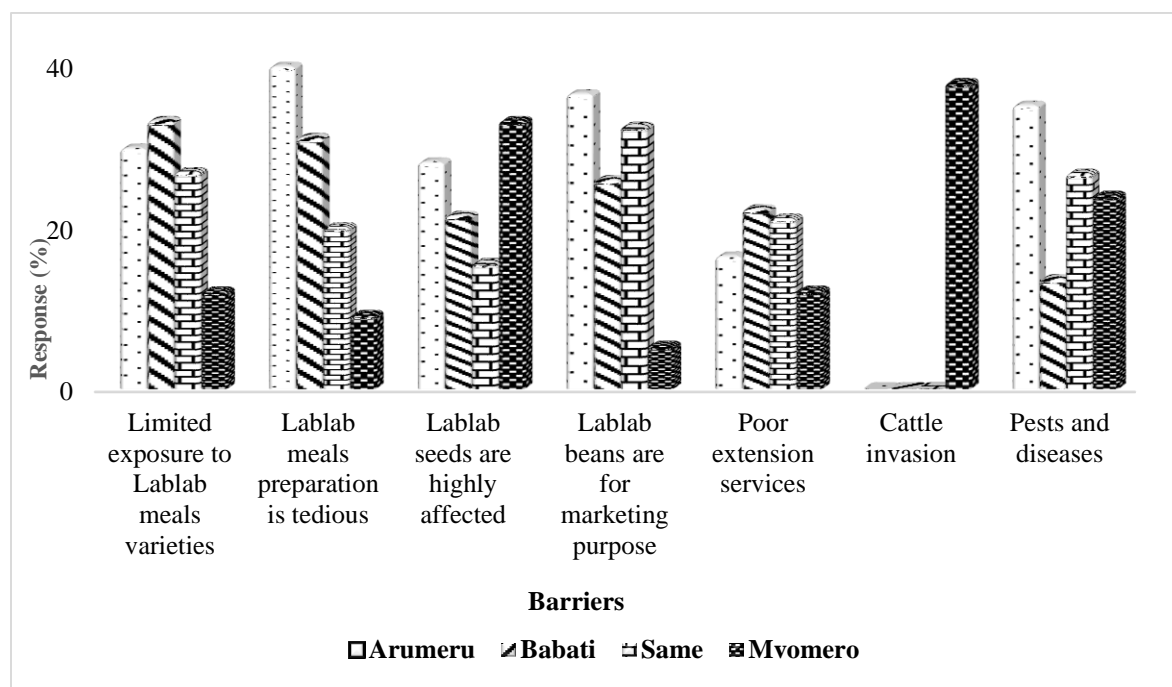
**Table 14: Attributes that contributed to the acceptability of cooked black Lablab accession**

| Variable       | District (%; n=344) |        |      |         | F-test     |
|----------------|---------------------|--------|------|---------|------------|
|                | Arumeru             | Babati | Same | Mvomero |            |
| <b>Colour</b>  |                     |        |      |         | 66.307***  |
| Unacceptable   | 55.8                | 20.8   | 3.1  | 1.0     |            |
| Neutral        | 23.3                | 36.5   | 14.6 | 5.2     |            |
| Acceptable     | 20.9                | 42.7   | 82.3 | 93.7    |            |
| <b>Smell</b>   |                     |        |      |         | 82.108***  |
| Unacceptable   | 52.3                | 62.5   | 9.4  | 1.0     |            |
| Neutral        | 17.4                | 26.0   | 42.7 | 24.0    |            |
| Acceptable     | 30.2                | 10.4   | 47.9 | 75.0    |            |
| <b>Texture</b> |                     |        |      |         | 53.740***  |
| Unacceptable   | 66.2                | 34.4   | 9.4  | 0.0     |            |
| Neutral        | 32.6                | 38.5   | 39.6 | 5.2     |            |
| Acceptable     | 1.2                 | 27.1   | 51.1 | 94.8    |            |
| <b>Taste</b>   |                     |        |      |         | 153.503*** |
| Unacceptable   | 45.4                | 85.4   | 33.3 | 0.0     |            |
| Neutral        | 53.5                | 11.5   | 37.5 | 16.7    |            |
| Acceptable     | 1.2                 | 3.1    | 29.2 | 83.4    |            |

Statistically significant level: \*\*\*P ≤ 0.001; \*\*P ≤ 0.01; \*P ≤ 0.05

#### 4.1.3 Barriers to the Utilization of Lablab Crop

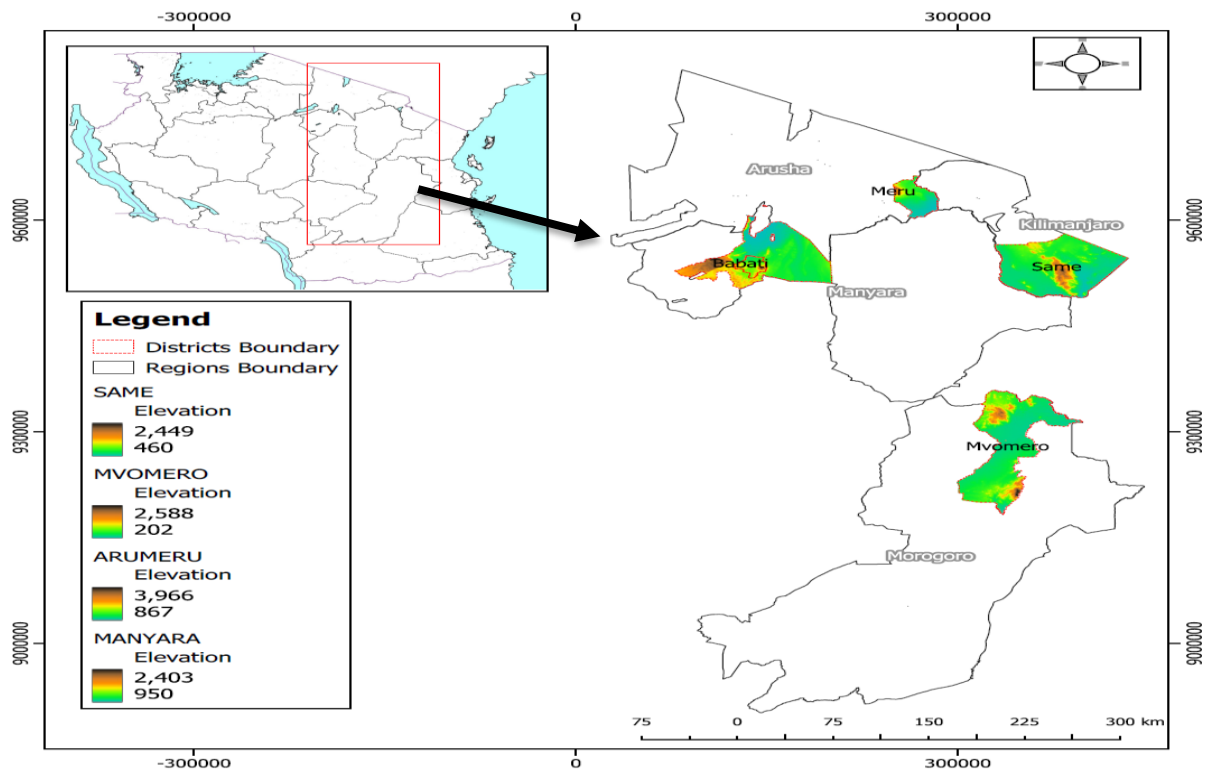
In the previous discussion, some of the factors which hinder Lablab eating were observed. To add up to Fig. 16, limited exposure to Lablab recipes was also identified across the study sites. Lablab crop in the form of green leaves, flowers, and green beans was not/less consumed. In some areas like Asian countries, they are consumed by human beings (Tyagi *et al.*, 2018; Grotelüschen, 2014). Lablab seeds were much affected by pod borers during storage compared to common beans. So, their immediate option was selling seeds after harvesting them at the farm gate. Similarly, Forsythe (2019) reported that farmers were selling Lablab seeds at the farm gate right after harvesting and little was left for either consumption or seeds for the next season. Cattle invasion, notably in Mvomero, was severe, affecting farmer productivity (Fig. 16). Overstocking by pastoralists has been observed to victimize farmer crops, resulting in conflicts that impact food security and livelihood, which necessity be resolved for better crop production and growers' livelihood.



**Figure 13: Based on the study district, farmers' responses to barriers to Lablab crop were identified**

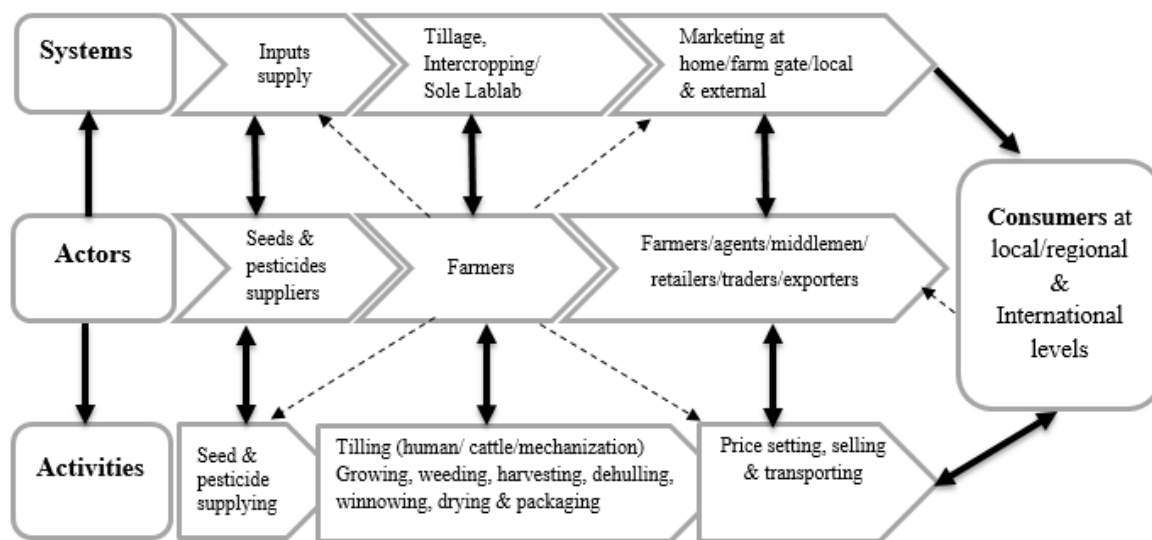
#### 4.2 Lablab Value Chain in Relation to Households' Livelihood\*

Recognized wisely in contributing to efforts to improve nutrition quality and livelihood, particularly among smallholder farmers (FAO *et al.*, 2020), mapping and value chain their crop should be widely focused on increasing consumption of nutritious foods and income (Grosso *et al.*, 2020; Ruel *et al.*, 2013). Crop mapping is among the approach for understanding agricultural production in detailing geographical and climate factors in a given location for better food sustainability, and income generation for smallholder farmers (Grosso *et al.*, 2020; Popoola *et al.*, 2019). According to Padulosi *et al.* (2013) and Venkatesha *et al.* (2007) crop maps are important datasets that contain precise and up-to-date imagery from a satellite-based radio-navigation system capable of displaying accurate data of interest. They been widely used globally for foods opportunities (Owenya *et al.*, 2011), understanding underutilized crops that yearly are available (Miah *et al.*, 2017; Arora, 2014; Venkatesha *et al.*, 2007), a driver to the rural economy in supporting smallholder farmers livelihood (FAO *et al.*, 2020).



**Figure 14: A map showing four agro-ecological zones for Lablab cultivation in Same, Mvomero, Arumeru, and Babati districts of Tanzania**

The Fig. 14 map shows that, in comparison to the other study sites, Arumeru had higher elevation areas, characterizing three agro-ecological zones: Highlands, midlands, and lowlands. The majority of Lablab was grown in the midlands and lowlands. Lablab farming in the midlands and highlands does have long harvesting times because the legumes do not dry all at once, and picking practices seem to be common. Furthermore, detailed Lablab production at various stages from farm to customer, a Lablab value chain (LVC) was established (Fig. 15). The LVC is composed of three channels of systems, actors, and activities based on the information collected in the study sites. The LVC is highly informal as it lacks integrated formal linkages, which is a characteristic of an underdeveloped value chain. Therefore, the LVC is characterized by systems, actors, and activities as detailed in sub-section 4.2.1 to 4.2.3.



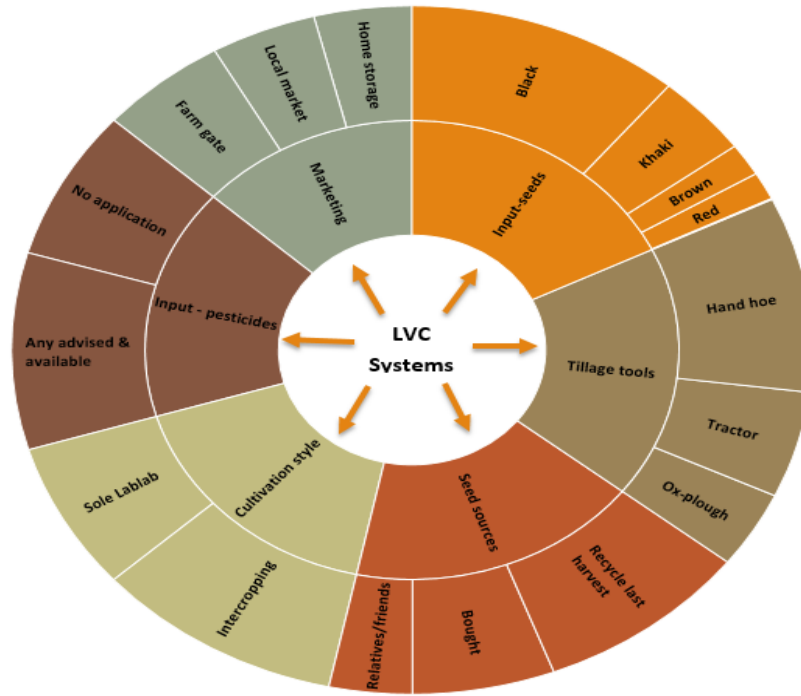
**Figure 15: The Lablab value chain mapping among Lablab growing districts in Tanzania**  
**Key:**

↔ Strong existing channels      - - - - -> Weak existing channels  
 → Normal existing channels

#### 4.2.1 The Lablab Value Chain Systems

Lablab's production system includes input supply, tillage, intercropping or sole, and marketing (Fig. 16). The input supply encompasses of seeds and pesticide suppliers. Primary the seed supply sources were from relatives/friends, buying from the local market, and recycling the last harvest, (Fig. 16). Usually, seeds were recycled (48.8%) from the previous harvests (Table 15). The black accession was the most cultivated seed in Arumeru (93.3%), Same (55.9%), Babati (53.8%), and Mvomero (45.9%) (Table 10). Compared to the khaki, brown, and red accessions, which were less grown, unfamiliar, and had low market value. According to Grotelüschen (2014), black seeds are well-marketed, and farmers are usually motivated by what is more important in terms of income generation (Morrison, 2019).

Pesticides are also used as inputs in Lablab farming in Tanzania. About 60.3% of interviewed farmers got advice and purchased available pesticides in agri-shops (Table 15). However, the pesticides and insecticides used for Lablab production were the same as those used for other crops. This implies the inability to control specific insect pests that affect the Lablab crop. Besides, the pesticide shops/suppliers were primarily located in urban and semi-urban areas, presenting accessibility challenges for farmers in remote areas (Shetto & Owenya, 2007). As a result, 61.4% of the interviewed farmers were worried about pesticide costs, and 39.8% were unable to use them during the 2020 farming season (Table 15). Insect and disease control is critical to ensuring profitable Lablab output because the crop is greatly affected by pests from planting to podding (Ewansiha *et al.*, 2017).



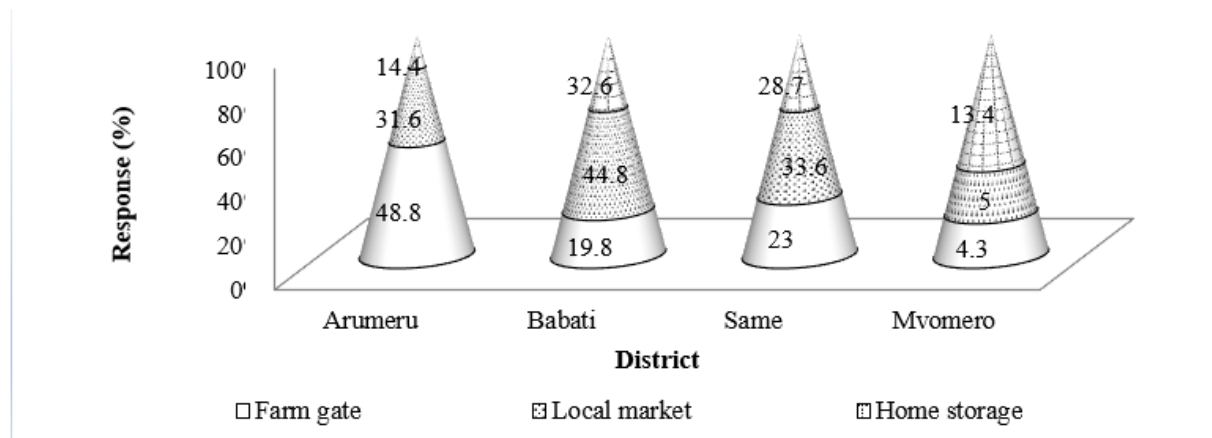
**Figure 16: The Lablab value chain systems wheel and their subdivision magnitude in Lablab crop growing districts in Tanzania**

The LVC on tillage systems were based on hand-hoes, ox-plows, and tractors (Fig. 16). In Mvomero (72.4%) and Same (52.4%) hand-hoe farming was most popular (Table 15). Results showed that human power was used substantially in agriculture, with mechanization being used less frequently (Table 15). Similarly, most smallholder farmers in Kenya tend to use hand hoes while the medium-sized landholders and large-scale farmers tend to employ oxen and tractors, respectively (Rusike *et al.*, 2013). One of the possible solutions for changing traditional agriculture practices is mechanized farming, which would enable smallholder farmers to participate in global value chains (Nájera, 2017). Both farming systems (sole and intercropping) statistically contributed to the farmers' livelihood ( $p \leq 0.01$ ), as per multiple linear regression (Table 18). The Lablab intercropping method was most widely utilized in Babati (73.3%) and Arumeru (67.4%), where staple crops such as maize were intercropped (Fig. 23). Similarly, maize and beans are often intercropped in Kenya (Rusike *et al.*, 2013) and other regions in Africa (Ewansiha *et al.*, 2016). Intercropping Lablab with other crops reduces tillage and save on labor (Shetto, & Owenya, 2007).

**Table 15: Inputs observed along the Lablab value chain in the study district**

| Variable<br>Inputs                    | Districts (%, n= 344) |        |      |         | Average<br>(%) |
|---------------------------------------|-----------------------|--------|------|---------|----------------|
|                                       | Arumeru               | Babati | Same | Mvomero |                |
| <b>Source of seeds</b>                |                       |        |      |         |                |
| Relatives/friends                     | 24.4                  | 5.8    | 10.5 | 34.9    | 18.9           |
| Recycle of last harvest               | 30.2                  | 76.7   | 38.4 | 50.0    | 48.8           |
| Buy                                   | 45.3                  | 17.4   | 51.2 | 15.1    | 32.3           |
| <b>Pesticides used</b>                |                       |        |      |         |                |
| Any advised and available             | 89.3                  | 67.3   | 68.2 | 12.9    | 60.3           |
| No application                        | 10.6                  | 32.9   | 31.9 | 88.4    | 39.8           |
| <b>Reasons not using pesticides</b>   |                       |        |      |         |                |
| They cause health problems            | 8.4                   | 9.1    | 0.0  | 5.1     | 5.7            |
| No specific pesticide for Lablab      | 36.1                  | 31.1   | 24.2 | 40.4    | 33.0           |
| They are costly                       | 55.4                  | 59.7   | 75.8 | 54.5    | 61.4           |
| <b>Where to get pesticides?</b>       |                       |        |      |         |                |
| Agrochemical shops                    | 82.7                  | 89.3   | 74.8 | 84.4    | 82.8           |
| Local markets                         | 17.3                  | 0.0    | 23.3 | 4.2     | 11.2           |
| Cooperative society                   | 0.0                   | 0.0    | 0.0  | 4.2     | 1.1            |
| Relative/friends                      | 0.0                   | 10.7   | 2.9  | 7.3     | 5.1            |
| <b>Cultivation tools/tillage used</b> |                       |        |      |         |                |
| Hand hoe                              | 44.4                  | 37.1   | 52.4 | 72.4    | 51.6           |
| Tractor                               | 26                    | 47.4   | 7.8  | 0.0     | 20.3           |
| Ox-plough                             | 29.5                  | 15.4   | 39.8 | 27.6    | 28.1           |

Lablab marketing system is another component in the LVC accomplished at either on the farm gate, local markets, or at home (Fig. 16). Farm gate selling was particularly common in the Arumeru district which entailed a sale of more than 40% of the produce (Fig. 17). Farm gate was highly preferred as it excluded transportation costs unlike selling in the distant local market which requires traveling to urban centers and markets once or twice every week. In the traditional local Lablab beans markets in the northern region included Hedaru, Kwasakwasa, Himo, Kikatiti, Ngaramtoni, and Mbauda. Most of the Lablab purchased from farmers exported to Kenya. Such external markets have largely motivated the Lablab farmers to expand their production for profits (Morrison, 2019).

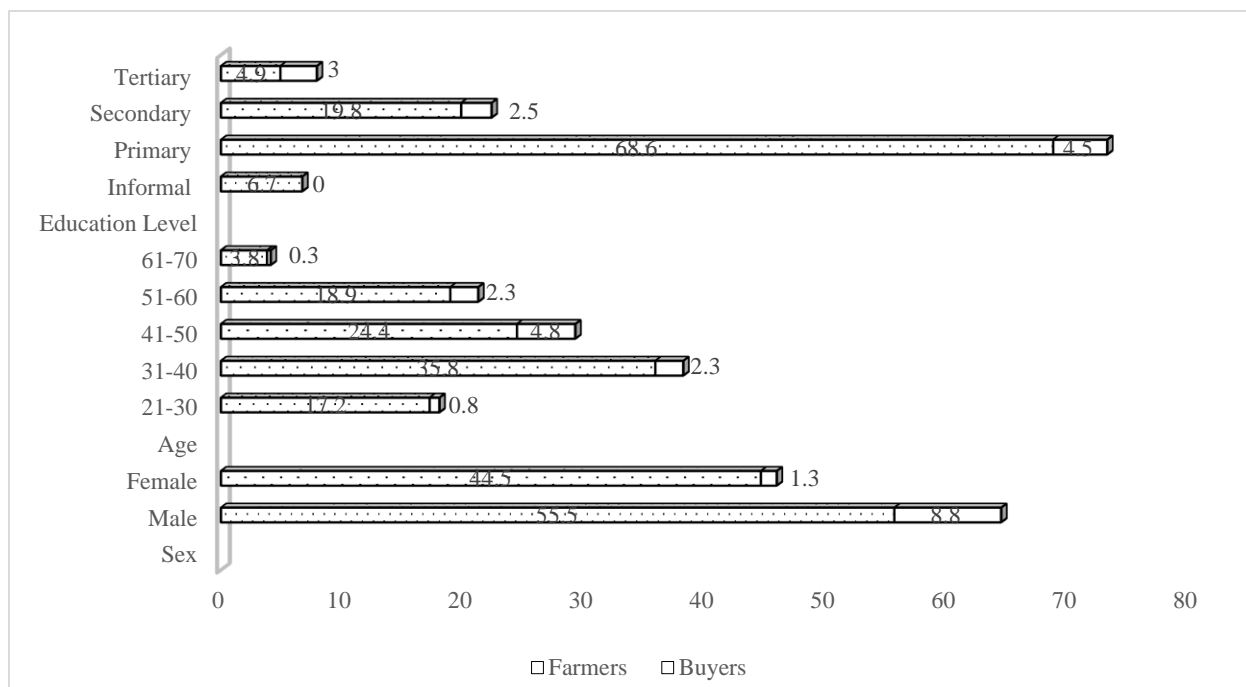
**Figure 17: Lablab marketing destinations where Lablab seeds are sold observed per the study district**



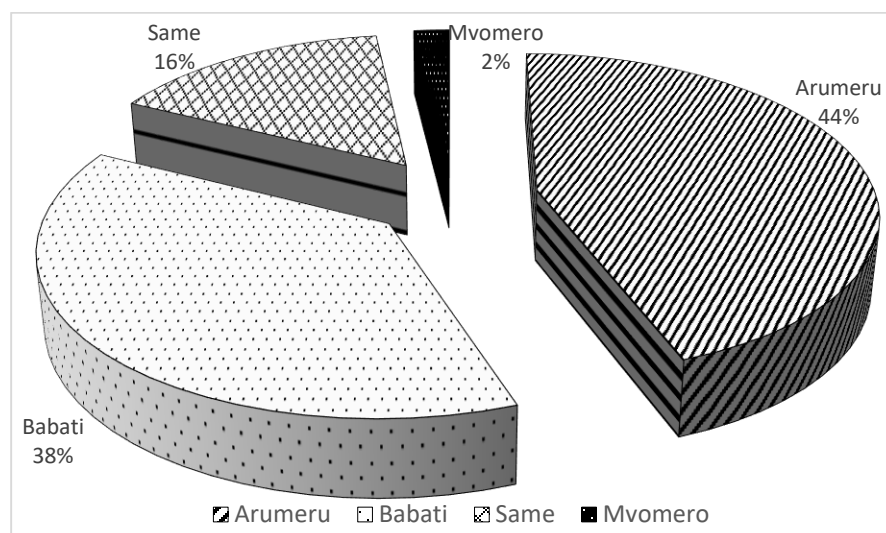
#### 4.2.2 The Lablab Value Chain Actors

Farmers, input suppliers, and traders/middlemen were the main actors in the LVC (Fig. 15). However, smallholder farmers were the major actors in Lablab production, taking part in a variety of activities along the value chain. According to Rusike *et al.* (2013) farmers usually engage in a variety of farming operations that help them to better their living conditions. Both gender played an important role in Lablab production (Table 10). For the input suppliers, none Agro-shops were found selling Lablab seeds. Further, no inorganic fertilizers supply since the crop has a higher ability to symbiosis with nitrogen-fixing bacteria, that enriches the soil (Popoola *et al.*, 2019).

Traders were key on LVC's marketing system. Noteworthy, traders were synonymously referred to buyers, agents, middlemen, and retailers. In Babati, the same scenario was recorded in a sunflower value chain (Larsson, 2018). In the LVC, traders were middlemen between farmers (producers) and retailers or consumers (Fig. 15). Moreover, the traders acted as agents for internal (farm gates/local) and external Lablab markets as well as input providers to the farmers. These findings revealed that traders' participation in Lablab marketing varied (Fig. 19), and was related to market reliability, particularly consistency of external market (Nord *et al.*, 2020; Forsythe, 2019). Most of the traders were young men (Fig. 18) capable of engaging in a variety of business activities (Darnhofer & Vienna, 2016). This study confirmed that farmers' markets are still dominated by traders playing a middle men mainly for price bargaining, leaving the farmers (Darnhofer & Vienna, 2016; Eskola, 2005) with no power on selling market hence selling their produce below-market price. Purchasing Lablab at the farm gate immediately after harvesting (Fig. 17) accounted for the low prices preferred by traders (Eskola, 2005). Consequently, majority of farmers were reaping low value from their produce due to poor bargaining capacity resulting in unfavorable prices (Larsson, 2018). Similarly, in developing countries, where transportation and communication systems are unreliable, farmers are pushing to sell their produce to middlemen or nearby local markets, at low price resulting in less income gain for livelihood improvement (Fan & Rue, 2020).



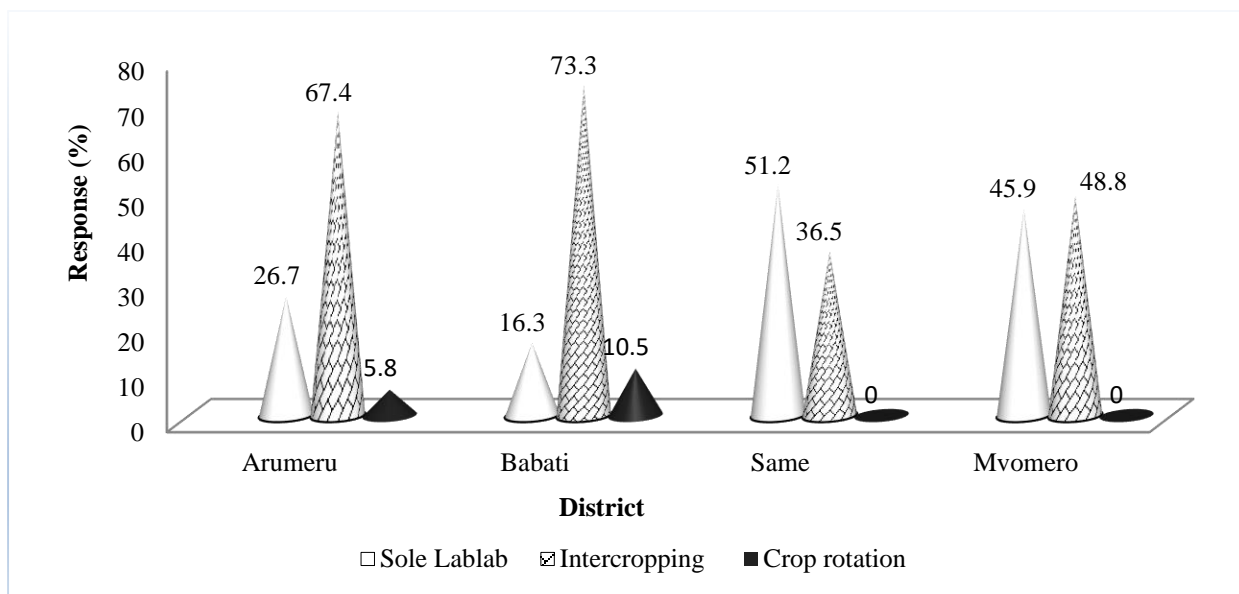
**Figure 18: Demographic characteristics of the LVC actors; farmers (n=344) and buyers (n=40)**



**Figure 19: Buyers' market involvement at the study the sites (n=40)**

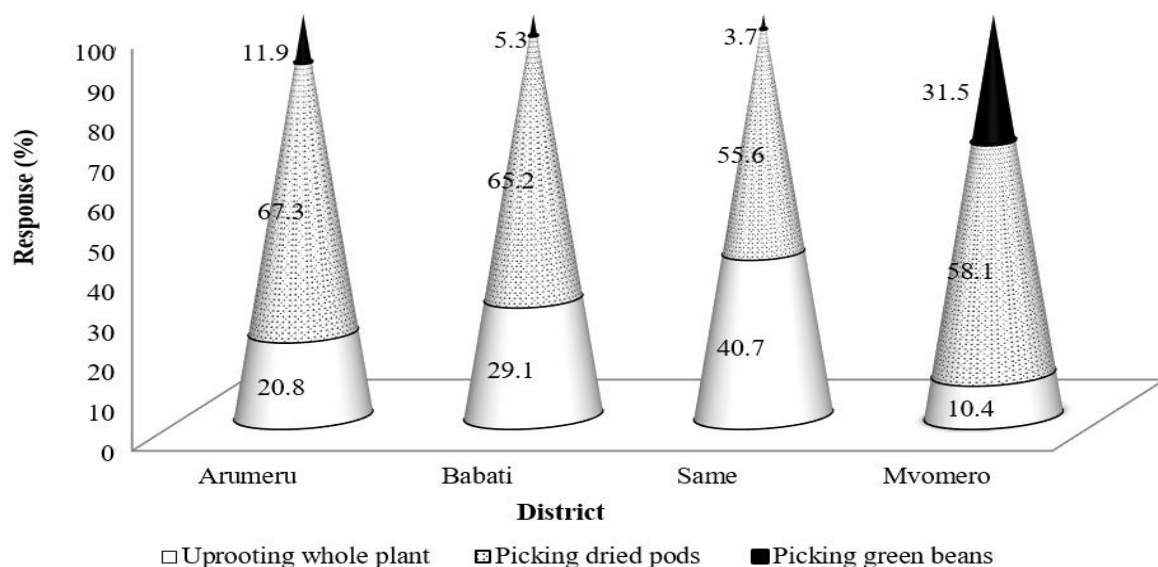
#### 4.2.3 The Lablab Value Chain Activities

Planting includes sole or intercropping seeding (Fig. 20). Small-scale farming used intercropping, whereas large-scale farming used solitary cropping. To reduce entanglement, Lablab seed was planted two to three weeks after staple maize germination (approximately 15 cm maize length). When climbing legumes like Lablab and Velvet are planted at the same time, they obstruct the physiological growth of cereal crops (Nord *et al.*, 2020; Mthembu *et al.*, 2017; Dahmardeh *et al.*, 2009; Eskandari *et al.*, 2009).



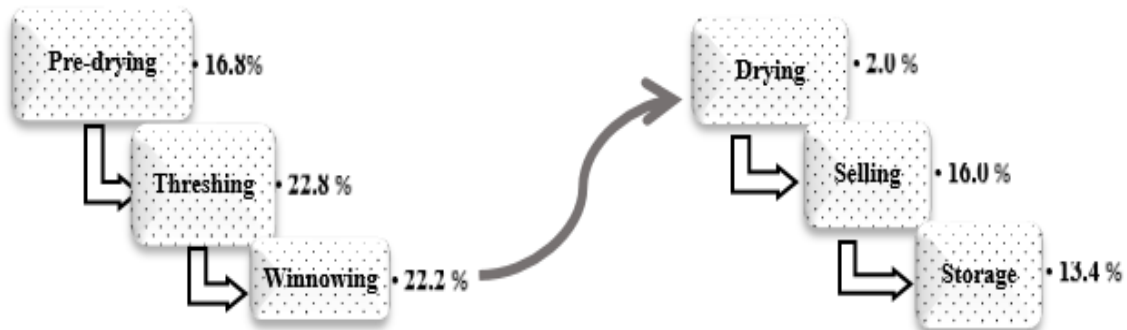
**Figure 20: Varied Lablab farming systems were found across the study sites**

Lablab weeding was recorded to require less labor because it is a cover crop with weeding costs reduction and significant labor savings (Silva & Delate, 2017), soil erosion reduction, evaporation (Silva & Delate, 2017; Shetto & Owenya, 2007) and biomass increases for livestock fodder (Mthembu *et al.*, 2017). Lablab harvesting is done manually by either picking the green beans and dry pods or uprooting the entire plant (Fig. 21). Harvesting by picking dry pods was common in Arumeru (67.3%) and Babati (65.2%) districts (Fig. 21). Owing to genetic and environmental conditions, Lablab beans do not dry all at once, making harvesting by picking up dry pods twice/thrice tiresome and costly (Cullis & Kunert, 2017; Kimani *et al.*, 2012). A casual laborer for harvesting costs TZS 1500 (about US\$ 0.64) every day or TZS 5000 (US\$ 2.16) per sac, thus increasing the cost of harvesting. According to Grotelüschen (2014), Lablab harvesting is a very expensive, laborious, and time-consuming activity.



**Figure 21: Harvesting procedures for Lablab crop as observed across the study sites**

Post-harvest processing and storage practices were noted to be varied (Fig. 22). After drying, the harvested Lablab was immediately sold at the farm gate/local market/collection center (Plate 6 and 7). Storage was less preferred because bruchid beetles caused significant damage. Pengelly and Maass (2001) reported that these insects cause significant damage to Lablab beans, necessitating careful storage measures.



**Figure 22:** Post-harvest handling of lablab seeds; pre-drying or not, threshing, winnowing, drying, and storage



**Plate 6:** Lablab beans collection center at a local market in Ngaramtoni juu at Arusha region



**Plate 7: Lablab beans weighed, and packed ready for transportation to the local market**

#### **4.2.4 Lablab Value Chain and Farmers' Household Livelihood**

Lablab production benefited the farmers considerably (Tables 16 and 17). Lablab was grown even in semi-arid areas as observed in the Same district (Same District Council, 2018). Lablab is considered a climate-smart crop and has been reintroduced in Tanzania to provide additional income to smallholder farmers due to its ability to withstand climate challenges such as unreliable rainfall (Forsythe, 2019; Grotelüschen, 2014; Shetto & Owenya, 2007). The participation of farmers in Lablab production supported their families in a variety of ways. In the context of livelihood assets (Rick de Satgé *et al.*, 2002), benefits resulting from Lablab production are described in sub-sections with their contribution to the smallholder farmer's lives.

Land and livestock ownership is tangible natural resources that can make a difference in the life of a farmer (Table 16). They are owned by Lablab growers as natural assets for their livelihood, which contributed to increased income, job opportunities, food/fodder, and soil conservation (Table 17). Natural assets contributed 70% of the total score per asset (Fig. 23). Farmers increased the rate of food production on a single plot of land by using an intercropping system (Mthembu *et al.*, 2017; Shetto & Owenya, 2007; Bwalya, 2005). Lablab leaves were cattle fodder that improved

milk output (Aganga & Tshwenyane, 2003), and it was an organic fertilizer that improved their farms (Popoola *et al.*, 2019; Owenya *et al.*, 2011). In general, Lablab cultivation had statistically significant effects on farmers' livelihoods at  $p \leq 0.05$  and  $p \leq 0.01$ , respectively (Table 18).

**Table 16: Developed indicators (DI), with definitions and expected relationships**

| Livelihood assets      | DI                              | Definition   | Reference   | Expected relationships in the farmers' household                                      |
|------------------------|---------------------------------|--|---|---|
| <b>Natural asset</b>   | Land and/or Livestock ownership | Land owned for agriculture                                   | Khatiwada <i>et al.</i> (2017)                                    | Agricultural activities; Collateral   |
|                        |                                 | Value of livestock and their products                        | Neudert <i>et al.</i> (2020) and Van Wijk <i>et al.</i> (2020)    | A resource flow to various dimension of living  |
| <b>Human asset</b>     | Education                       | Schooling years  | Neudert <i>et al.</i> (2020)                                      | Competence (knowledge & skills).  |
|                        | Farming experience              | Number of years involved in farming                          | Kraaijvanger <i>et al.</i> (2016)                                 | More skills and knowledge.  |
|                        | Training/Advice                 | Participation on training/advice related to agriculture      | Huang <i>et al.</i> (2015) and Rick de Satgé <i>et al.</i> (2002) | More exposure to farming activities   |
|                        | Family size                     | Total household members                                      | Khatiwada <i>et al.</i> (2017)                                    | Bigger family size of working age are of beneficial                                   |
| <b>Physical asset</b>  | Production tools                | Availability of production tools                             | Rick de Satgé, <i>et al.</i> (2002)                               | Expected to follow commercial agriculture/Simplify farming activity.                  |
|                        | Transport facilities            | Transportation capability                                    | Seville <i>et al.</i> (2011)                                      | Ease goods transportation.  |
|                        | Household and its goods         | Counted valued non-agricultural assets resulted from farming | Rick de Satgé <i>et al.</i> (2002)                                | Expected to add more worth to the household.  |
|                        | Access to market                | Distance in kilometer/s to nearest market                    | Rick de Satgé <i>et al.</i> (2002)                                | Closer to the market/passable roads simplify marketing.                               |
|                        | Agricultural inputs             | Access and affordable  | Van Wijk <i>et al.</i> (2020)                                     | Improve production hence commercialization  |
| <b>Social Asset</b>    | Social support Friend/relatives | Ways of supporting to each other                             | Østerberg <i>et al.</i> (2013)                                    | Relationships of trust draw people on profitable farm and non-farm activities.        |
|                        | Communication (networks)        | Communication facilities                                     | Khatiwada <i>et al.</i> (2017)                                    | Social resources networks updated shared information.                                 |
| <b>Financial Asset</b> | Income from Lablab production   | Money collections from Lablab business.                      | Seville <i>et al.</i> (2011)                                      | Financial resources from Lablab farming contribution to different livelihood options. |
|                        | Income not from Lablab          | Collection from other sources                                | Khatiwada <i>et al.</i> (2017)                                    | More addition to livelihood activities.   |

Human assets are intangible assets such as the ability to work, household labor-power, knowledge, and skills acquired over generations to improve living and search for more opportunities (FAO & ILO, 2009). The Lablab farming experience was related to farmer age, and the older farmers were more knowledgeable and experienced (Table 17). Through training platforms, farmers can gain access to a broader range of information, such as crop improvement for FNS (Tefera, 2006). Also, farmers sought advice primarily from their elder parents/relatives or other more experienced farmers. Human assets also considered the family size and gender (Table 10), both showed a statistical ( $p \leq 0.05$ ) influence in Lablab farming (Table 18). Bwalya (2005) observed similar gender participation in Lablab farming. Collectively, human assets contributed about 50% of the farmers' livelihood by average score per asset (Fig. 23).

**Table 17: Developed indicators from LVC used to measure farmers' household livelihood assets**

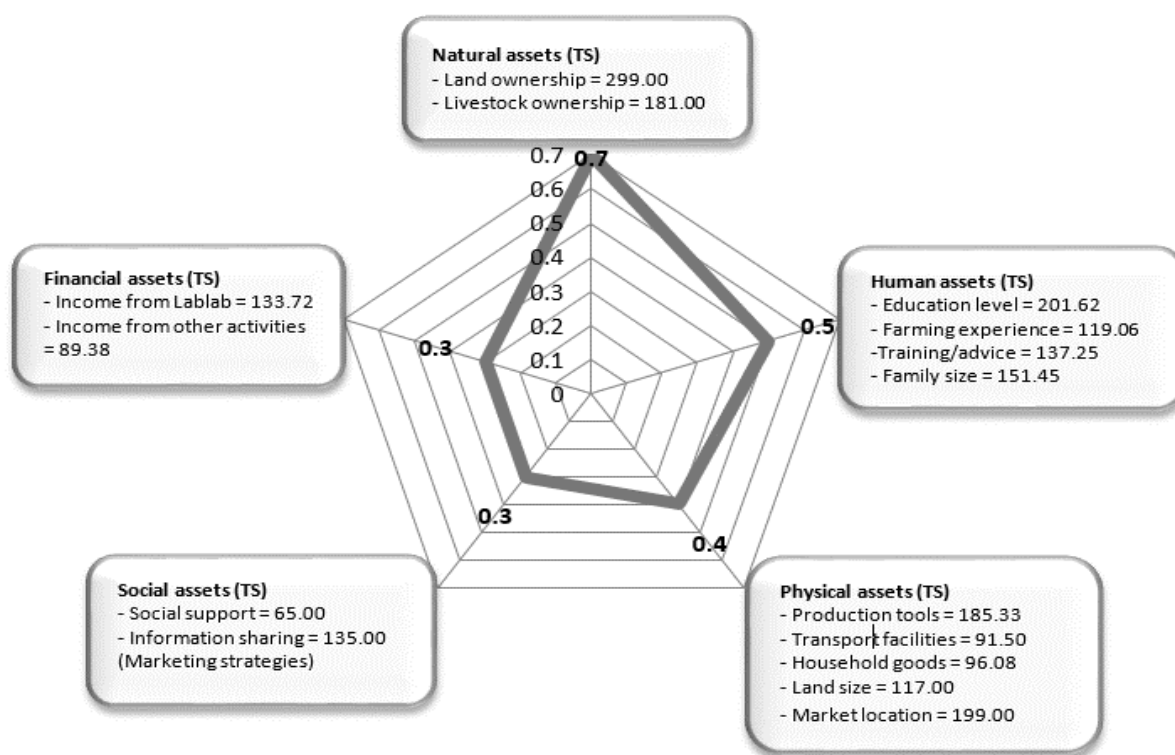
| Livelihood asset categories | Indicator                                 | Total scores (n= 344) | Average score per indicator | Total average scores per asset category | Average score per asset category |
|-----------------------------|---|-----------------------|-----------------------------|---|----------------------------------|
| <b>Natural asset</b>        | (a) Land ownership                        | 299.00                | 0.87                        | 1.40                                    | 0.70                             |
|                             | (b) Livestock ownership                   | 181.00                | 0.53                        |   |                                  |
| <b>Human asset</b>          | (a) Education                             | 201.62                | 0.59                        | 1.78                                    | 0.45                             |
|                             | (b) Farming experience                    | 119.06                | 0.35                        |   |                                  |
|                             | (c) Training/Advice                       | 137.25                | 0.40                        |   |                                  |
|                             | (d) Family size                           | 151.45                | 0.44                        |   |                                  |
| <b>Physical asset</b>       | (a) Production Tools                      | 185.33                | 0.54                        | 2.01                                    | 0.40                             |
|                             | (b) Transport facilities                  | 91.50                 | 0.27                        |   |                                  |
|                             | (c) House and its goods                   | 96.08                 | 0.28                        |   |                                  |
|                             | (d) Distance to the nearest market        | 117.00                | 0.34                        |   |                                  |
|                             | (e) Usage of Pesticides                   | 199.00                | 0.58                        |   |                                  |
| <b>Social Asset</b>         | (a) Social support from Friends/Relatives | 65.00                 | 0.19                        | 0.58                                    | 0.29                             |
|                             | (b) Communication to networks             | 135.00                | 0.39                        |   |                                  |
| <b>Financial Asset</b>      | (a) Income from Lablab                    | 133.72                | 0.39                        | 0.65                                    | 0.33                             |
|                             | (b) Income from other activities          | 89.38                 | 0.26                        |   |                                  |
| <b>Total</b>                |   |                       |                             |   | <b>0.43</b>                      |

Farmers' families benefitted from financial assets, or capital/income from Lablab production, as well as job opportunities (Table 16). Smallholder farmers were enticed to invest in the Lablab business due to the potential export market (Forsythe, 2019), and it was regarded as a cash crop (Same District Council, 2018). Lablab contributes to farmers' livelihood on a season-by-season basis (Table 18), and financial assets account for approximately 30% of a farmer's income among the five livelihood assets (Fig. 23). Household goods purchased/improved from Lablab earnings were considered as physical assets (Table 16). The income allowed the farmers to repair or build or furnish their homes, buy cell phones, and motorcycles (*boda-boda*). Farmers who owned *boda-bodas* provided transportation services while also increasing their family's income statistically observed in Table 18, and physical assets accounted for roughly 40% of farmers living (Fig. 23). Gathering multiple indicators from a broader perspective in agricultural aspects related to rural livelihoods could reveal detailed data such as income, food security, and poverty relations for future improvement of smallholder farmers' living conditions (Van Wijk *et al.*, 2020).

Social assets linked Lablab farmers to a variety of social networks. Social networks are critical components of agricultural systems (Darnhofer & Vienna, 2016). From Fig. 23, social assets contributed about 30% of farmers' livelihoods. Even though social assets are important tools for



connecting farmers to social groups, and credit and savings organizations (FAO & ILO, 2009), the results in this category are less supported.



**Figure 23:** Livelihood assets spider pentagon representing the average score per asset category: Calculated from the total scores (T. S.) of each developed indicator based on farmers' households' characteristics (Rick de Satgé *et al.*, 2002)

**Table 18:** Relationship between the livelihood index and social economic factors

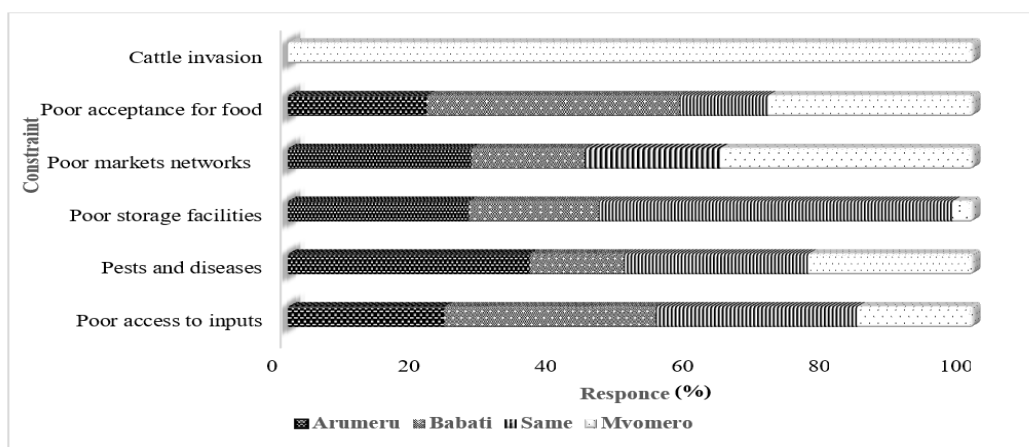
| Variable          | Coefficient | Standard Error | P-value | 95% Conf. Interval |       |
|-------------------|-------------|----------------|---------|--------------------|-------|
| Sex               | 0.145*      | 0.063          | 0.023   | 0.020              | 0.269 |
| Age               | 0.012***    | 0.003          | 0.000   | 0.006              | 0.018 |
| Marital status    | 0.057       | 0.039          | 0.147   | -0.020             | 0.134 |
| Farm size         | 0.042*      | 0.019          | 0.029   | 0.004              | 0.080 |
| Seed sources      | 0.081*      | 0.039          | 0.038   | 0.005              | 0.157 |
| Farming style     | 0.130**     | 0.038          | 0.001   | 0.055              | 0.206 |
| Harvesting style  | 0.059       | 0.070          | 0.400   | -0.079             | 0.197 |
| Season harvest    | 0.065**     | 0.021          | 0.002   | 0.023              | 0.107 |
| Sell destinations | 0.320***    | 0.036          | 0.000   | 0.249              | 0.392 |
| Farm gate         | 0.106**     | 0.035          | 0.003   | 0.366              | 0.176 |
| Number of obs.    | 344         |                |         |                    |       |
| F (11, 333)       | 360.25      |                |         |                    |       |
| Prob > F          | 0.0000      |                |         |                    |       |
| R-squared         | 0.9225      |                |         |                    |       |
| Adj R-squared     | 0.9199      |                |         |                    |       |
| Root MSE          | 0.61273     |                |         |                    |       |

Statistically significant level: \*\*\*P ≤ 0.001; \*\*P ≤ 0.01; \*P ≤ 0.05

To summarize, Lablab farming was critical in improving smallholder lives, moreover several barriers inhibited crop improvement. Figure 24 displays the major impediments to Lablab cultivation in the study districts. Cattle invasion, for example, was the most severe in the Mvomero district, due to pastoralists' illegal cattle grazing on the farms. Also, farmers' income was reduced



due to a lack of unreliable markets for Lablab beans. Poorly organized and non-coordinated crop market linkages can result in high operating costs, volatile costs, unrealistic markets, and lower farmer returns (Rusike *et al.*, 2013). Thus, immediate and long-term solutions in Lablab production are required to improve the livelihoods of smallholder farmers (Darnhofer, 2020).



**Figure 24: Constraints to the Lablab production as summarized across the Lablab producing districts in Tanzania**

### 4.3 Physicochemical Characteristics of Lablab Seeds

#### 4.3.1 Physical Characteristics

Results in Table 19 demonstrate a Lablab accessions based on color and weight. For each accession 100 randomly selected seeds with an average weight of 25 – 35 g. No noticeable difference in length amongst the accessions, except for ELD K2 and D-104, with 13.02 mm and 13.07 mm, respectively. The D-394 (8.13 mm) and HA-4 (9.00 mm) accessions had the shortest lengths and the smallest widths of 5.00 mm and 5.05 mm, respectively. Except for two HA-4 and D-422, the thickness of the majority of the accessions was greater than 5.00 mm. According to Dobrzański and Stepniewski (2013), understanding seed physical properties is useful in finding high-quality seeds and food processing methods. Moreover, Appleton *et al.* (2021) stated that knowing physical qualities is advantageous in modifying food products for increased promotion and development of newer products in the food chain. The physical characteristics observed were also in line with the Lablab varieties grown in Kenya (Kilonzi, 2020).

**Table 19: Physical properties of the seeds**

| Accession | Colour | Seed weight 100 seeds (g) | Length (mm)        | Width (mm)        | Thickness (mm)      |
|-----------|--------|---------------------------|--------------------|-------------------|---------------------|
| D-422     | Black  | 34.93 <sup>a</sup>        | 10.38 <sup>d</sup> | 7.05 <sup>a</sup> | 5.02 <sup>e</sup>   |
| D-397     | Black  | 29.08 <sup>b</sup>        | 9.89 <sup>e</sup>  | 5.89 <sup>c</sup> | 5.1 <sup>e</sup>    |
| D-394     | Black  | 25.10 <sup>e</sup>        | 8.05 <sup>f</sup>  | 5.01 <sup>d</sup> | 4.35 <sup>f</sup>   |
| D-419     | Black  | 29.24 <sup>b</sup>        | 10.01 <sup>c</sup> | 7.02 <sup>a</sup> | 6.79 <sup>d</sup>   |
| D-360     | Black  | 29.01 <sup>b</sup>        | 10.01 <sup>c</sup> | 6.62 <sup>b</sup> | 7.02 <sup>bcd</sup> |
| ELD K2    | Black  | 34.40 <sup>a</sup>        | 13.02 <sup>a</sup> | 7.11 <sup>a</sup> | 7.4 <sup>bc</sup>   |
| D-287     | Brown  | 29.04 <sup>b</sup>        | 11.09 <sup>c</sup> | 7.03 <sup>a</sup> | 7.51 <sup>ab</sup>  |
| D-104     | Brown  | 28.50 <sup>c</sup>        | 13.03 <sup>a</sup> | 7.10 <sup>a</sup> | 6.93 <sup>cd</sup>  |
| HA-4      | Brown  | 27.02 <sup>d</sup>        | 8.97 <sup>f</sup>  | 5.02 <sup>d</sup> | 5.01 <sup>e</sup>   |
| D-96      | Red    | 34.69 <sup>a</sup>        | 12.01 <sup>b</sup> | 7.27 <sup>a</sup> | 7.93 <sup>a</sup>   |

Mean value (n = 3) ± SD. Means with different superscript letters within a column are significantly different p < .05.

### 4.3.2 Proximate Compositions

Results on the proximate composition which include moisture, protein, ash, fats, and carbohydrates are presented in Table 20. The moisture content ranged from 8 -13.42% with D-96 showing the highest (13.42%) and D-104 (8.0%) had the lowest moisture level. Moisture content evaluation allows for more accurate estimates of storage life and seed quality. Depending on the seed variety and physical parameters, harvested beans can be dried to 16.5% moisture and stored for long periods at 15.5% moisture or less, however, seeds with a moisture content of 6% have the highest strength (Dobrzański & Stępniewski, 2013). It should be noted that rapid changes in moisture during seed drying can cause shrinkage or broken seeds since they depend on their moisture content (Dobrzański & Stępniewski, 2013). Similar findings on moisture suitable for longer preservation among Lablab accessions has been reported (Davari & Kasture, 2018). Likewise, the moisture content is an important parameter for seed quality since it can cause deformations in the shape of the seed, resulting in lower acceptance by consumers hence, a lower income value for farmers' livelihood.

The protein content ranged of 23% – 28% with D-422, D-104, and D-394 exhibiting considerably higher levels than the other accessions (Table 20). There was no major difference in the amounts of proteins in most of the accession except HA-4 (23.5%) low in comparison to the other accessions. Moreover, Davari and Kasture (2018) documented that the seeds are good sources of plant protein, particularly in low-income households. Therefore, Lablab bean is considered a poor man's meat. The study suggests that the accessions with the highest protein content (some presented in Table 4) be submitted to seed breeders for further replication in order to improve farmers' nutritional quality and livelihoods.

**Table 20: The proximate composition of Lablab accessions**

| Accessions | Moisture content   | Crude protein      | Ash content       | Crude fat         | Carbohydrate       |
|------------|--------------------|--------------------|-------------------|-------------------|--------------------|
| D-422      | 8.24 <sup>d</sup>  | 28.13 <sup>a</sup> | 3.91 <sup>c</sup> | 1.01 <sup>d</sup> | 59.09 <sup>d</sup> |
| D-397      | 8.01 <sup>e</sup>  | 25.03 <sup>d</sup> | 3.92 <sup>c</sup> | 2.01 <sup>b</sup> | 60.10 <sup>c</sup> |
| D-394      | 10.03 <sup>c</sup> | 27.18 <sup>b</sup> | 4.30 <sup>a</sup> | 2.04 <sup>b</sup> | 56.45 <sup>f</sup> |
| D-419      | 8.92 <sup>d</sup>  | 24.50 <sup>e</sup> | 4.09 <sup>b</sup> | 0.98 <sup>d</sup> | 61.00 <sup>a</sup> |
| D-360      | 10.01 <sup>c</sup> | 24.03 <sup>f</sup> | 3.80 <sup>d</sup> | 2.24 <sup>a</sup> | 59.00 <sup>d</sup> |
| ELD-K2     | 9.80 <sup>cd</sup> | 23.60 <sup>f</sup> | 3.93 <sup>c</sup> | 2.06 <sup>b</sup> | 59.60 <sup>d</sup> |
| D-287      | 12.03 <sup>b</sup> | 25.00 <sup>d</sup> | 3.32 <sup>e</sup> | 2.02 <sup>b</sup> | 56.60 <sup>f</sup> |
| D-104      | 8.00 <sup>e</sup>  | 27.22 <sup>b</sup> | 4.11 <sup>b</sup> | 2.01 <sup>b</sup> | 58.66 <sup>e</sup> |
| HA-4       | 10.70 <sup>c</sup> | 23.05 <sup>g</sup> | 3.62 <sup>d</sup> | 1.82 <sup>c</sup> | 60.33 <sup>b</sup> |
| D-96       | 13.42 <sup>a</sup> | 25.27 <sup>c</sup> | 3.39 <sup>e</sup> | 1.96 <sup>c</sup> | 56.15 <sup>f</sup> |

Mean value (n = 3) ± SD. Means with different superscript letters within a column are significantly different p < .05. The results were expressed in g/100g DW (dry weight)

The ash content was found to range between 3.00% and 4.30% across all accessions (Table 20). The ash level in seeds is an important parameter in the assessment of nutritional quality and an indicator of mineral content as part of proximate analysis for nutritional evaluation. According to Davari and Kasture (2018), increased ash level correlates with mineral richness in plant food. On the other hand, the fat content was less than 2.5%, with the lowest fat content in D-419. The results are in line with those from Kilonzi (2020), Morrison (2019), Davari and Kasture (2018) and Hossain *et al.* (2016). In addition, according to Hossain *et al.* (2016), Lablab seeds receive little attention locally, despite the fact that they are thought to contain essential two types of polyunsaturated fats (PUFAs) of omega-3 and omega-6 fatty acids, which are good sources of food quality. Foods high in PUFAs have been linked to lower risks of heart disease and stroke.

The carbohydrate content found to have significantly higher amounts of energy above 50% (Table 20). The accession D-419 (61.00%) had significantly superior carbohydrate content in comparison to the other accessions (Table 20). Other studies, such as Kilonzi *et al.* (2017), Kamatchi *et al.* (2010) and Davari *et al.* (2018), found compatible results. Carbohydrates in legume seeds are considered to have unique properties such as high temperature stability when compared to similar cereal or tuber starch depending on the legume species, but only a few of these seeds have been investigated (Tsaju & Yanou, 2021). Proper understanding of carbohydrates in different accessions of legumes could play an essential role in food industries which would improve food quality and framers' livelihoods as they make good market in food industries.

### 4.3.3 Mineral Content

Finding from Table 21 presented the mineral quantities for the accessions of Magnesium (Mg), Iron (Fe), Silicon (Si), Calcium (Ca), Cupper (Cu) and Zinc (Zn). Magnesium was found to be statistically significant higher in D-104 (135.0±5.0 mg/100 g, p<0.05) and D-397 (121.4±4.2 mg/100 g, p<0.05) compared to the other accessions. Iron was present all accessions, being highest in D-96 (16.1±0.1 mg/100 g, p<0.05). Silicon in D-303 (38.4±0.7 mg/100 g, p<0.05), Phosphorus

in D-96 ( $429.8 \pm 4.1$  mg/100 g,  $p < 0.05$ ) and HA-4 ( $439.1 \pm 7.2$  mg/100 g,  $p < 0.05$ ). Whereas Ca had no significant difference among the accessions noted. Copper level was significantly high in D-303 ( $0.74 \pm 0.02$  mg/100 g,  $p < 0.05$ ) and D-96 ( $0.81 \pm 0.02$  mg/100 g,  $p < 0.05$ ). There was no statistically significant difference in the level of Zn among the accessions. The mineral content of the different accessions was rich, as previously reported by Kilonzi (2020), Morrison (2019), and Davari and Kasture (2018). Minerals are necessary for good health, and each mineral performs a specific set of functions in the human body (Vidigal *et al.*, 2018; Cullis & Kunert, 2017).

**Table 21: Mineral contents in Lablab accessions (mg/100 g)**

| Lablab accessions | Mg                | Fe                  | Si               | Ca               | Cu                | Zn              |
|-------------------|-------------------|---------------------|------------------|------------------|-------------------|-----------------|
| D-422             | $92.0^b \pm 4.8$  | $10.0^b \pm 0.2$    | $1.3^d \pm 0.1$  | $17.8^d \pm 0.4$ | $0.53^d \pm 0.04$ | $2.0^b \pm 0.1$ |
| D-397             | $121.4^a \pm 4.2$ | $11.0^b \pm 0.3$    | $1.3^d \pm 0.0$  | $21.0^b \pm 0.4$ | $0.67^b \pm 0.02$ | $1.9^b \pm 0.0$ |
| D-394             | $81.0^c \pm 3.1$  | $15.1^a \pm 0.4$    | $21.7^b \pm 2.8$ | $23.2^b \pm 1.3$ | $0.59^c \pm 0.04$ | $2.2^b \pm 0.1$ |
| D-419             | $86.3^c \pm 5.7$  | $12.5^{ab} \pm 0.5$ | $1.1^d \pm 0.0$  | $17.2^d \pm 0.6$ | $0.53^d \pm 0.02$ | $1.7^b \pm 0.1$ |
| D-360             | $104.7^b \pm 5.4$ | $15.4^a \pm 0.4$    | $16.5^c \pm 1.2$ | $32.1^a \pm 0.4$ | $0.68^b \pm 0.04$ | $2.7^a \pm 0.0$ |
| ELD-K2            | $94.4^b \pm 2.0$  | $14.7^{ab} \pm 0.5$ | $38.4^a \pm 0.7$ | $28.0^b \pm 0.6$ | $0.74^b \pm 0.02$ | $2.6^a \pm 0.1$ |
| D-287             | $103.5^b \pm 2.7$ | $13.8^{ab} \pm 0.1$ | $1.3^d \pm 0.0$  | $29.3^b \pm 1.0$ | $0.53^d \pm 0.04$ | $2.3^b \pm 0.0$ |
| D-104             | $135.0^a \pm 5.0$ | $12.4^b \pm 0.1$    | $1.3^d \pm 0.0$  | $31.6^a \pm 0.9$ | $0.47^d \pm 0.01$ | $2.1^b \pm 0.1$ |
| HA-4              | $90.1^b \pm 7.6$  | $13.2^b \pm 0.1$    | $1.3^d \pm 0.1$  | $38.8^a \pm 1.2$ | $0.55^d \pm 0.02$ | $2.3^b \pm 0.1$ |
| D-96              | $107.6^b \pm 3.3$ | $16.1^a \pm 0.1$    | $21.2^b \pm 1.8$ | $20.1^b \pm 0.6$ | $0.81^a \pm 0.02$ | $3.0^a \pm 0.1$ |
| F-value           | 35.3              | 136.7               | 1449             | 217.5            | 29.44             | 134.3           |
| P value           | <0.001            | <0.001              | <0.001           | <0.001           | <0.001            | <0.001          |

Descriptive statistics (Means  $\pm$  SD); One-way ANOVA was used to compare the mean differences of minerals across spouted seeds followed by a Post hoc test (Tukey's HSD) at a 5% confidence level. Different letters across rows show significant difference while the same letter across rows shows non-significance difference elements in a sample

#### 4.4 Effects of Processing Methods on ANFs, Mineral Contents

##### 4.4.1 Effects of Sprouting on ANFs

Despite the aforementioned potentials of Lablab seeds, their use as food source is limited due to the presence of several ANFs such as phytic acid, tannin, and trypsin inhibitors (TI) (Table 22). The ANFs are naturally occurring secondary metabolites that protect plant legumes from certain biological stressors and have impacts on human health (Soetan & Oyewole, 2009). However, processing approaches such as sprouting has been utilized to remove/minimize the ANFs (Gupta *et al.*, 2015). Individual analysis of ANFs, such as phytic acid levels, showed a significant ( $P < 0.05$ ) reduction in sprouted seeds of D-360 (64.6%), ELD K2 (62.8%), HA-4 (62.3%), D-394 (60.5%), and D-96 (50.5%), in comparison to raw seeds. Similarly, Kilonzi (2020) reported low phytic acid levels on sprouted Lablab varieties. Therefore, sprouted seeds have lower levels of ANFs, which are beneficial for mineral absorption in the body (Avilés-Gaxiola *et al.*, 2018; Gupta *et al.*, 2015).

**Table 22: Anti-nutrient contents of raw, sprouted, and fermented Lablab accessions (mg/100 g)**

| Lablab accessions | Phytic acid              |                         |                           | Tannins                  |                         |                         |
|-------------------|--------------------------|-------------------------|---------------------------|--------------------------|-------------------------|-------------------------|
|                   | Raw                      | Sprouted                | Fermented                 | Raw                      | Sprouted                | Fermented               |
| D-394             | 712.4 <sup>a</sup> ±23.1 | 431.4 <sup>b</sup> ±7.4 | 230.1 <sup>a</sup> ±2.5   | 323.3 <sup>a</sup> ±10.1 | 210.4 <sup>a</sup> ±5.0 | 138.4 <sup>a</sup> ±2.4 |
| D-360             | 710.1 <sup>a</sup> ±21.8 | 459.1 <sup>a</sup> ±4.9 | 202.3 <sup>b</sup> ±1.8   | 210.0 <sup>c</sup> ±2.0  | 118.7 <sup>d</sup> ±2.1 | 127.5 <sup>b</sup> ±2.0 |
| ELD-K2            | 668.8 <sup>a</sup> ±11.5 | 420.9 <sup>b</sup> ±3.0 | 209.7 <sup>c</sup> ±3.0   | 284.0 <sup>b</sup> ±5.3  | 157.7 <sup>b</sup> ±4.9 | 130.1 <sup>b</sup> ±2.1 |
| HA-4              | 577.8 <sup>b</sup> ±8.0  | 360.4 <sup>c</sup> ±5.1 | 142.2 <sup>e</sup> ±<0.01 | 222.8 <sup>c</sup> ±8.8  | 211.2 <sup>a</sup> ±2.6 | 81.9 <sup>d</sup> ±2.7  |
| D-96              | 609.3 <sup>b</sup> ±16.3 | 307.7 <sup>d</sup> ±4.8 | 150.6 <sup>d</sup> ±<0.01 | 225.2 <sup>c</sup> ±4.9  | 139.0 <sup>c</sup> ±1.7 | 100.7 <sup>c</sup> ±1.4 |
| F-value           | 37.05                    | 435.8                   | 1701                      | 143                      | 454.2                   | 354.6                   |
| P-value           |                          | <0.001                  | <0.001                    | <0.001                   | <0.001                  | <0.001                  |

Descriptive statistics (Means ± SD); One-way ANOVA was used to compare the mean differences of anti-nutrient content of raw, sprouted, and fermented seeds across seeds followed by a Post hoc test (Tukey's HSD) at a 5% confidence level. The same letter within a column has no significant difference but different letters have significant differences

Tannin levels were also found to be reduced in HA-4 (94.7%), D-394 (65.0%), D-96 (61.8%), D-360 (56.5%), and in ELD K2 (55.5%). Morrison (2019) confirmed comparable results on lower levels of tannins found in ILRI 6536 and Echo Cream Lablab varieties on sprouting. It has been shown to dramatically reduce ANFs in cereal and legume seeds ( $p<0.05$ ), since the seed uses its storage food during sprouting result to nutritious sprouted foods (Morrison, 2019; Gupta *et al.*, 2015) of low tannin levels (Kilonzi *et al.*, 2017). Reduction of tannin may be due to leaching during germination, activation of enzymes on sprouting which involve breaking down of compounds like tannin for energy (Avilés-Gaxiola *et al.*, 2018; Gupta *et al.*, 2015).

#### 4.4.2 Effects of Fermentation on ANFs

The ANFs like phytic acid were statistically ( $p<0.001$ ) reduced during fermentation, with levels of reduction reaching 75% in D-96 and HA-4 seeds (Table 22). Tannin in fermented seeds was also reduced significantly ( $p<0.001$ ) and considerably in accession HA-4 from 222.8 mg/100 g to 81.9 mg/100 g (61% decrease). Since Lablab beans are so diverse, boiling has been shown to reduce tannin by 75% among its varieties (Kilonzi, 2020). Furthermore, fermentation and cooking are the best methods for improving flavor and reducing ANFs (Morrison, 2019; Avilés-Gaxiola *et al.*, 2018). Fermentation is a widely used processing method that has been used in Africa for generations to improve flavour, texture, aroma, and appearance of fermented foods, which require less energy to cook (Mukherjee *et al.*, 2016).

Fermentation of plant-based food crops is among the traditional food preservation method prior to the use of modern technologies such as refrigeration (Kilonzi, 2020; Adeyemo & Onilude, 2013). During fermentation, pH is monitored for a number of reasons, including nutrient availability and microbial activity. The pH level is an important factor for safe storage and improving sensory characteristics (Ramadoss & Shunmugan, 2014). Moreover, the use of lactic acid bacteria such as *Lb. plantarum* noted to decrease phytic acid (Chuen, 2018). Furthermore,

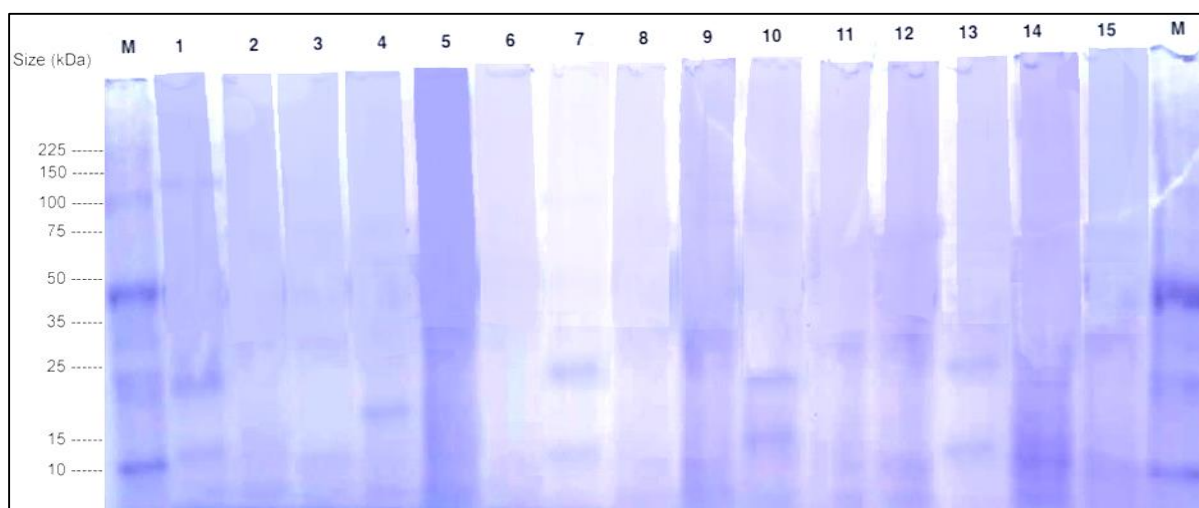
during fermentation, legume seeds not only reduce ANFs but also improve nutritional quality by increasing mineral availability such as zinc (Kilonzi, 2020; Avilés-Gaxiola *et al.*, 2018). Thus, fermentation improves sensory properties, consumer acceptability and significantly removes/reduces ANFs. Also, alerts a novel economic perspective on energy serving and simple methods on the pre-prepared seeds (Avilés-Gaxiola *et al.*, 2018). In addition, fermentation improves the bioavailability and accessibility of nutrients in Lablab food products. As a result, encourage the use of plant products as low-cost macro- and micronutrient sources. The fermentation process is efficient and robust of processing legume seeds as it produces products with nutritional and health benefits for the consumer (Chuen, 2018). In general, according to Ramadoss and Shunmugan (2014) fermentation is a controlled process that use microorganisms like LAB that break down complex compounds in the legume seeds. Hence, improve the nutritional value of the legume seeds by lowering ANFs and enhancing beneficial enzymes. Likewise, the fermentation procedure preserved the seeds by producing lactic acid, which also enhanced the flavor, texture, and quality of the protein. In addition, it develops a tasty flavor, reduction in bitterness, and an improvement in taste makes the legumes more enticing (Kilonzi, 2020; Avilés-Gaxiola *et al.*, 2018).

#### **4.4.3 Effect of Processing Methods on Trypsin Inhibitor**

Finding on trypsin inhibitor (TI) displayed bands of diverse intensity score (Plate 8). Protein characterization for TIs showed the presence of inhibitors in the Lablab accessions (Plate 8). The TI band intensities were found to differ depending on the molecular weight sizes in each each accession. Compared with the standard molecular marker, TIs with a molecular weight of 23-25 kDa were found in raw D-394 (lane 1) but after sprouting (lane 2) and fermentation (lane 3) all the TI bands disappeared. This implies that sprouting is an effective method for lowering trypsin inhibitor levels (Murugkar, 2014). In sprouting proteases break down cellular proteins in the presence of endogenous enzymes and decreased the protease inhibitor content on seedling autotrophic growth (Avilés-Gaxiola *et al.*, 2018; Chuen, 2018). This could reduce over 60% trypsin inhibitory activities between four to five days of sprouting among bean species (Aguilera *et al.*, 2013).

Furthermore, the raw D-360 black accession (lane 4) had a lower TI band intensity of 20 kDa, but after sprouting (lane 5), it resulted into a less visible band. Similary raw ELD K2 (lane 7) with a visible TI band of 25 kDa disappeared after sprouting (lane 8), similar to HA-4 (lane 11) and (lane 14) respectively. According to Avilés-Gaxiola *et al.* (2018), the inconsistent results on band intensity are likely due to the type of legume seeds, maturity, sprouting environments, and sprouting duration. However, in general, sprouting is an efficient process for reducing TI. The TI

is known to affect protein digestibility in legumes by interfering with protein digestion and absorption (Avilés-Gaxiola *et al.*, 2018). However, various processing methods for reducing TI have been reported (Murugkar, 2014). According to Osman (2007), soaking alone can reduce TI by up to 6%, but soaking and sprouting together can reduce TI by more than 20%. Based on type of the seed and sprouting times, TI could be reduced by more than 80% (El-Adawy, 2002). Although TIs are among the antinutritional factors that limit protein digestion and absorption by forming complexes compounds in the nutrition field (Gemedé & Ratta, 2014), other studies have reported a possibility of clinical healthy application to noncommunicable diseases (Murugkar, 2014; Aguilera *et al.*, 2013). According to Cristina (2019), TIs have a promising ability to treat obesity, but more studies and research in this area are required.



**Plate 8: SDS-PAGE for Lablab protein characterization for the presence of TI in the accessions**

Referrint to Plate 8: Lane 1= Raw D-394; Lane 2= Sprouted D-394; Lane 3= Fermented D-394; Lane 4= Raw D-360; Lane 5= Sprouted D-360; Lane 6 = Fermented D-360; Lane 7= Raw ELD K2; Lane 8= Sprouted ELD K2; Lane 9= Fermented ELD K2; Lane 10= HA-4; Lane 11= Sprouted HA-4; Lane 12= Fermented HA-4; Lane 13= Raw D-96; Lane 14= Sprouted D-96 and Lane 15= Fermented D-96. M=Standard molecular weight/ (kDa) Beta-galactosidase 120, Phosphorylase B 94, Bovine Serum Albumin (BSA) 67, Ovalbumin 43, Turkey Albumin 40, Carbonic Anhydrase 30, Soybean Trypsin Inhibitor 20.1, α-Lactalbumin 14.4, and Lysozyme 14 (Margareta 2004) Promega V8491, USA.

Likewise, fermentation reduced TI bands intensities of the Lablab seeds as per Plate 9. Fermented D-394 (lane 3), D-360 (lane 6) and ELD K2 (lane 9) accessions had no visible bands. Likewise, no bands were detected in fermented HA-4 (lane 12) and D-96 (lane 15), respectively. Generally, all fermented accessions with *L. plantarum* resulted in significant degradation of TI. Fermentation is both an anaerobic and catabolic process in which microorganisms convert complex compounds

into simple ones in growth (Avilés-Gaxiola *et al.*, 2018). The ANFs such as tannins, oligosaccharides (stachyose and raffinose), phytic acid, and protease inhibitors can be reduced (Chuen, 2018). However, the intensity levels of TI band in fermented legumes may vary owing to beans type, maturity, fermentation duration, and microbe species used, as they do differ in their metabolic activities (Mukherjee *et al.*, 2016). The use of microorganisms such as *Lactobacillus plantarum*, *Lactobacillus acidophilus*, *Bacillus amyloliquefaciens*, and *Saccharomyces cerevisiae* in the fermentation of pulses produces TI-free/reduced food like as soy sauce from soybeans. Gao *et al.* (2013) found 89.2% TI reduction after five days of inactivation. Similarly, Adeyemo and Onilude (2013) concluded that fermentation with *L. plantarum* reduced 99.17% of the trypsin inhibitor activity. Avilés-Gaxiola *et al.* (2018) also found that common beans fermented with *Lactobacillus fermentum* ATCC 14931 reduces TI by about 38%. These findings are all compatible with the current study and in comparison to the standard soybean, almost all accessions had low levels of TIs (Plate 16).

According to Avilés-Gaxiola *et al.* (2018), fermented soybean seeds in foods such as soy sauce are safe to take in terms of TI reduction. Similarly, when *Aspergillus oryzae* is used for fermentation for 5 days, TI is inactivated by 89.2% (Gao *et al.*, 2013). Likewise, Adeyemo and Onilude (2013) found that fermentation with *L. plantarum* inactivated 99.17% of TI as observed in study column six when the same bacteria were used (Plate 16). Furthermore, Avilés-Gaxiola *et al.* (2018) documented that fermented seeds treated with *L. acidophilus*, *L. plantarum*, *Bacillus amyloliquefaciens*, and *Saccharomyces cerevisiae* separately over a 2-day period could reduce TI by 82.6%, 88.9%, 85.9%, and 73.8%, respectively. Globally scientific interest in plant-food crops is developing particularly on underutilized crops, to meet the need of nutritious food for an ever-growing population. Thus, fermentation with the use of food microorganisms is gaining popularity due to the high quality of the food-products and the potential for health benefits.

#### **4.4.4 Effects of Processing on Mineral Contents**

Fermented seeds improved mineral content based on accession type (Table 23). Seeds fermented with LAB not only reduce anti-nutrients but also improve mineral availability. Avilés-Gaxiola *et al.* (2018), Gupta *et al.* (2015) and Shunmugam (2014) commented that fermented seeds often have higher mineral availability due to lower levels of phytic acids and tannins. Fermented seeds, such as HA-4, improved Mg content by 0.09-0.23% and Zn content by 0.23-0.35%. Fermentation is a metabolic process in which sugars are oxidized and phytic acid complexes are normally degraded by enzymes, resulting in the liberation of accessible minerals such as iron, zinc, and calcium, which increases the nutritional quality of the seeds (Gupta *et al.*, 2015; Gao *et al.*, 2013). Furthermore, fermentation duration needs to be taken into account. Adebiyi *et al.* (2018) reported



that fermented pearl millet increases minerals such as Ca, Na, Cu, Fe, Zn, and K after 3 days of fermentation. Similarly, Olagunju *et al.* (2018) found an increase in mineral contents in fermented soymilk, mung bean flour, and tamarind seeds. Moreover, the finding was supported by Obadina *et al.* (2013) and Onwurafor *et al.* (2014) in increases in Ca, Fe, Mg, and Zn contents as fermentation progressed. According to Kilonzi (2020) Lablab beans fermented with *Rhizopus oligosporus* and *Rhizopus oryzae* in tempeh products had more nutritional value than unfermented beans.

On the other side, sprouted seeds also demonstrated improvement in mineral contents like Mg (0.11 - 0.25%), (0.09 - 0.20%), and Zn (0.03 - 0.34%), and (0.23 - 0.32%) in D-96 and HA-4, respectively (Table 23). Regardless of the variation in mineral increase, factors such as seed type, and sprouting duration, sprouting is an effective method for increasing nutrient bioavailability (Avilés-Gaxiola *et al.*, 2018). Furthermore, Gupta *et al.* (2015) and Shunmugam (2014) reported higher mineral availability due to the degradation of ANFs in sprouted seeds. According to Gupta *et al.* (2015), phytic acid, a phosphorus storage form found in cereals, legumes, oil seeds, and nuts, is an anti-nutritive agent that binds to minerals such as Fe, Zn, and Ca, preventing absorption by producing an insoluble salt. However, processes such as soaking and sprouting can reduce the ANFs and improves nutritional quality depending on the type, and concentration which varies depending on the seeds of plant crops (Shunmugam, 2014). Noteworthy, the highest mineral availability is greatly linked to seed type, and environment conditions, which has been observed in minerals such as iron in wheat, zinc in rice and wheat, manganese in rice and soybean, and calcium in soybean, rice, and faba beans (Smith *et al.*, 2018; Gupta *et al.*, 2015).

**Table 23: Effect of sprouting and fermentation on the mineral content in Lablab accessions**

| Accessions     | Mg                             | Si                             | Ca                             | Fe                             | Cu                             | Zn                            |
|----------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|-------------------------------|
| <b>D-394r</b>  | <b>0.08<sup>b</sup> ± 3.10</b> | <b>0.02<sup>a</sup> ± 0.40</b> | <b>0.02<sup>b</sup> ± 2.80</b> | <b>0.02<sup>a</sup> ± 1.30</b> | <b>0.06<sup>a</sup> ± 0.04</b> | <b>0.22<sup>a</sup> ± 0.1</b> |
| D-394s         | 0.06 <sup>b</sup> ± 0.01       | 0.01 <sup>a</sup> ± 0.01       | 0.07 <sup>a</sup> ± 0.01       | 0.01 <sup>a</sup> ± 0.01       | 0.02 <sup>b</sup> ± 0.01       | 0.16 <sup>b</sup> ± 0.01      |
| D-394f         | 0.11 <sup>a</sup> ± 0.01       | 0.00 <sup>b</sup> ± 0.01       | 0.04 <sup>ab</sup> ± 0.00      | 0.01 <sup>a</sup> ± 0.00       | 0.00 <sup>c</sup> ± 0.31       | 0.18 <sup>b</sup> ± 0.45      |
| <b>D-360r</b>  | <b>0.11<sup>b</sup> ± 5.40</b> | <b>0.02<sup>a</sup> ± 0.40</b> | <b>0.02<sup>b</sup> ± 1.20</b> | <b>0.03<sup>a</sup> ± 0.40</b> | <b>0.01<sup>a</sup> ± 0.04</b> | <b>0.27<sup>b</sup> ± 0.0</b> |
| D-360s         | 0.22 <sup>a</sup> ± 0.05       | 0.02 <sup>a</sup> ± 0.01       | 0.06 <sup>a</sup> ± 0.00       | 0.01 <sup>b</sup> ± 0.00       | 0.02 <sup>a</sup> ± 0.74       | 0.34 <sup>a</sup> ± 0.75      |
| D-360f         | 0.09 <sup>c</sup> ± 0.01       | 0.00 <sup>b</sup> ± 0.01       | 0.05 <sup>a</sup> ± 0.00       | 0.01 <sup>b</sup> ± 0.02       | 0.01 <sup>a</sup> ± 0.65       | 0.19 <sup>c</sup> ± 0.55      |
| <b>ELD-K2r</b> | <b>0.09<sup>b</sup> ± 2.00</b> | <b>0.01<sup>b</sup> ± 0.50</b> | <b>0.04<sup>b</sup> ± 0.70</b> | <b>0.03<sup>a</sup> ± 0.60</b> | <b>0.01<sup>a</sup> ± 0.02</b> | <b>0.26<sup>b</sup> ± 0.1</b> |
| ELD-K2s        | 0.22 <sup>a</sup> ± 0.06       | 0.01 <sup>b</sup> ± 0.01       | 0.07 <sup>a</sup> ± 0.01       | 0.01 <sup>b</sup> ± 0.00       | 0.01 <sup>a</sup> ± 0.17       | 0.33 <sup>a</sup> ± 0.25      |
| ELD-K2f        | 0.06 <sup>c</sup> ± 0.01       | 0.03 <sup>a</sup> ± 0.01       | 0.05 <sup>ab</sup> ± 0.00      | 0.01 <sup>b</sup> ± 0.00       | 0.02 <sup>a</sup> ± 0.21       | 0.15 <sup>c</sup> ± 0.12      |
| <b>HA-4r</b>   | <b>0.09<sup>c</sup> ± 7.60</b> | <b>0.03<sup>a</sup> ± 0.10</b> | <b>0.01<sup>c</sup> ± 0.10</b> | <b>0.04<sup>a</sup> ± 1.20</b> | <b>0.11<sup>a</sup> ± 0.02</b> | <b>0.23<sup>c</sup> ± 0.1</b> |
| HA-4s          | 0.20 <sup>b</sup> ± 0.02       | 0.01 <sup>b</sup> ± 0.02       | 0.11 <sup>a</sup> ± 0.02       | 0.02 <sup>ab</sup> ± 0.01      | 0.01 <sup>b</sup> ± 0.01       | 0.32 <sup>b</sup> ± 0.01      |
| HA-4f          | 0.23 <sup>a</sup> ± 0.00       | 0.01 <sup>b</sup> ± 0.01       | 0.06 <sup>b</sup> ± 0.01       | 0.01 <sup>b</sup> ± 0.00       | 0.01 <sup>b</sup> ± 0.00       | 0.35 <sup>a</sup> ± 0.01      |
| <b>D-96r</b>   | <b>0.11<sup>b</sup> ± 3.30</b> | <b>0.02<sup>a</sup> ± 0.10</b> | <b>0.02<sup>b</sup> ± 1.80</b> | <b>0.02<sup>a</sup> ± 0.60</b> | <b>0.01<sup>a</sup> ± 0.02</b> | <b>0.03<sup>c</sup> ± 0.1</b> |
| D-96s          | 0.25 <sup>a</sup> ± 0.01       | 0.02 <sup>a</sup> ± 0.01       | 0.06 <sup>a</sup> ± 0.01       | 0.01 <sup>a</sup> ± 0.01       | 0.02 <sup>a</sup> ± 0.01       | 0.34 <sup>a</sup> ± 0.01      |
| D-96f          | 0.07 <sup>c</sup> ± 0.01       | 0.01 <sup>a</sup> ± 0.01       | 0.04 <sup>ab</sup> ± 0.01      | 0.01 <sup>a</sup> ± 0.00       | 0.01 <sup>a</sup> ± 0.32       | 0.18 <sup>b</sup> ± 0.65      |

Descriptive statistics (Means ± SD); One-way ANOVA was used to compare the mean differences of minerals across raw(r), sprouted(s), and fermented(f) seeds followed by a Post hoc test (Tukey's HSD) at a 5% confidence level. Different letters across rows show significant differences while the same letter across rows shows non-significance difference elements in a sample. Mean value (n=3) express in %

## 4.5 Effect of processing on the Consumer Acceptability of Lablab Cookies

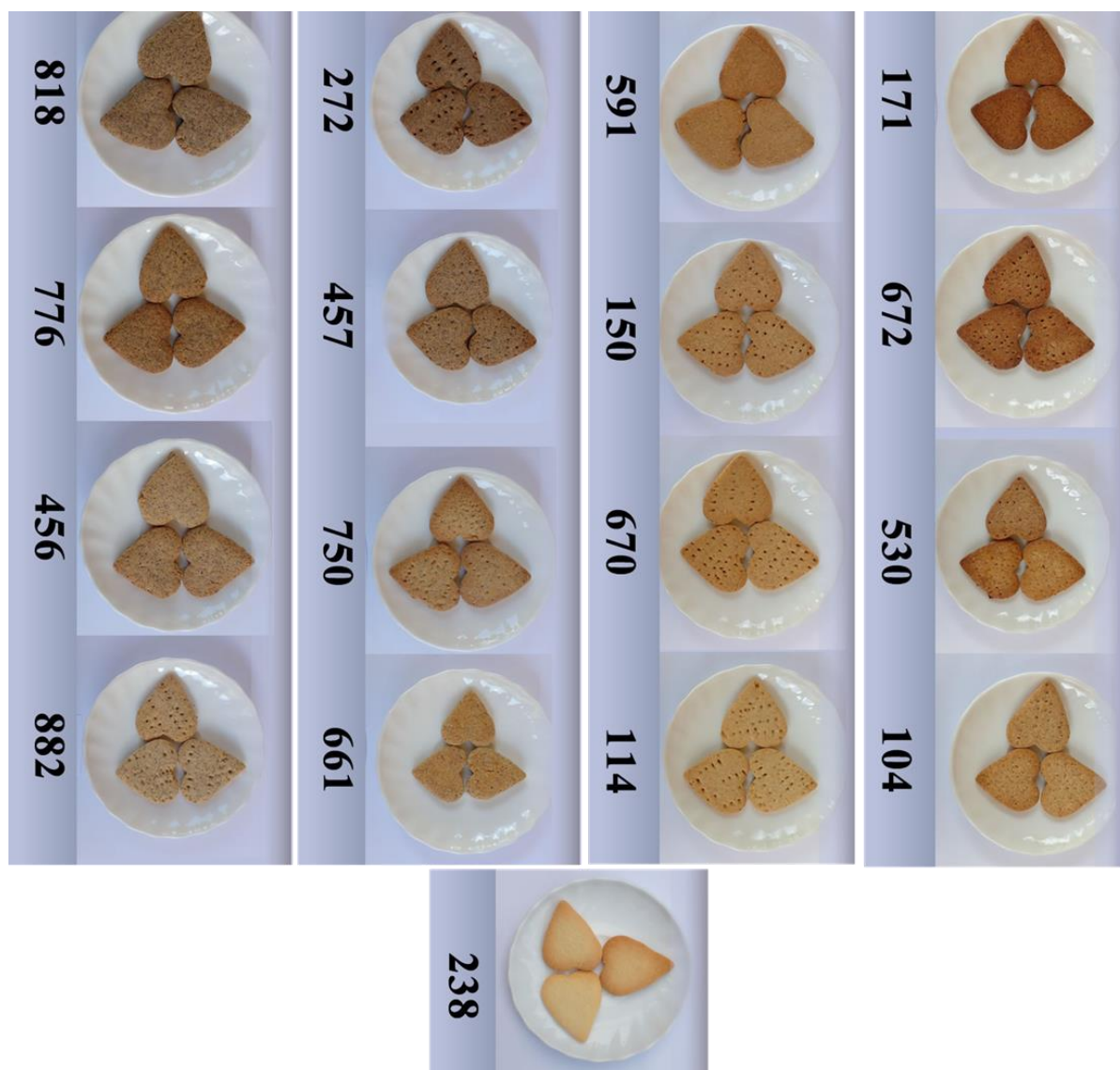
### 4.5.1 Consumer Acceptance of Sprouted Cookies

The majority of consumers preferred sprouted HA-4 and D-96 cookies, with an average score of 6.2 and 7.2, respectively (Table 24). Cookies made from D-394 and ELD K2 the black accessions were less preferred (Table 24). The cookies prepared with red/brown accessions such as D-96 and HA-4 ranked higher as they appear to be similar to control cookies. The sprouted HA-4 and D-96 exhibited moderate liking, whereas ELD K2 and D-94 liked slightly. Many sprouted beans retain their parent characteristics, like flavour and aroma challenge their acceptability (Avilés-Gaxiola *et al.*, 2018; Chuen, 2018; Smith *et al.*, 2018). Moreover, cookies prepared from black Lablab accessions still retained colour (Plate 9) which had an implication on consumers' preferences. Black Lablab seeds are rarely consumed (Forsythe, 2019; Grotelüschen, 2014). This further suggests that consumers' perceptions on developed products can pave the way for future improvement (Appleton *et al.*, 2021). Therefore, sprouted D-96 and HA-4 accessions are the best and can be used in baked industries to improve cereal products.

**Table 24: Mean (S. D.) scores liking on the sensory attributes of sprouted cookies**

| Lablab        |        | Parameter              |                        |                       |                        |                        | OA* |
|---------------|--------|------------------------|------------------------|-----------------------|------------------------|------------------------|-----|
| Cookies       | Ratios | Appearance             | Crunchiness            | Sponginess            | Aroma                  | Taste                  |     |
| <b>D-394</b>  | 1      | 3.6 <sup>ab</sup> ±1.9 | 3.3 <sup>b</sup> ±2.0  | 2.8 <sup>c</sup> ±1.9 | 3.3 <sup>b</sup> ±2.6  | 2.9 <sup>c</sup> ±1.8  | 3.0 |
|               | 2      | 3.2 <sup>b</sup> ±1.3  | 3.2 <sup>b</sup> ±1.6  | 2.7 <sup>c</sup> ±1.7 | 3.7 <sup>b</sup> ±1.5  | 3.9 <sup>b</sup> ±1.6  |     |
|               | 3      | 3.8 <sup>b</sup> ±1.0  | 3.3 <sup>b</sup> ±1.7  | 3.4 <sup>b</sup> ±1.9 | 3.6 <sup>b</sup> ±1.3  | 4.0 <sup>b</sup> ±1.8  |     |
|               | 4      | 3.9 <sup>a</sup> ±2.8  | 4.3 <sup>a</sup> ±1.5  | 4.1 <sup>a</sup> ±1.6 | 4.2 <sup>a</sup> ±1.3  | 4.5 <sup>a</sup> ±1.6  |     |
| <b>ELD K2</b> | 1      | 3.5 <sup>b</sup> ±1.5  | 3.6 <sup>b</sup> ±1.3  | 3.6 <sup>b</sup> ±1.4 | 3.4 <sup>a</sup> ±1.0  | 3.5 <sup>b</sup> ±1.4  | 4.0 |
|               | 2      | 3.5 <sup>b</sup> ±1.2  | 4.2 <sup>a</sup> ±1.7  | 3.8 <sup>a</sup> ±1.2 | 3.5 <sup>b</sup> ±1.6  | 3.6 <sup>ab</sup> ±0.9 |     |
|               | 3      | 3.4 <sup>b</sup> ±0.9  | 3.8 <sup>b</sup> ±1.8  | 3.6 <sup>b</sup> ±1.6 | 3.4 <sup>b</sup> ±1.4  | 3.9 <sup>a</sup> ±1.0  |     |
|               | 4      | 3.5 <sup>a</sup> ±1.1  | 3.2 <sup>c</sup> ±0.6  | 3.1 <sup>c</sup> ±0.8 | 3.4 <sup>c</sup> ±1.8  | 3.6 <sup>b</sup> ±0.0  |     |
| <b>HA-4</b>   | 1      | 7.0 <sup>b</sup> ±1.2  | 7.6 <sup>b</sup> ±1.2  | 7.7 <sup>a</sup> ±2.0 | 8.3 <sup>a</sup> ±0.8  | 8.9 <sup>a</sup> ±0.5  | 6.2 |
|               | 2      | 7.0 <sup>b</sup> ±1.0  | 7.1 <sup>c</sup> ±1.7  | 6.8 <sup>b</sup> ±2.6 | 8.4 <sup>a</sup> ±0.9  | 8.6 <sup>b</sup> ±0.8  |     |
|               | 3      | 7.2 <sup>b</sup> ±1.0  | 7.3 <sup>bc</sup> ±1.0 | 7.7 <sup>a</sup> ±1.4 | 8.3 <sup>a</sup> ±1.2  | 8.7 <sup>ab</sup> ±0.5 |     |
|               | 4      | 8.1 <sup>a</sup> ±1.7  | 8.0 <sup>a</sup> ±0.8  | 7.8 <sup>a</sup> ±1.6 | 7.9 <sup>b</sup> ±1.7  | 8.5 <sup>b</sup> ±0.9  |     |
| <b>D-96</b>   | 1      | 6.2 <sup>c</sup> ±1.6  | 5.4 <sup>c</sup> ±1.8  | 7.8 <sup>a</sup> ±0.5 | 8.2 <sup>c</sup> ±0.4  | 8.2 <sup>c</sup> ±0.4  | 7.2 |
|               | 2      | 7.2 <sup>b</sup> ±1.5  | 7.9 <sup>a</sup> ±8.1  | 7.5 <sup>a</sup> ±1.0 | 8.5 <sup>b</sup> ±0.6  | 8.5 <sup>b</sup> ±0.5  |     |
|               | 3      | 7.1 <sup>bc</sup> ±2.0 | 6.6 <sup>b</sup> ±2.1  | 7.5 <sup>a</sup> ±1.7 | 8.3 <sup>bc</sup> ±1.0 | 8.5 <sup>b</sup> ±0.6  |     |
|               | 4      | 7.9 <sup>a</sup> ±1.3  | 7.1 <sup>ab</sup> ±1.9 | 7.5 <sup>a</sup> ±1.9 | 8.8 <sup>a</sup> ±0.4  | 8.8 <sup>a</sup> ±0.4  |     |
| Control       |        | 8.8                    | 8.6                    | 8.7                   | 8.8                    | 9.0                    | 8.8 |
| OAPP*         |        | 5.8                    | 5.5                    | 4.9                   | 6.0                    | 6.3                    | 5.7 |

Descriptive statistics (mean±SD); One-way ANOVA was used to compare the mean differences of cookies made with spouted flour followed by a Post hoc test (Tukey's HSD) at a 5% confidence level. Different letters across rows show significant difference while the same letters across rows show a non-significance difference in cookies. OAPP\* = Overall acceptability per parameter, OA\* = Overall acceptability per accession by average scores. Sensory attributes re measured on a 9-point Hedonic scale ranging from 1 (extremely dislike) to 9 (extremely like). (n = 80). Ratio of flour 1=sprouted, 2=three quarter sprouted 3=half sprouted, and 4= quarter sprouted

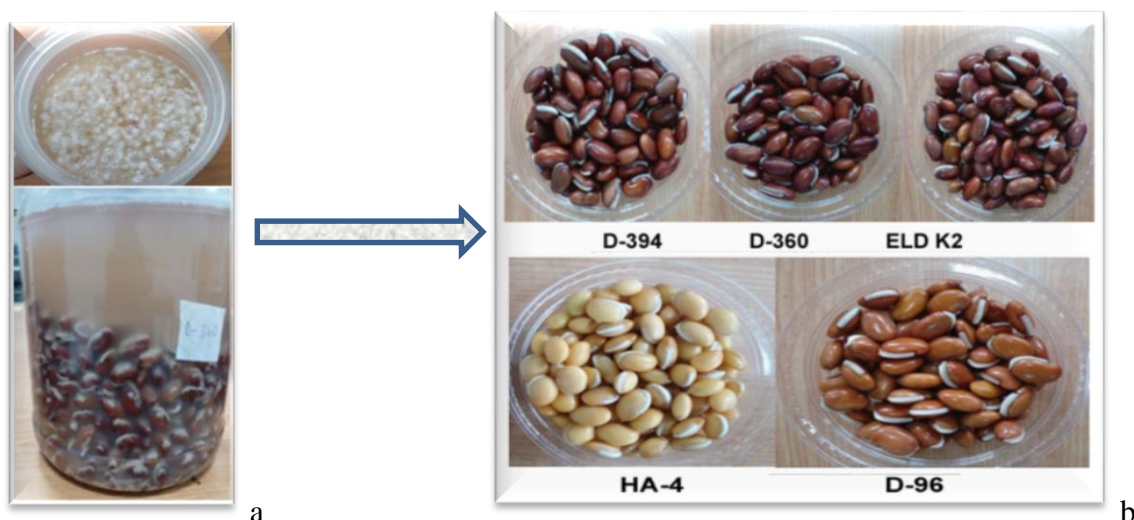


**Plate 9:** Lablab cookies prepared from sprouted Lablab flour: 818:D-394 (1); 776:D-394 (2); 456:D-394 (3); 882:D-394 (4); 272:ELD K2 (1); 457:ELD K2 (2); 750:ELD K2 (3); 661:ELD K2 (4); 591:HA-4 (1); 150:HA-4 (2); 670:HA-4 (3); 114:HA-4 (4); 171:D-96 (1); 672:D-96 (2); 530:D-96 (3); 104:D-96 (4) and 238:Control

#### 4.5.2 Consumer Acceptance of Fermented Cookies

The consumers generally preferred fermented cookies regardless of the differences in fermented flour ratios, parameters, and accession types (Table 25, Plate 11). In all parameters of the fermented cookies were highly preferred by the consumers, such as appearance at a score of 7.3 (Table 25). Fermentation of legume seeds with microorganisms improves sensory characteristics and leads to the development of healthier food products (Kilonzi, 2020). Fermentation usually significantly reduce undesired beany characteristics (Avilés-Gaxiola *et al.*, 2018). The "beany" off-flavour present in the beans can be considerably reduced or eliminated during fermentation by using LAB (Emkan *et al.*, 2022). The LAB reduces beany and bitterness while improving the sensory

properties of soymilk (Olagunju *et al.*, 2018). Likewise, the colour of the beans were change after fermentation including the black accessions (D-394, D-360, and ELD K2) (Plate 10).



**Plate 10: Fermented of Lablab accessions (a) fermentation with LAC at ambient temperature for 72 hours (b) fermented accessions**

Furthermore, fermentation of Lablab beans not only modifies their sensory properties, but also reduces ANFs and improves the nutritional quality. Appleton *et al.* (2021), Kitum *et al.* (2020), Avilés-Gaxiola *et al.* (2018), and Smith *et al.* (2018) reported that fermentation significantly reduces ANFs content and also improves food sensory characteristics, which are key elements for nutritional quality in the food industry. Fermentation of legume beans depended also on the kind of microorganisms used, and the fermenting conditions which require careful attention as are associated with enzymatic actions related to nutritional quality of the developed new products. Therefore, this study demonstrates how diverse underutilized Lablab accessions can be transformed into new products such as baked products by the LAB for improving the nutritional and sensory qualities as well as customer acceptability. The observed differences among the Lablab cookies could be due to the accession type or the usage of a specific LAB, which calls for further research.

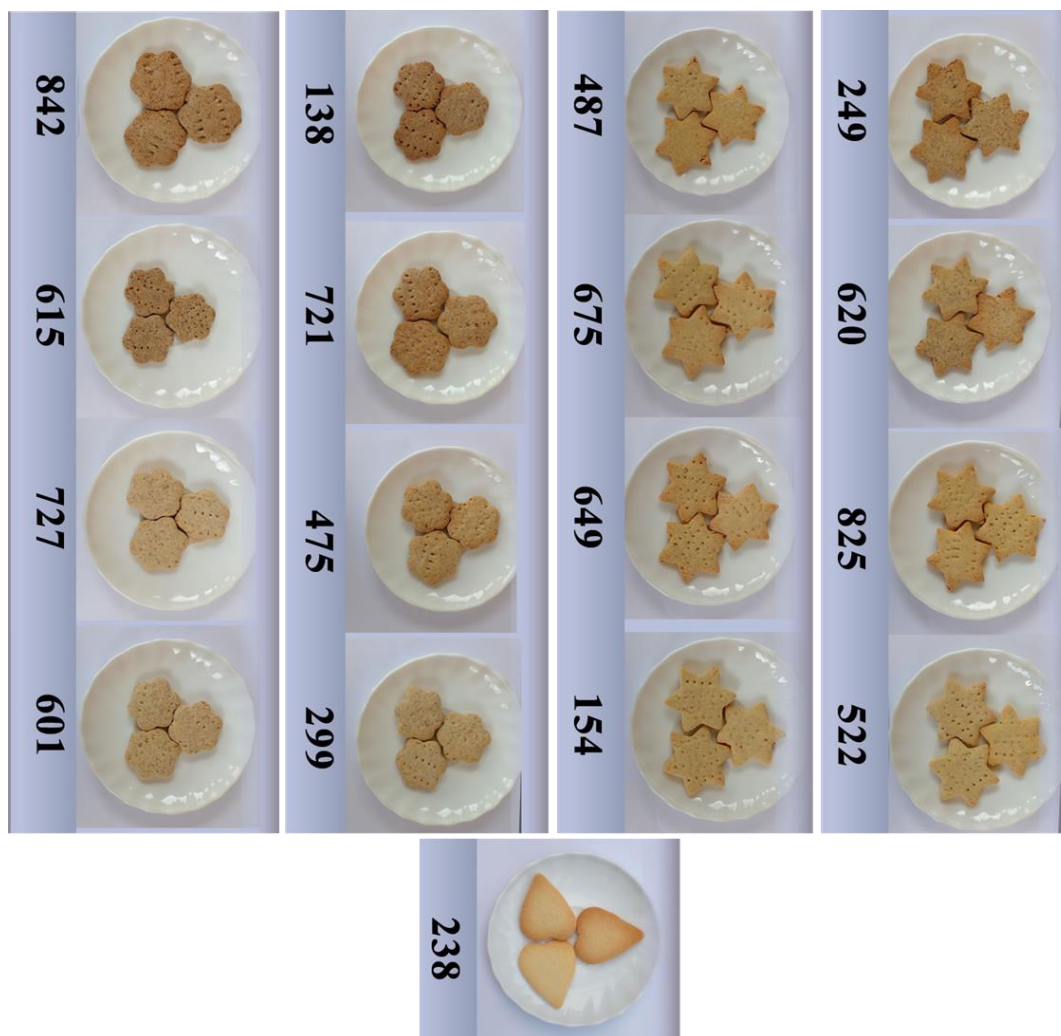
**Table 25: Mean (S. D) scores liking on sensory attributes of fermented cookies**

| Cookies | Ratios | Parameter              |                        |                        |                        |                        | OA* |
|---------|--------|------------------------|------------------------|------------------------|------------------------|------------------------|-----|
|         |        | Appearance             | Crunchiness            | Sponginess             | Aroma                  | Taste                  |     |
| D-394   | 1      | 6.1 <sup>a</sup> ±2.2  | 5.3 <sup>a</sup> ±2.1  | 5.6 <sup>a</sup> ±2.1  | 7.0 <sup>a</sup> ±1.3  | 7.3 <sup>a</sup> ±1.1  | 5.4 |
|         | 2      | 6.2 <sup>a</sup> ±1.9  | 5.3 <sup>a</sup> ±1.7  | 4.0 <sup>b</sup> ±1.2  | 6.8 <sup>a</sup> ±1.5  | 6.5 <sup>b</sup> ±1.8  |     |
|         | 3      | 6.4 <sup>a</sup> ±1.6  | 4.3 <sup>b</sup> ±1.8  | 4.0 <sup>b</sup> ±0.0  | 6.8 <sup>a</sup> ±1.7  | 4.0 <sup>c</sup> ±0.0  |     |
|         | 4      | 6.1 <sup>a</sup> ±1.9  | 5.7 <sup>a</sup> ±1.8  | 5.8 <sup>a</sup> ±1.8  | 5.3 <sup>b</sup> ±1.2  | 4.1 <sup>c</sup> ±0.6  |     |
| ELDK2   | 1      | 6.1 <sup>c</sup> ±1.5  | 5.6 <sup>c</sup> ±2.0  | 5.4 <sup>c</sup> ±1.7  | 6.8 <sup>a</sup> ±1.7  | 7.0 <sup>ab</sup> ±1.5 | 6.4 |
|         | 2      | 4.9 <sup>bc</sup> ±1.0 | 8.2 <sup>a</sup> ±1.2  | 5.6 <sup>bc</sup> ±2.0 | 6.3 <sup>b</sup> ±1.9  | 6.8 <sup>b</sup> ±1.8  |     |
|         | 3      | 4.6 <sup>b</sup> ±0.9  | 6.5 <sup>b</sup> ±1.4  | 6.5 <sup>a</sup> ±1.6  | 7.3 <sup>a</sup> ±1.6  | 7.2 <sup>ab</sup> ±1.9 |     |
|         | 4      | 7.0 <sup>a</sup> ±1.4  | 7.0 <sup>ab</sup> ±1.8 | 6.5 <sup>ab</sup> ±2.3 | 7.3 <sup>a</sup> ±1.6  | 7.9 <sup>a</sup> ±1.9  |     |
| HA-4    | 1      | 5.6 <sup>c</sup> ±2.0  | 5.8 <sup>b</sup> ±1.9  | 5.1 <sup>b</sup> ±1.8  | 7.5 <sup>b</sup> ±1.3  | 7.8 <sup>b</sup> ±1.3  | 7.6 |
|         | 2      | 7.2 <sup>b</sup> ±1.7  | 6.8 <sup>a</sup> ±1.7  | 7.1 <sup>a</sup> ±1.3  | 7.8 <sup>ab</sup> ±1.3 | 8.1 <sup>ab</sup> ±1.2 |     |
|         | 3      | 7.8 <sup>a</sup> ±1.4  | 7.0 <sup>a</sup> ±2.2  | 7.5 <sup>a</sup> ±1.5  | 8.1 <sup>a</sup> ±1.3  | 8.2 <sup>a</sup> ±1.2  |     |
|         | 4      | 8.1 <sup>a</sup> ±1.4  | 7.4 <sup>a</sup> ±2.0  | 7.2 <sup>a</sup> ±2.0  | 7.6 <sup>b</sup> ±1.9  | 8.1 <sup>ab</sup> ±1.3 |     |
| D-96    | 1      | 6.7 <sup>d</sup> ±1.8  | 6.2 <sup>c</sup> ±1.9  | 7.2 <sup>b</sup> ±2.0  | 6.3 <sup>c</sup> ±2.0  | 7.2 <sup>b</sup> ±1.8  | 8.4 |
|         | 2      | 8.0 <sup>c</sup> ±0.9  | 7.3 <sup>b</sup> ±1.6  | 7.0 <sup>b</sup> ±2.0  | 8.3 <sup>b</sup> ±0.8  | 8.6 <sup>a</sup> ±0.5  |     |
|         | 3      | 8.4 <sup>b</sup> ±0.7  | 7.9 <sup>a</sup> ±1.4  | 7.8 <sup>a</sup> ±1.7  | 8.7 <sup>a</sup> ±0.6  | 8.9 <sup>a</sup> ±0.3  |     |
|         | 4      | 8.8 <sup>a</sup> ±0.4  | 8.0 <sup>a</sup> ±1.6  | 8.1 <sup>a</sup> ±1.4  | 8.9 <sup>a</sup> ±0.3  | 8.9 <sup>a</sup> ±0.3  |     |
| Control |        | 8.8                    | 8.6                    | 8.7                    | 8.8                    | 9.0                    | 8.8 |
| OAPP*   |        | 7.3                    | 7.0                    | 6.9                    | 7.6                    | 7.9                    | 7.3 |

Descriptive statistics (mean±SD); One-way ANOVA used to compare the mean differences of cookies made with fermented flour followed by Post hoc test (Tukey's HSD) at 5% confidence level. Different letters across rows shows significant difference while the same letters across rows shows non-significance difference in cookies. OAPP\* = Overall acceptability per parameter, OA\* = Overall acceptability per accession by average scores. Sensory attributes measured on a 9-point hedonic scale ranging from 1 (extremely dislike) to 9 (extremely like). (n = 80). Ratio of flour 1=fermented 2=three quarter fermented 3=half fermented, and 4= quarter fermented

### 4.5.3 Overall Acceptability

Overall, majority of the consumers over 50% preferred fermented cookies (Table 26). The sensory acceptability score observed highly (8.8) liked on control cookies, followed by fermented very much liked (7.3) and sprouted liked (5.7) (Tables 24 and 25). The control cookies were produced entirely from wheat flour and were compared to the cookies made from flours of either fermented or sprouted Lablab mixed with different ration of wheat flour. Considering that the indigenous Lablab crop is underutilized, regular exposure to diversified Lablab products may influence increased consumption rates.



**Plate 11:** Lablab Cookies prepared from fermented Lablab flour: 842:D-394 (1); 615:D-394 (2); 727:D-394 (3); 601:D-394 (4); 138:ELD K2 (1); 721:ELD K2 (2); 475:ELD K2 (3); 299:ELD K2 (4); 487:HA-4 (1); 675:HA-4 (2); 649:HA-4 (3); 154:HA-4 (4); 249:D-96 (1); 620:D-96 (2); 825:D-96 (3); 522:D-96 (4) and 238:Control

People's desire for diverse selections is a key driver to exposure and utilization of underutilized legume seeds' that can be incorporated into food industries, such as baked products, which rely primarily on wheat flour (Chinma *et al.*, 2011). Underutilized beans such as Lablab are suggested because they have a diverse nutritrional quality with protein content compatible to soybeans (Table 4). Furthermore, fermented cookies were mostly preferred in all attributes evaluated (Plate 11 and Table 25). Therefore, cookies prepared from D-96 accessions was the most liked regardless of the processing method with higher score in all attributes (appearance, crunchiness, sponginess, aroma, and flavour similar to control cookies (Plate 11 and Table 25). The HA-4 ranked the second most preferred.

In addition, the majority (60%) of consumers claimed that they could purchase one piece of the cookie for 500-600 TZS (Table 26). The cookies presented for the sensory evaluation approximately weighed 10 grams. Today's society has a high demand for bakery items that are convincing (Hooper *et al.*, 2019). Therefore, since legume beans are more affordable, nutritious

and widely available in many low-income regions, through product diversification such as incorporating them into novel products like cookies can increase the potential for their consumption and thus improve nutritional quality (Hooper *et al.*, 2019).

**Table 26: General comments**

| Parameters                            | Percentages (%) |
|---------------------------------------|-----------------|
| Most liked cookies by the respondents |                 |
| Sprouted                              | 41.6            |
| Fermented                             | 53.9            |
| <b>Total</b>                          | <b>100</b>      |
| Selling price per one piece           |                 |
| 200-400                               | 21.3            |
| 500-600                               | 60.0            |
| 700 and above                         | 18.8            |
| <b>Total</b>                          | <b>100</b>      |

Promoting plant-based products of nutritious quality such as Lablab accessions can increase its acceptance hence further improve its utilization. Nord *et al.* (2020) and Morrison (2019) reported that Lablab beans are underutilized due to a lack of awareness, diversified Lablab meals, and promotion. In addition, according to Hooper *et al.* (2019), a major drawback linked with bean underutilization is the use of whole-form beans that require a long-time in cooking. Consumers in today's market are driven by a need for high-quality, healthy convenience foods that are versatile and easy to prepare. Diversifying Lablab in a convenient and versatile form is important not only for nutritional qualities but also for generating more income for a livelihood. From the study, the farmers were selling mainly Lablab beans with no value addition which necessitated a survey to uncover the income collected from the sales to provide dietary diversity in their households. According to FAO and FHI 360 (2016), dietary diversity is a proxy indicator that can be used to evaluate production and diet quality in agricultural communities for a particular context or intervention.

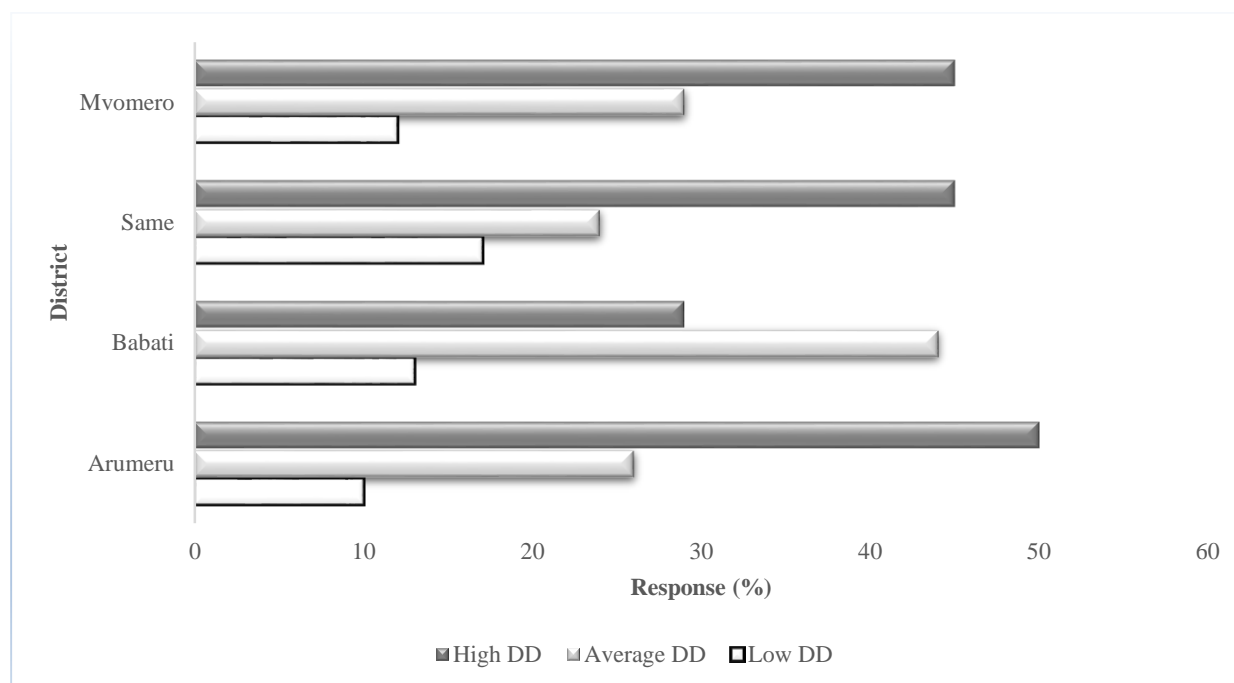
## **4.6 Lablab Production and Dietary Diversity**

### **4.6.1 Dietary Diversity per District**

Dietary diversity was higher in Arumeru (50%) than in Mvomero and Same (less than 45% and 29%, respectively) (Fig. 25). Babati (44%), Mvomero (29%), Arumeru (26%), and Same (24%), on average, had a 4-5 food group dietary diversity (Fig. 25). Similar to Ochieng *et al.* (2017)'s study, 31% of the respondents consume less dietary diversity. According to FAO and FHI 360 (2016) assessing nutritional quality and farm produce demonstrates the crop's impact on the community/society. Smallholder farmer households in developing countries continue to eat inadequate diets, adding to the burden of malnutrition (Nabuma *et al.*, 2021; Fan & Rue, 2020;



Liao & Brown, 2018). Furthermore, agricultural production for diet quality among smallholder farmers is debatable in terms of dietary diversity contribution (Adubra *et al.*, 2019; FAO *et al.*, 2017). Similarly, agricultural produce is rarely linked to the quality of growers' diets, particularly among women, who play an important role in farming but are also massively vulnerable (Kiptoo *et al.*, 2021; Habtemariam *et al.*, 2021; Nabuuma *et al.*, 2021; Adubra *et al.*, 2019).



**Figure 25: Dietary Diversity of Women Lablab farmers in the Study Districts: High dietary diversity score = 6 and above; Average = 4-5; Low = 3 or fewer**

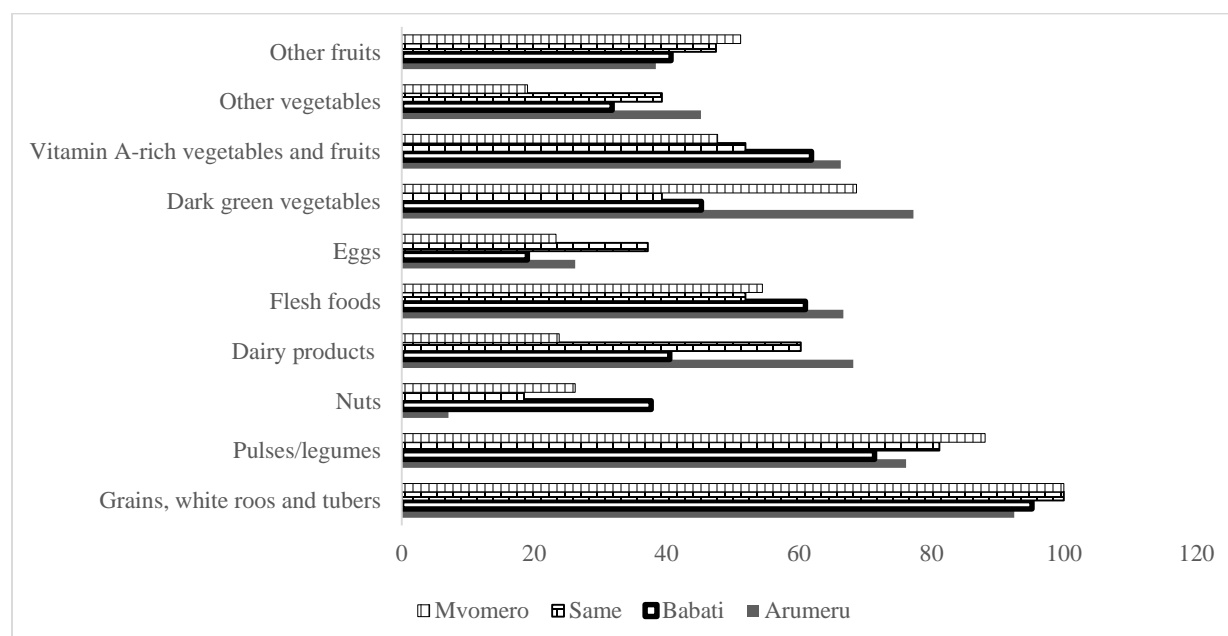
#### 4.6.2 Dietary Diversity in the Farmer's Household

Most of the Lablab farmer's household food came from cereal-based items, accounting for almost 95% of the total (Fig. 26). In Mvomero and Same districts, diets were entirely cereal-based (100%), similar to Ochieng *et al.* (2017) study. Furthermore, Kiptoo *et al.* (2021) and Minja *et al.* (2021) established that cereal-based foods are consumed by a substantial number of small-scale farmers' households at 99.4 and 99.7%, respectively. This further concurs with other studies conducted in SSA and the Middle East which found that cereal intake is rather high compared to other dietary categories (Howe *et al.*, 2008; Rutstein & Johnson, 2004; Filmer & Pritchett, 2001). On the other hand, over 80% of the women consume legumes/pulses (Fig. 26), particularly common beans. Although farmers grew diverse of Lablab beans (Maass *et al.*, 2010; Forsythe, 2019; Grotelüschen, 2014). Lablab beans offer a substantial nutritional value (Morrison, 2019; Davari & Kasture, 2018). For instance, the protein content of Lablab beans is comparable with that of soybeans (Omondi, 2011), ranging from 22 to 35% (Sarma *et al.*, 2010). In Kenya, breastfeeding mothers use the bean to stimulate milk production and used school meals programs (Davari & Kasture, 2018; Omondi, 2011). Lablab dry beans, green beans (immature), and green leafy vegetables are



commonly used in Asian cuisines for stews, vegetables, and snacks (Dhaliwal, 2017; Abate *et al.*, 2012). Traditionally, beans boiling is considered as disadvantage method for increasing consumption of the bean foods (Hooper *et al.*, 2019; Oghbaei & Prakash, 2016; Tefera, 2006).

Furthermore, meat-based products (beef, poultry, and fish) were consumed by 70% of people in the Arumeru district (Fig. 26). Besides that, consumption of milk and dairy products was higher in the same district (66.7%) and Same (60.3%), but lower in Babati (40.5%) and Mvomero (23.3%) (Fig. 26). Likewise, in Arumeru (26.2%), Babati (19%), Same (37.2%), and Mvomero (23.3%), egg consumption was less than 50% (Fig. 26). This suggests that farmers disliked eggs or did not regard them as a priority food. Even though the data only covers a 24-hour period, it is clear that many households consume fewer eggs. Nut consumption, like eggs, was less than 40% in all districts (Fig. 26). According to French *et al.* (2019) and the World Bank (2008), most low-income families rarely purchase a variety of healthy foods. It is unclear why Lablab farmers take less dietary diversity (Fig. 26), despite the fact that the Lablab was grown primarily for household income (Forsythe, 2019; Grotelüschen, 2014; Shetto & Owenya, 2007).



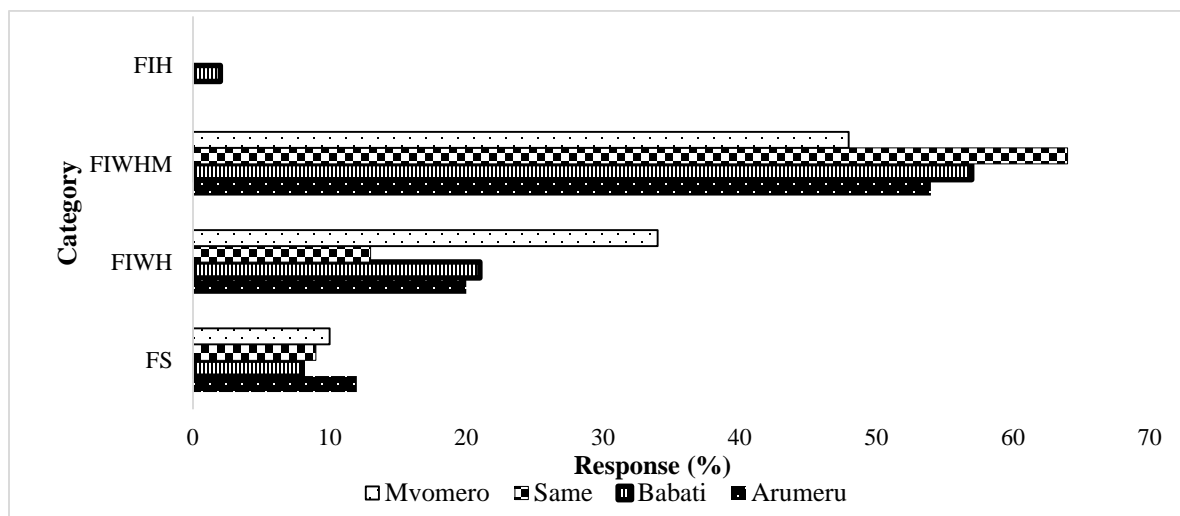
**Figure 26: Food groups (%) consumed by women on the previous day per district**

#### 4.6.3 Lablab Production and Household Dietary Diversity

Results in Table 27 signify ( $p \leq 0.05$ ) Lablab land size to have favourable effect in household food diversity. The majority of farmers could cultivate approximately 3 hectares. Fan and Rue (2020) commented that although smallholder farmers cultivate less than two hectares of land their farmlands provide an estimated 80% of the food produced for FNS (Wijk *et al.*, 2018; Nájera, 2017). Since Lablab support intercropping system (Fig.16), other crops such as maize, sunflower, intercropped with it added to dietary diversity. Findings also showed intercropping system was

positively contributed to household dietary diversity (Table 27). The findings are consistent with those of Nord *et al.* (2020) and Mthembu *et al.* (2017), who reported that intercropping increased food groups and allow variety of food crops grown on the same farm. In addition, the revenue from Lablab production can serve other household purposes, such as purchasing foods not grown on the farms, thereby increase diverse of foods (Saaka *et al.*, 2021). Besides that, Lablab crop is a good source of protein fodder for livestock which simulative milk production, further diversify diet by adding animal proteins to farmers' diets (National Research Council, 2006). Although revenue from Lablab sales contributed significantly ( $p \leq 0.05$ ) to growers' lives, it had a negative impact on the diet diversity (Table 27). Perhaps gender blindness on women's purchasing power within their households might explain this negative relation (Doss & Quisumbing, 2020), as a significant ( $p \leq 0.05$ ) the number of women (respondents) were married (Table 27). Patriarchy persists in many African cultures, affecting almost all family members' economic sources, eating habits, and a wife's decision-making freedom (Doss & Quisumbing, 2020; Ochieng *et al.*, 2017).

Other factors, such as income from other sources, improved dietary diversity positively and significantly ( $p \leq 0.05$ ), as reported in Arumeru (Table 27). According to FAO *et al.* (2021) households with multiple sources of income are more likely to spend a portion of their money on a variety of foods, which are typically expensive and infrequently purchased by low-income households. Though results revealed, still less than 20% of Lablab farmers' household are food secured (Fig. 27). This implies that Lablab production contributes less to farmer food quality. FAO and FHI 360 (2016) commented that realizing farmers' produce in terms of diet quality provides a promising context for Nutrition-sensitive agriculture in terms of improving growers' nutritional quality and livelihood, as well as future recommendation interventions if necessary.



**Figure 27: Household food security status: FS=food secure, FIWTH=food insecure without hunger, FIWHM=food insecure with moderate hunger, and FIWHSH=food insecure with severe hunger**

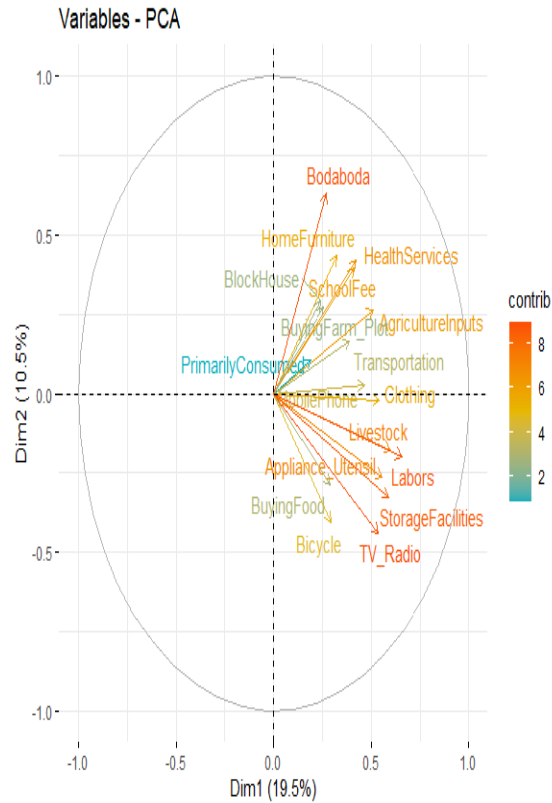
**Table 27: Lablab production determinants and MDD-W for household diet quality**

| Variable                        | Districts       |             |         | Arumeru         |             |         | Babati          |             |         | Same            |                |                | Mvomero         |                |                |
|---------------------------------|-----------------|-------------|---------|-----------------|-------------|---------|-----------------|-------------|---------|-----------------|----------------|----------------|-----------------|----------------|----------------|
|                                 | Coef            | SE          | P-value | Coef            | SE          | P-value | Coef            | SE          | P-value | Coef            | SE             | P-value        | Coef            | SE             | P-value        |
| Age                             | .047            | .0222       | .033*   | .103            | .0495       | .038*   | -.087           | .0896       | .334    | .103            | .0917          | .260           | .037            | .0461          | .428           |
| Education level                 | .017            | .0815       | .834    | .377            | .1713       | .028*   | -.238           | .4226       | .573    | -.041           | .3836          | .915           | -.041           | .1748          | .815           |
| Marital status= married         | 2.292           | .9323       | .014*   | 4.936           | 1.7643      | .005*   | 13.035          | 4.9190      | .008*   | .882            | 2.3060         | .702           | .249            | 1.2535         | .842           |
| Household size                  | .064            | .1109       | .566    | .402            | .2498       | .108    | .381            | .4044       | .347    | .297            | .4640          | .522           | .186            | .2236          | .406           |
| Years in Lablab farming         | -.001           | .0188       | .955    | .017            | .0435       | .691    | .071            | .0726       | .331    | -.032           | .0736          | .663           | -.011           | .0394          | .779           |
| Land size ≤ 1 hector            | 1.991           | 1.3113      | .129    | 4.384           | 3.0055      | .145    | 9.244           | 4.1610      | .026*   | 3.756           | 1.7282         | .030*          | 1.153           | 1.8952         | .543           |
| .Land size >1 and ≤ 2 hector    | -.490           | 1.2710      | .700    | 3.665           | 3.8606      | .342    | 2.562           | 3.8733      | .508    | 2.432           | 1.5526         | .117           | .754            | 2.8617         | .792           |
| Land size >2 and ≤3 hector      | 1.239           | .6079       | .042*   | -.382           | 1.5159      | .801    | 4.637           | 2.7642      | .093    | 0 <sup>a</sup>  | 0 <sup>a</sup> | 0 <sup>a</sup> | 3.144           | 1.3663         | .061           |
| Cropping system=1 sole          | -1.457          | 1.4691      | .321    | 1.851           | 2.5456      | .467    | -1.360          | 2.5561      | .962    | 1.919           | 1.6238         | .237           | 6.727           | 5.2063         | .196           |
| Cropping system=2 intercropping | .849            | 1.4033      | .545    | 3.342           | 2.4012      | .164    | 13.035          | 2.5687      | .695    | .882            | 2.3060         | .702           | 0 <sup>a</sup>  | 0 <sup>a</sup> | 0 <sup>a</sup> |
| Distance to market (km)         | .046            | .0355       | .191    | -.142           | .2040       | .487    | .049            | .0690       | .475    | .030            | .3372          | .928           | .015            | .0799          | .850           |
| Income from Lablab              | -<br>2.942E-006 | 1.2211E-006 | .016*   | -<br>2.007E-006 | 3.4246E-006 | .558    | -<br>4.366E-006 | 2.8901E-006 | .131    | -<br>4.785E-006 | 3.6264E-006    | .187           | -<br>7.536E-006 | 4.2345E-006    | .075           |
| Income from other sources       | 4.972E-007      | 4.4637E-007 | .265    | 1.858E-006      | 8.6357E-007 | .031*   | 5.711E-007      | 1.4864E-006 | .701    | 4.144E-007      | 1.0781E-006    | .701           | -<br>7.783E-006 | 8.8398E-006    | .379           |
| Constant                        | 2.724           | 2.1314      | .201    | -7.881          | 6.1442      | .200    | 2.766           | 5.3048      | .602    | -1.418          | 4.8668         | .771           | 2.849           | 3.1078         | .359           |
| Likelihood Ratio Chi-Square     | 30.543          |             |         | 21.684          |             |         | 34.566          |             |         | 14.466          |                |                | 20.848          |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |
|                                 |                 |             |         |                 |             |         |                 |             |         |                 |                |                |                 |                |                |

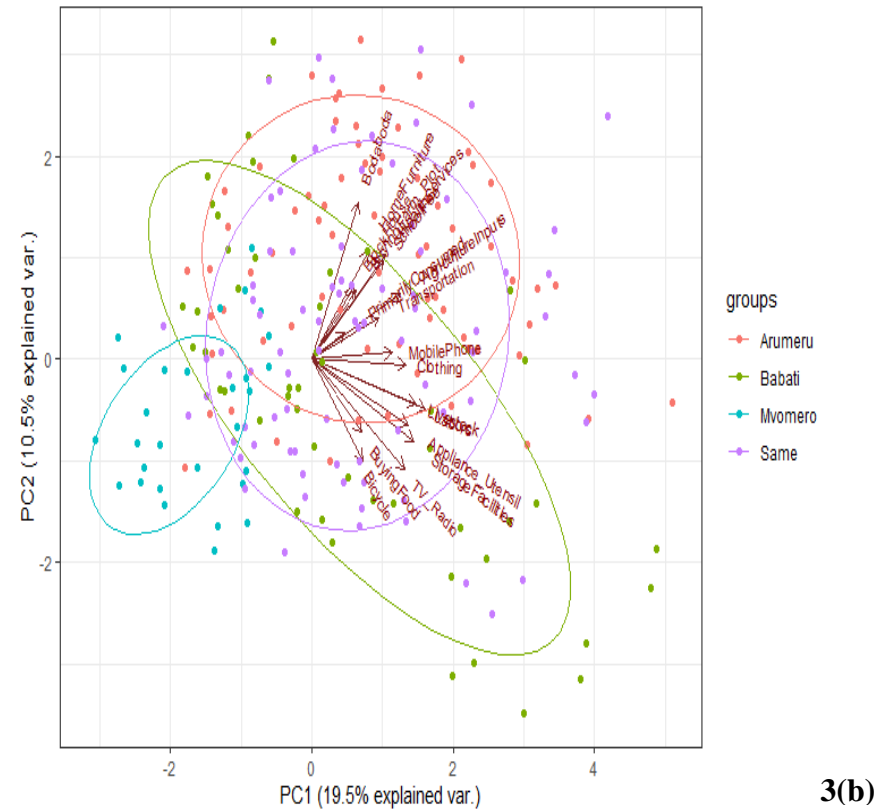
#### 4.6.4 Lablab Income Distributions

The products purchased by farmers' households as a result of Lablab production revenue are demonstrated in Figure 28. Lablab revenue was mostly used to buy *Bodaboda* (motorcycles), household furniture, animals, storage facilities, and television/radios in Arumeru, Babati, and Same (Fig. 28a). The crop was a primary source of sustenance for Mvomero households, where it was grown for food rather than cash (Fig. 28b). Farmers were discouraged from growing Lablab for commercial purposes due to an unreliable market in Mvomero. According to Morrison (2019), farmers are more inclined to produce crops with high market demand. In comparison to the northern part of Tanzania, perhaps market networking on Lablab is not as well established in the eastern zone (Nord *et al.*, 2020). Lablab are valued more for their economic value in northern Tanzania than for their direct food value, and they have a reliable market in Kenya (Nord *et al.*, 2020; Morrison, 2019). As per Fan and Rue (2020), despite being global food producers, smallholder farmers' household consumption of a variety of food categories remains questionable. Nutritional knowledge programs are required for farmers' households to have a better consumption of nutritious foods (FAO *et al.*, 2021).

Furthermore, Fig. 29 depicts the Dim-1 eigenvalue with higher component loadings above the dashed red line, which includes labor services, cattle acquisition, storage facilities, home appliances, television/radio, and health-care payment with no food items. According to the Dim-2 findings, the Lablab sales were prioritized on *bodaboda*, television/radio, home furniture, health services, bicycles, and storage facilities. Nonetheless, as seen in Dim-2, food had a lower contribution from Lablab earnings, as presented below the cutoff, indicating that the component less receives the contribution. It is possible to conclude that Lablab is less potentially utilized as food in the study sites despite its nutritional value like a protein source. This undervalues efforts to improve nutritional quality for human health among growers' households, where diverse food consumption is less prioritised. As said by Carletto *et al.* (2017) despite having empirically viable data on agricultural commercialization, smallholder farmers continue to suffer from poor household diet qualities. Therefore, since smallholder farmers are not a homogeneous group, the intervention or support required may depend on what they have commercialized in terms of the affordability to various diets (FAO *et al.*, 2021; Fan & Rue, 2020).

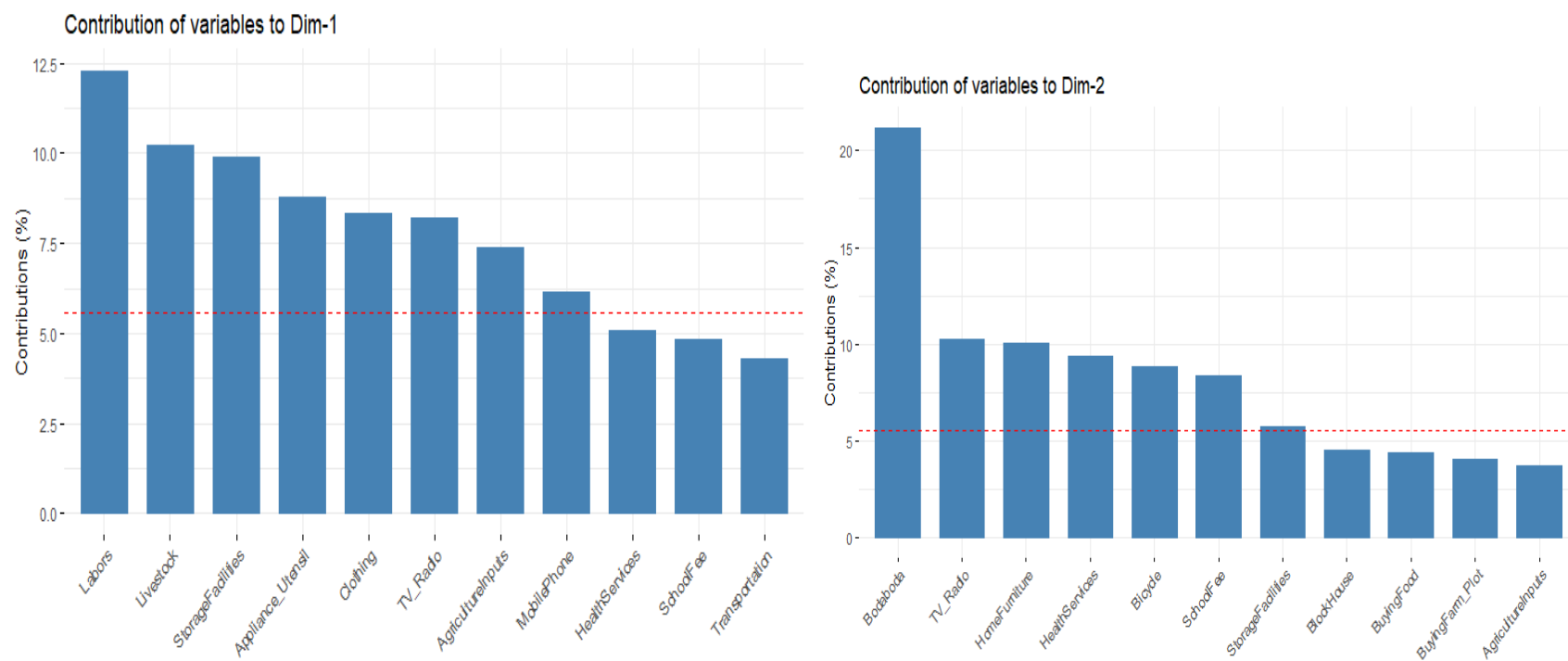


3(a)



3(b)

**Figure 28: Principal Component Analysis displaying the crop's resulting assets or services: 36(a) A biplot proxy of item variables presented as result of Lablab income gain in the household. Long arrows indicate an important contribution of the income in the acquired items. 36(b) A biplot showing items purchased using Lablab money by district (Arumeru, Babati, Mvomero, and Same)**



**Figure 29: Component loaded for patterns that retained in each of the item variables measured**

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATIONS

#### 5.1 Conclusion

From the findings, KAPs influenced farmers' understanding of black accessions cultivation significantly. In comparison to non-black accessions, which were unfamiliar across the study sites, black beans provided a strong source of money, motivating farmers to cultivate. Further, black beans were consumed less for food. Viewing the Lablab value chain revealed informed framework categories were systems, actors, and activities for enhanced farmer livelihood. The key actors are farmers, who have little bargaining power in the market, resulting in the sale of Lablab seeds at low prices. Middlemen buy at low prices and sell at high prices in Lablab's markets. This adds less to farmers' livelihood assets, particularly physical, social, and income assets.

Physical characteristics revealed that D-422, D-96, and ELD K2 had good seed quality. In terms of nutritional value, the protein content in all accessions was more than 23% higher than in common beans. Protein content is a criterion used for selecting the best accessions because it is a fundamental component of legumes. The black color (D-394) accession from Same District had the highest protein content of the four accessions typically cultivated by smallholder farmers (D-422, D-397, and D-419). Moreover, the accessions included a sufficient content of minerals, and during the sprouting and fermentation processes, D-96 and HA-4 from the NM-AIST Gene-bank were best reduced in ANFs, resulting in better mineral content availability such as Mg and Zn content. Among the two methods, fermentation is the most effective way for anti-nutrients reduction and sensory enhancement. Consumers observed this in cookies made using fermented D-96 and HA-4 flours. Therefore, the two accessions HA-4 and D-96 are the best and can be formulated to produce nutritious food products while also increasing income for a better livelihood. The remaining accessions should not be overlooked and should be submitted to more research in order to disclose their potential. Nonetheless, the commercially important black accessions (Arumeru D-422, Babati D-397, Same D-394, and D-419) had a lower impact on diet diversification. Likewise, income from Lablab business is less valued among farmers for diet diversity in improving nutritional quality in contrast to non-food items.

## **5.2 Recommendations**

Farmers should be educated on the nutritional value of Lablab seed, particularly as a source of nutrition security. Similarly, farmers should be made aware of the value addition of black-dominated beans as well as the availability of non-black beans for broader consuming options.

Farmers should also receive training and capacity building in marketing bargaining powers in order to gain more influence and effectively navigate the Lablab value chain. In addition, input supplies should provide optimum yielding seeds in rural agri-shops and at local marketplaces on time to boost production to enhance smallholder farmers' livelihoods.

Likewise, seeds with good quality and the best nutrient compositions should be promoted, and breeders of plants ought to replicate them to improve nutrition security and livelihoods. Furthermore, breeding Lablab seeds that are low in phytic acid, tannins, and trypsin inhibitors to increases the beans' utility in food systems. On the other hand, fermentation method should be promoted because it reduces anti-nutrients, improves nutritional values, and improves the sensory attributes of the bean foods.

In addition, diverse Lablab food products should be exhibited on various platforms, such as leaflet distribution for increase consumption and income creation. Further, food preparation and cooking training should be encouraged and supported for Lablab. Also, multi-stakeholder participation, including policymakers, encourages the use of Lablab seeds in diets and the best distribution of Lablab income at the household level for improved health and livelihood.



## REFERENCES

- Abate, T., Alene, A. D., Bergvinson, D., Shiferaw, B., Silim, S., Orr, A., & Asfaw, S. (2012). *Tropical Grain Legumes in Africa and South Asia: Knowledge and Opportunities*. International Crops Research Institute for the Semi-Arid Tropics. [https:// scholar. google. com/ scholar](https://scholar.google.com/scholar)
- Abioye, A. A., Zaid, Y. A., & Egberongbe, H. S. (2014). Documenting and disseminating agricultural indigenous knowledge for sustainable food security: The efforts of agricultural research libraries in Nigeria. *Libri*, 64(1), 75-84.
- Ade-Omowaye, B. I. O., Tucker, G. A., & Smetanska, I. (2015). Nutritional potential of nine underexploited legumes in Southwest Nigeria. *International Food Research Journal*, 22(2), 798–806.
- Adebisi, J. A., Obadina, A. O., Adebo, O. A., & Kayitesi, E. (2018). Fermented and malted millet products in Africa: Expedition from traditional/ethnic foods to industrial value-added products. *Critical Reviews in Food Science and Nutrition*, 58(3), 463-474.
- Adeyemo, S. M., & Onilude, A. A. (2013). Enzymatic Reduction of Anti-nutritional Factors in Fermenting Soybeans by *Lactobacillus plantarum* Isolates from Fermenting Cereals. *Nigerian Food Journal*, 31(2), 84–90. [https://doi.org/10.1016/S0189-7241\(15\)30080-1](https://doi.org/10.1016/S0189-7241(15)30080-1)
- Adhikari, L., Hussain, A., & Rasul, G. (2017). Tapping the potential of neglected and underutilized food crops for sustainable nutrition security in the mountains of Pakistan and Nepal. *Sustainability*, 9(2), 291.
- Adubra, L., Savy, M., Fortin, S., Kameli, Y., Kodjo, N. E., Fainke, K., Mahamadou, T., Le Port, A., & Martin-Prevel, Y. (2019). The minimum dietary diversity for women of reproductive age (MDD-W) indicator is related to household food insecurity and farm production diversity: Evidence from rural Mali. *Current Developments in Nutrition*, 3(3), 002.
- Aganga, A. A., & Tshwenyane, S. O. (2003). Lucerne, Lablab and *Leucaena leucocephala* Forages: Production and Utilization for Livestock Production. *Pakistan Journal of Nutrition*, 2(2), 46–53.
- Aguilera, Y., Díaz, M. F., Jiménez, T., Benítez, V., Herrera, T., Cuadrado, C., & Martín-Cabrejas, M. A. (2013). Changes in nonnutritional factors and antioxidant activity during germination of nonconventional legumes. *Journal of Agricultural and Food Chemistry*, 61(34), 8120–8125. <https://doi.org/http://doi.org/10.1021/jf4022652>

- Ahmed, O., & Sallam, W. (2020). Assessing the Potential of Improving Livelihoods and Creating Sustainable Socio-Economic Circumstances for Rural Communities in Upper Egypt. *Sustainability*, 12(16), 6307.
- Alayande, L. B. (2012). Comparison of nutritional values of brown and white beans in Jos North Local Government markets. *African Journal of Biotechnology*, 11(43), 10135–10140. <https://doi.org/10.5897/ajb11.3908>
- Ambrose, M., Fondevilla, S., Mcgeough, E., Mcphee, K., & Thompson, R. (2016). *Hyacinth bean: A Gem among Legumes: State of the Art in Lablab purpureus Research*. [http:// www. ias. csic. es/grainlegumesmagazine/legum\\_perspect\\_13.pdf](http://www.ias.csic.es/grainlegumesmagazine/legum_perspect_13.pdf)
- AOAC. (2005). *Association of Official Analytical Chemists Determination of Moisture Content, Fat Content, Ash Content, Protein Content and Fibre Content in Foods using Official Method no. 925.10, 2003.05, 923.03, 960.52 and 962.09, respectively*. [https:// scholar. google. com/ schola](https://scholar.google.com/schola)
- Appleton, K. M., Newbury, A., Almiron-Roig, E., Yeomans, M. R., Brunstrom, J. M., De Graaf, K., Geurts, L., Kildegaard, H., & Vinoy, S. (2021). Sensory and physical characteristics of foods that impact food intake without affecting acceptability Systematic review and meta-analyses. *An Official Journal of the International Association for the Study of Obesity*, 22(8), e13234. <https://doi.org/doi.org/10.1111/obr.13234>
- Ariina, M. M. S. (2018). *Studies on Genetic Variability in Indian Bean [Lablab purpureus (L) Sweet]*. <http://krishikosh.egranth.ac.in/handle/1/5810059477>
- Arora, R. K. (2014). *Diversity in Underutilized Plant Species: An Asia- Pacific Perspective*. *Biodiversity International*, New Delhi, India 203 p.
- Avilés-Gaxiola, S., Chuck-Hernández, C., & Serna Saldívar, S. O. (2018). Inactivation methods of trypsin inhibitor in legumes: A review. *Journal of Food Science*, 83(1), 17-29.
- Babati District Council. (2020). *United Republic of Tanzania Office of the President Regional Administration and Local Government Babati District Council*. [http:// www. babatidc. go. tz/ background](http://www.babatidc.go.tz/background)
- Bailey, R. L., Denby, N., Haycock, B., Sherif, K., Steinbaum, S., & von Schacky, C. (2015). Perceptions of a Healthy Diet Insights from a 3-Country Survey. *Nutrition Today*, 50(6), 282–287. <https://doi.org/doi:10.1097/nt.0000000000000119>

- Bailey, R. L., Akabas, S. R., Paxson, E. E., Thuppal, S. V., Saklani, S., & Tucker, K. L. (2017). Total Usual Intake of Shortfall Nutrients Varies With Poverty among US Adults. *Journal of Nutrition Education and Behavior*, 49(8), 639-646.e3.
- Baldermann, S., Blagojević, L., Frede, K., Klopsch, R., Neugart, S., Neumann, A., Ngwene, B., Norkewit, J., Schröter, D., Schröter, A., & Schweigert, F. J. (2016). Are Neglected Plants the Food for the Future? *Critical Reviews in Plant Sciences*, 35(2), 106–119. <https://doi.org/10.1080/07352689.2016.1201399>
- Bhuvaneshwari, S. (2008). *Assessment of Genetic Diversity in Local Collections of Field Bean (Lablab purpureus (L.) Sweet)*. <https://scholar.google.com/scholar>
- Bokeloh, G., Maria, G. B., Lioba, W., & Klaus, K. (2009). *Achieving Food and Nutrition Security Actions to Meet the Global Challenge A Training Course Reader*. [https:// doi. org/ http:// docplayer. net](https://doi.org/http://docplayer.net)
- Botelho, R., Araújo, W., & Pineli, L. (2018). Food formulation and not processing level: Conceptual divergences between public health and food science and technology sectors. *Critical Reviews in Food Science and Nutrition*, 58(4), 639–650.
- Bwalya, M. (2005). *Eotulelo Farmer Field School Group Likamba Village, Arumeru Arusha Region, Tanzania Soil and Water Conservation to Conservation Agriculture Practices (experiences and lessons from the efforts Eotulelo Farmer Field A)*. <http://www.fao.org>
- Caldas, B. M. (2009). *Inheritance of Seed Condensed Tannins and their Relationship with Seed-Coat Colour and pattern Genes in Common Bean (Phaseolus vulgaris L.* [https:// doi. org/ 10. 1007/ s00122-009-1023-4](https://doi.org/10.1007/s00122-009-1023-4). Epub 2009 Apr 12.
- Campbell, M. J., Radecki, Z., Trinkl, A., & Burns, K. I. (2000). *Report on the Intercomparison Runs for the Determination of Trace and Minor Elements in IAEA-359*. [https:// nucleus. iaea. org](https://nucleus.iaea.org)
- Carletto, C., Corral, P., & Guelfi, A. (2017). Agricultural commercialization and nutrition revisited Empirical evidence from three African countries. *Food Policy*, 67, 106–118. [https:// doi. org/ doi. org/10.1016/j.foodpol.2016.09.020](https://doi.org/doi.org/10.1016/j.foodpol.2016.09.020)
- Chinma, C. E., James, S., Ocheme, O., & Julian, A. (2011). Physicochemical and Sensory Properties, and In-Vitro Digestibility of Biscuits Physicochemical and Sensory Properties, and In-Vitro Digestibility of Biscuits Made from Blends of Tigernut (*Cyperus esculentus*) and Pigeon Pea (*Cajanus cajan*). *Nigerian Journal of Nutritional Sciences*, 32(1), 55–62.

- Chuen, C. W. (2018). *Optimisation of Soaking and Thermal Processing Methods in Reducing the trypsin, Chymotrypsin and Alpha-Amylase Inhibitors found in Underutilised Legumes for use as Aquafeed*. The University of Nottingham Malaysia Campus. <http://eprints.nottingham.ac.uk>
- Chung, K. T., Wong, T. Y., Wei, C. I., Huang, Y. W., & Lin, Y. (1998). Tannins and human health: A review. *Critical Reviews in Food Science and Nutrition*, 38(6), 421-464.
- Clydesdale, F. (2004). Functional foods: Opportunities and challenges. *Food Technology*, 2004, 35–40.
- Croffie, M. E., Williams, P. N., Fenton, O., Fenelon, A., Metzger, K., & Daly, K. (2020). Optimizing sample preparation and calibrations in EDXRF for quantitative soil analysis. *Agronomy*, 10(9), 1–16. <https://doi.org/10.3390/agronomy10091309>
- Cristina, O. D. L., V., Piuvezam, G., Leal, L. M. B., & Heloneida, D. A. M. A. (2019). Trypsin inhibitors: Promising candidate satietogenic proteins as complementary treatment for obesity and metabolic disorders?. *Journal of Enzyme Inhibition and Medicinal Chemistry*, 34(1), 405-419.
- Cullis, C., & Kunert, K. J. (2017). Unlocking the potential of orphan legumes. *Journal of Experimental Botany*, 68(8), 1895–1903. <https://doi.org/10.1093/jxb/erw437>
- Custodio, E., Kayikati, F., Fortin, S., Thomas, A. C., Kameli, Y., Nkunuzimana, T., Ndiaye, B., & Martin-Prevel, Y. (2020). Minimum dietary diversity among women of reproductive age in urban Burkina Faso. *Maternal and Child Nutrition*, 16(2), 1–12.
- Custodio, E., Kayitakire, F., & Thomas, A. C. (2016). *Exploring the new Indicator Minimum Dietary Diversity-Women*. <https://doi.org/10.2788/860238>
- Dansi, A., Vodouhè, R., Azokpota, P., Yedomonhan, H., Assogba, P., Adjatin, A., Loko, Y.L., Dossou-Aminon, I., & Akpagana, K. J. T. S. W. J. (2012). Diversity of the neglected and underutilized crop species of importance in benin. *The Scientific World Journal*, 2012, 1-20. <https://doi.org/10.1100/2012/932947>
- Darnhofer, I. (2020). Farming from a Process-Relational Perspective: Making Openings for. *Sociologia Ruralis*, 60(3), 1–24. <https://doi.org/10.1111/soru.12294>
- Darnhofer, I., & Vienna, L. S. (2016). *Contributing to a Transition to Sustainability of Agri-Food*

*Systems: Contributing to a Transition to Sustainability of Agri-Food Systems: Potentials and Pitfalls for Organic Farming.* <https://scholar.google.com/schola>

- Davari, S. A., & Kasture, M. C. (2018). Wal (*Lablab purpureus* L.): An unexploited potential food legumes SA Davari, NB Gokhale, VN Palsande and MC Kasture. *International Journal of Chemical Studies*, 6(2), 946–949.
- Dave, V. D. (2014). *Genetic Diversity Analysis in Indian Bean [Lablab purpureus (L.) Sweet]*. <http://krishikosh.egranth.ac>.
- De Vicente, M., Guzmán, F., Engels, J., & Rao, R. (2006). *Genetic Characterization and its Use in Decision-Making for the Conservation of Crop Germplasm. The Role of Biotechnology in Exploring and Protecting Agricultural Genetic Resources*. FAO.
- Dhaliwal, M. S. (2017). *Legume Vegetables*. <https://www.researchgate.net>
- Dobermann, A. (2018). *Putting the Sustainable Development Goals into Practice. In Putting the Sustainable Development Goals into Practice (pp. 328–338)*. Harpenden, Hertfordshire, United Kingdom. Retrieved from <https://www.karger.com/Article/PDF/452396>
- Dobrzański, B., & Stępniewski, A. (2013). *Physical Properties of Seeds in Technological Processes*. <https://doi.org/doi10.5772/3341>
- El-Adawy, T. A. (2002). Nutritional composition and antinutritional factors of chickpeas (*Cicer arietinum* L.) undergoing different cooking methods and germination. *Plant Foods for Human Nutrition*, 57, 83-97.
- Ertiro, B. T., Azmach, G., Keno, T., Chibsa, T., Abebe, B., Demissie, G., Worku, M. (2019). *Fast-Tracking the Development and Dissemination of a Drought-Tolerant Maize Variety in Ethiopia in Response to the Risks of Climate Change. The Climate-Smart Agriculture Papers*.
- Eskola, E. (2005). *Agricultural Marketing and Supply Chain Management in Tanzania: A Case Study*. Working Paper Series No. 16. 1-72
- Ewansiha, S. U., Chiezey, U. F., & Tarawali, S. A. (2007). Morpho-phenological variation in *Lablab purpureus*. *Tropical Grasslands*, 41, 277–284.
- Ewansiha, S. U., Ogedegbe, S. A., & Falodun, E. J. (2016). Utilization potentials of lablab (*Lablab purpureus* (L.) Sweet) and the constraints of field pests and diseases in Nigeria. *Agro-Science*, 15(1), 11-16.

- Fabbri, A. D., & Crosby, G. A. (2016). A review of the impact of preparation and cooking on the nutritional quality of vegetables and legumes. *International Journal of Gastronomy and Food Science*, 3, 2-11.
- Fan, S., & Rue, C. (2020). The role of smallholder farms in a changing world. *The Role of Smallholder Farms in Food and Nutrition security*, 2020,13-28.
- FAO, IFAD, UNICEF, WHO, & WFP. (2020). *Food Security and Nutrition in the World*. <https://doi.org/10.4060/ca9692en>
- FAO, IFAD, UNICEF, WHO, & WFP. (2021). *Food Security and Nutrition in the World for Food Security, Improved Nutrition and Affordable Healthy Diets for All*. Rome: FAO. <https://doi.org/10.4060/cb4474en>
- FAO. (2018). *Future Smart Food Rediscovering Hidden Treasures of Neglected and Underutilized Species for Zero Hunger in Asia, Executive summary, Bangkok, 36 pp*. <https://doi.org/http://www.fao.org/3/I8907EN/i8907en.pdf>
- FAO. (2009). *A Global Treaty for Food Security and Sustainable Agriculture*. <http://www.fao.org/3/a-i0510e.pdf>
- FAO. (2019). *Farm Management Guide*. <https://scholar.google.com/scholar>
- FAO & ILO. (2009). *The Livelihood Assessment Tool-kit: Analysing and Responding to the Impact of Disasters on the Livelihoods of People. The Effects of Brief Mindfulness Intervention on Acute Pain Experience: An examination of Individual Difference*. <http://www.fao.org>
- FAO & FHI 360. (2016). *Minimum Dietary Diversity for Women: A Guide for Measurement*. Rome: FAO. <https://doi.org/ISBN978-92-5-109153-1> (FAO)
- FAO IFAD UNICEF, WHO, & WFP (2017). *The State of Food Security and Nutrition in the World 2017. Building Resilience for Peace and Food Security*. Rome FAO. <https://doi.org/10.1080/15226514.2012.751351>
- FAO, IFAD, UNICEF, WFP, & WHO. (2019). *State of Food Security and Nutrition in the world 2019. Safeguarding against economic slowdowns and downturns*. <http://www.fao.org/3/ca5162en/ca5162en.pdf>
- Forsythe, C. (2019). *Exploring The Viability of Re- Introducing Lablab Purpureus ( L . ) Sweet as a Multifunctional Legume in Northern Tanzania*. <https://stud.epsilon.slu.se>

- Foyer, C. H., Lam, H. M., Nguyen, H. T., Siddique, K. H., Varshney, R. K., Colmer, T. D., Cowling, W., Bramley, H., Mori, T. A., Hodgson, J. M., & Cooper, J. W. (2016). Neglecting legumes has compromised human health and sustainable food production. *Nature Plants*, 2(8), 1-10.
- French, S. A., Tangney, C. C., Crane, M. M., Wang, Y., & Appelhans, B. M. (2019). Nutrition quality of food purchases varies by household income: The SHoPPER study. *BMC Public Health*, 19, 1-7.
- Fuller, D., Korisettar, R., Venkatasubbaiah, P. C., & Jones, M. K. (2004). Early plant domestications in southern India: Some preliminary archaeobotanical results. *Vegetation History and Archaeobotany*, 13, 115-129.
- Gacula, M., & Rutenbeck, S. (2006). Sample size in consumer test and descriptive analysis. *Journal of Sensory Studies*, 21(2), 129–145.
- Gao, Y. L., Wang, C. S., Zhu, Q. H., & Qian, G. Y. (2013). Optimization of solid-state fermentation with *Lactobacillus brevis* and *Aspergillus oryzae* for trypsin inhibitor degradation in soybean meal. *Journal of Integrative Agriculture*, 12(5), 869-876.
- Gemedie, H. F., & Ratta, N. (2014). Antinutritional factors in plant foods: Potential health benefits and adverse effects. *International Journal of Nutrition and Food Sciences*, 3(4), 284-289.
- Kumawat, G., Gupta, S., Ratnaparkhe, M. B., Maranna, S., & Satpute, G. K. (2016). QTLomics in soybean: A way forward for translational genomics and breeding. *Frontiers in Plant Science*, 7, 1852.
- Gopi, P., Satyanarayana, A., Rama, K., & Sambasiva K. R. S. (2017). Studies on the inheritance of bush habit and photo insensitivity in garden bean (*Lablab purpureus*) (*Dolichos lablab*). *Journal of Crop Research and Fertilizers*, 2, 1–3.
- Govindaraj, M., Vetriventhan, M., & Srinivasan, M. (2015). Importance of genetic diversity assessment in crop plants and its recent advances: An overview of its analytical perspectives. *Genetics Research International*, 2015, 1–14. <https://doi.org/10.1155/2015/431487>
- van der Greef, J., Van Wietmarschen, H., Schroën, Y., Babouraj, N., & Trousselard, M. (2015). Systematic approaches to evaluation and integration of eastern and Western medical practices. *Medical Acupuncture*, 27(5), 384-395.
- Grosso, G., Mateo, A., Rangelov, N., Buzeti, T., & Birt, C. (2020). Nutrition in the context of the

- Sustainable Development Goals. *European Journal of Public Health*, 30(1), i19–i23. <https://doi.org/10.1093/eurpub/ckaa034>
- Grotelüschen, K. (2014). *Lablab purpureus (L.) Sweet: A Promising Multipurpose Legume for Enhanced Drought Resistance and Improved Household Nutritional Status in Smallholder Farming Systems of Eastern Kenya [Doctoral Dissertation]*. Georg-August University. <https://scholar.google.com/>
- Gupta, R. K., Gangoliya, S. S., & Singh, K. N. (2015). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. *Journal of Food Science and Technology*, 52(2), 676–684. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4325021/>
- Guretzki, S., & Papenbrock, J. (2013). Characterization of Lablab purpureus regarding drought tolerance, trypsin inhibitor activity and cyanogenic potential for selection in breeding programmes. *Journal of Agronomy and Crop Science*, 200(1), 24–35.
- Habtemariam, L. T., Gornott, C., Hoffmann, H., & Sieber, S. (2021). Farm production diversity and household dietary diversity: Panel data evidence from rural households in Tanzania. *Frontiers in Sustainable Food Systems*, 5, 612341.
- Hadavani, J. K., Mehta, D. R., Lata, J. R., & Ghetiya, K. P. (2018). Genetic variability parameters in Indian bean (*Lablab purpureus* L.). *International Journal of Pure & Applied Bioscience*, 6(4), 164–168. <https://doi.org/http://dx.doi.org/10.18782/2320-7051.6785>
- Halewood, M., Chiurugwi, T., Sackville-Hamilton, R., Kurtz, B., Marden, E., Welch, E., Michiels, F., Mozafari, J., Sabran, M., Patron, N., & Kersey, P. (2018). Plant genetic resources for food and agriculture: Opportunities and challenges emerging from the science and information technology revolution. *New Phytologist*, 217(4), 1407–1419.
- Harouna, D. V., Venkataramana, P. B., Ndakidemi, P. A., & Matemu, A. O. (2018). Under-exploited wild Vigna species potentials in human and animal nutrition: A review. *Global Food Security*, 18(June), 1–11. <https://doi.org/10.1016/j.gfs.2018.06.002>
- Hassan, B. A., Mohamed A. A. I., Osman, M. N., Eltayeb, M. M., Osman, A. G., & Babiker, E. E. (2006). Effect of Processing Treatments Followed by Fermentation on Protein Content and Digestibility of Pearl Millet (*Pennisetum typhoideum*) Cultivars. *Pakistan Journal of Nutrition*, 5(1), 86–89. <https://doi.org/10.3923/pjn.2006.86.89>
- Hillenbrand, E. P., & Waid, J. L. (2014). *Adapting Food-based Strategies to Improve the Nutrition of Landless: A Review of HKI's Homestead Food Production in Bangladesh*. In Brian



- Thompson and Leslie Amoroso (Ed.), *Improving Diets and Nutrition: Food-based Approaches* (pp. 173–193). UK and USA: The Food and Agriculture Organization of the United Nations and CABI. <https://scholar.google.com/scholar>
- Hooper, S. D., Glahn, R. P., & Cichy, K. A. (2019). Single Varietal Dry Bean (*Phaseolus vulgaris* L.) Pastas: Nutritional Profile and Consumer Acceptability. *Plant Foods for Human Nutrition*, 74, 342–349.
- Hossain, S., Ahmed, R., Bhowmick, S., Mamun, A. A., & Hashimoto, M. (2016). Proximate composition and fatty acid analysis of Lablab purpureus (L.) legume seed: Implicates to both protein and essential fatty acid supplementation. *Springerplus*, 5(1), 1-10.
- Huang, J., Huang, Z., Jia, X., Hu, R., & Xiang, C. (2015). Long-term reduction of nitrogen fertilizer use through knowledge training in rice production in China. *Agricultural Systems*, 135, 105–111. <https://doi.org/10.1016/j.agsy.2015.01.004>
- ISTA. (2008). *Grinding in ISTA Moisture Testing*. [https:// doi. org/ http:// www. academia. edu/ 26670244](https://doi.org/http://www.academia.edu/26670244)
- Jain, A. K., Kumar, S., & Panwar, J. D. (2009). Antinutritional factors and their detoxification in pulses: A review. *Agricultural Reviews*, 30(1), 64-70.
- John, H. (2018). Studies on Minimally Processed Field Beans (*Dolichos lablab*) for Extending the Shelf-Life. *International Journal of Current Microbiology and Applied Sciences*, 7(06), 642–650.
- Kala, B. K., Soris, P. T., Mohan, V. R., & Vadivel, V. (2010). Nutrient and chemical evaluation of raw seeds of five varieties of Lablab purpureus (L.) sweet. *Advances in Bio research*, 1(1), 44-53.
- Mugambi, I. K. (2013). *Enhanced Legume Productivity Through Incorporation of Lablab Residues and Use of Legume Species Tolerant to Root Rot Disease Complex [Doctoral dissertation]*. <https://scholar.google.com>
- Karanja, D. (2016). *Pulses crops grown in Ethiopia, Kenya and United Republic of Tanzania for local and Export Market*. Int Trade Centre, East Afr Grain Counc. Geneva, Switzerland, 1-31.
- Kennedy, G., Ballard, T., & Dop, M. (2010). *Guidelines for Measuring Household and Individual Dietary Diversity*. <http://www.fao.org/3/a-i1983e.pdf>.

- Kerth, C. R. (2013). *The Science of Meat Quality*. Blackwell Publishing. [https:// scholar. google. com/scholar](https://scholar.google.com/scholar)
- Paudel, K. S., Deng, W., Paudel, B., Khatiwada, J. R., Zhang, J., & Su, Y. (2017). Household livelihood strategies and implication for poverty reduction in rural areas of central Nepal. *Sustainability*, 9(4), 612.
- Kilonzi, S. M. (2020). *Physicochemical and Functional Characterization of Three Lablab Bean (Lablab Purpureus L. (Sweet) Varieties Grown in Kenya*. Jomo Kenyatta University of Agriculture and Technology. <https://scholar.google.com/>
- Kilonzi, S. M., Makokha, A. O., & Kenji, G. M. (2017). Physical characteristics, proximate composition and anti-nutritional factors in grains of lablab bean (*Lablab purpureus*) genotypes from Kenya. *Journal of Applied Biosciences*, 114, 11289-11298.
- Kimani, E., Matasyoh, J., Kinyua, M., & Wachira, F. N. (2019). *Characterisation of Volatile Compounds and Flavour Attributes of Lablab purpureus Bean Accessions*. <https://scholar.google.com>
- Wachira, F. N., Kimani, E. N., & Kinyua, M. G. (2012). Molecular Diversity of Kenyan Lablab Bean (*Lablab purpureus* (L.) Sweet) Accessions Using Amplified Fragment Length Polymorphism Markers. *American Journal of Plant Sciences*, 2012(3), 313–321.
- Kimberly, M., & Deepa, G. (2014). *Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods*. <https://scholar.google.com/>
- Kiptoo, E., Waswa, L. M., & Ayuya, O. I. (2021). Linking farm production to household diets: Evidence from two low potential areas in Kenya. *Cogent Food & Agriculture*, 7(1), 1913842.
- Kitum, V. C., Kinyanjui, P. K., Mathara, J. M., & Sila, D. N. (2020). Effect of Lb. plantarum BFE 5092 Fermentation on Antinutrient and Oligosaccharide Composition of Whole Red Haricot Bean (*Phaseolus vulgaris* L). *International Journal of Food Science*, 2020(8876394), 1–22. <https://doi.org/doi.org/10.1155/2020/8876394>
- Kraaijvanger, R., Veldkamp, T., & Almekinders, C. (2016). Considering change: Evaluating four years of participatory experimentation with farmers in Tigray (Ethiopia) highlighting both functional and human–social aspects. *Agricultural Systems*, 147, 38–50.
- Larsson, S. (2018). *The sunflower value chain: A case study in Babati, Tanzania*. Södertörn University. <https://scholar.google.com>

- Lenné, J. M., & Wood, D. (2011). Agrobiodiversity management for food security: A critical review. *Agrobiodiversity Management for Food Security: A Critical Review*. <https://doi.org/10.5860/choice.49-2662>
- Letting, F. K., Venkataramana, P. B., & Ndakidemi, P. A. (2022). Farmers' Participatory Plant Selection of Lablab (*Lablab purpureus* (L.) Sweet) in Tanzania. *Frontiers in Plant Science*, 13, 784032. <https://doi.org/10.3389/fpls.2022.784032>
- Letting, F. K., Venkataramana, P. B., & Ndakidemi, P. A. (2021). Breeding potential of lablab [Lablab purpureus (L.) Sweet ]: A review on characterization and bruchid studies towards improved production and utilization in Africa. *Genetic Resources and Crop Evolution*, 68(8), 3081–3101. <https://doi.org/10.1007/s10722-021-01271-9>
- Maass, B. L., Robotham, O., & Chapman, M. A. (2017). Evidence for two domestication events of hyacinth bean (*Lablab purpureus* (L.) Sweet): A comparative analysis of population genetic data. *Genetic Resources and Crop Evolution*, 64, 1221-1230.
- Maass, B. L., Ayisi, K. K., Bopape, P. M., Usongo, M., & Pengelly, B. C. (2003). *Appropriate Germplasm Facilitates New Interest in Neglected Crops*. <https://scholar.google.com/scholar>
- Maass, B. (2006). *Changes in seed Morphology, Dormancy and Germination from wild to Cultivated Hyacinth bean Germplasm (Lablab purpureus Papilionoideae)*. <https://doi.org/10.1007/s10722-005-2782-7>
- Maass, B. (2016). *Domestication, Origin and Global Dispersal of Lablab Purpureus (L.)* [https://www.researchgate.net/publication/283634749\\_Domestication\\_origin\\_and\\_global\\_dispersal\\_of\\_Lablab\\_purpureus\\_L\\_Sweet\\_Fabaceae\\_current\\_understanding](https://www.researchgate.net/publication/283634749_Domestication_origin_and_global_dispersal_of_Lablab_purpureus_L_Sweet_Fabaceae_current_understanding)
- Maass, B. L., Knox, M. R., Venkatesha, S. C., Angessa, T. T., Ramme, S., & Pengelly, B. C. (2010). Lablab purpureus-A Crop Lost for Africa? *Tropical Plant Biology*, 3(3), 123–135. <https://doi.org/10.1007/s12042-010-9046-1>
- Mabhaudhi, T., Chimonyo, V. G., Chibarabada, T. P., & Modi, A. T. (2017). Developing a roadmap for improving neglected and underutilized crops: A case study of South Africa. *Frontiers in Plant Science*, 8, 2143.
- Macías, F. Y., & Glasauer, P. (2014). *Guidelines for Assessing Nutrition-Related Knowledge, Attitudes and Practices*. <http://www.fao.org/3/i3545e/i3545e00.htm>
- Mahadevu, P., & Gowda, M. B. (2005). Genetic improvement of Dolichos bean (*Lablab purpureus*

- (L.) Sweet) through use of exotic and indigenous germplasm. *Indian Journal of Plant Genetic Resources*, 18(1), 47-48.
- Maphosa, Y., & Jideani, V. A. (2017). The role of legumes in human nutrition. *Functional Food-Improve Health through Adequate Food*, 2017, 1, 13.
- Maro, C. N., Massawe, D. P., Tryphone, G. M., Myers, J. R., Davis, J. W., & Kusolwa, P. M. (2022). Identification of potential seed storage protein responsible for bruchid resistance in common bean landraces from Tanzania and Malawi. *African Journal of Biotechnology*, 21(1), 35-45. <https://doi.org/10.5897/AJB>
- Mayes, S., Massawe, F. J., Alderson, P. G., Roberts, J. A., Azam-Ali, S. N., & Hermann, M. (2012). The potential for underutilized crops to improve security of food production. *Journal of Experimental Botany*, 63(3), 1075–1079. <https://doi.org/10.1093/jxb/err396>
- Meru District Council. (2017). *The United Republic of Tanzania President's Office Regional Administration and Local Government*. <http://www.merudc.go.tz>
- Messina, M. (2016). Soy and Health Update: Evaluation of the Clinical and Epidemiologic Literature. *Nutrients*, 2016, 8(12), 754. <https://doi.org/10.3390/nu8120754>
- Miah, M. R. U., Barman, N., Alam, M. Z., Yesmin, K., & Ahmad, M. (2017). Effectiveness of Some IPM Packages Consisting of Chemical and Non Chemical Components for Suppressing Pod Borer and Aphid in Summer Country Bean. *Journal of Environmental Sciences & Natural Resources*, 10(1), 109–115.
- Minja, E. G., Swai, J. K., Mponzi, W., Ngowo, H., Okumu, F., Gerber, M., Pühse, U., Long, K. Z., Utzinger, J., Lang, C., & Beckmann, J. (2021). Dietary diversity among households living in Kilombero district, in Morogoro region, South-Eastern Tanzania. *Journal of Agriculture and Food Research*, 5, 100171.
- Mlyneková, Z., Chrenková, M. & Formelová, Z. (2004). Cereals and Legumes in Nutrition of People with Celiac Disease Request PDF. *International Journal of Celiac Disease*, 2(3), 105-109. <https://doi.org/10.12691/ijcd-2-3-3>.
- Mohan, N., & Aghora, T. S. (2018). Research Article Dolichos Bean: An Underutilized and Unexplored Crop with Immense Potential. *International Journal of Recent Advances in Multidisciplinary Research*, 05(12), 4338–4341.
- Molina, B. P., D'Alessandro, C., Dekeyser, K. & Marson, M. (2020). *Sustainable Food Systems*

*Through Diversification and Indigenous Vegetables. An Analysis of The Arusha Area.*  
<http://www.google.com>

Morrison, M. M. (2019). *Nutrient composition of Cooked Lablab Bean Varieties for Improving Nutrition and Food Security in Tanzania.* <http://www.suaire.sua.ac.tz>

Mthembu, B. E., Everson, T. M., & Everson, C. S. (2017). Intercropping maize (*Zea mays* L.) with lablab (*Lablab purpureus* L.) for sustainable fodder production and quality in smallholder rural farming systems in South Africa. *Agroecology and Sustainable Food Systems*, 42(4), 362–382. <https://doi.org/doi:10.1080/21683565.2017.1393649>

Mubarak, A. E. (2005). Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. *Food Chemistry*, 80(4), 489–495. <https://doi.org/doi:10.1016/j.foodchem.2004.01.007>

Mukherjee, R., Chakraborty, R., & Dutta, D. (2016). Role of Fermentation in Improving Nutritional Quality of Soybean Meal: A Review. *Asian-Australasian Journal of Animal Science*, 29(11), 1523–1529.

Muoni, T. (2019). *Integrating Legumes in Mixed Crop-Livestock Systems in East Africa: Farmers' Perceptions, Ecosystem Services and Support for Decision Making.* Swedish University of Agricultural Sciences. [https://pub.epsilon.slu.se/16308/7/muoni\\_t\\_190903.pdf](https://pub.epsilon.slu.se/16308/7/muoni_t_190903.pdf)

Murphy, A. M., & Colucci, P. E. (1999). A review of Lablab purpureus. <http://www.fao.org/livestock>

Murugkar, D. A. (2014). Effect of sprouting of soybean on the chemical composition and quality of soymilk and tofu. *Journal of Food Science and Technology*, 51(5), 915–921.

Mutambuka, M. (2013). *Iron Bioavailability and Consumer Acceptability of Extruded Common Bean (Phaseolus vulgaris) flour.* Iowa State University. <https://scholar.google.com/scholar>

Mvomero District Council. (2018). *United Republic of Tanzania Office of the President Regional Administration and Local Government Same District Council.* <http://mvomerodc.go.tz/>

Nájera, J. (2017). Integration of Small Farmers Into Global Value Chains: Challenges and opportunities inside the current global demand. Integración de pequeños agricultores en cadenas globales de valor: Desafíos y oportunidades dentro de la demanda global actual. *Empresarial*, 11(2), 7. <https://doi.org/10.18845/te.v11i2.3229>

National Research Council. (2006). *Lost Crops of Africa: Volume II: Vegetables / The National*

- Naveed, T. A., Gordon, D., Ullah, S., & Zhang, M. (2021). The construction of an asset index at household level and measurement of economic disparities in Punjab (Pakistan) by using MICS-micro data. *Social Indicators Research*, 155, 73-95.
- NBS. (2018). *Tanzania GDP Expanded by 7.1% in 2017*. <https://scholar.google.com/scholar>
- Naylor, R. L., Falcon, W. P., Goodman, R. M., Jahn, M. M., Sengooba, T., Tefera, H., & Nelson, R. J. (2004). Biotechnology in the developing world: A case for increased investments in orphan crops. *Food Policy*, 29(1), 15-44.
- Neudert, R., Allahverdiyeva, N., Mammadov, N., Didebulidze, A., & Beckmann, V. (2020). Diversification of livestock-keeping smallholders in mountainous rural regions of Azerbaijan and Georgia. *Land*, 9(8), 1–23. <https://doi.org/10.3390/LAND9080267>
- Ngailo J. A, Kaihura, F. B. S., Baijukya, F., & Kiwambo, B. (2003). *Land Use Changes and their Impact on Agricultural Biodiversity in Arumeru, Tanzania*. <https://scholar.google.com>
- Ngala, S. (2015). *Evaluation of Dietary Diversity Scores to Assess Nutrient Adequacy among Rural Kenyan Women* S. A. Ngala. <https://doi.org/ISBN 978-94-6257-423-6>
- Nord, A. (2017). *Abstract Uncovering the Potential of a Multi-Purpose Legume, (I)Lablab Purpureus(I) (L.* <https://scisoc.confex.com/crops/2017am/webprogram/Paper107072.html>
- Nord, A., Miller, N. R., Mariki, W., Drinkwater, L., & Snapp, S. (2020). Investigating the diverse potential of a multi-purpose legume, Lablab purpureus (L.) Sweet, for smallholder production in East Africa. *Plos One*, 15(1), e0227739.
- Nyende, P., & Delve, R. J. (2004). Farmer participatory evaluation of legume cover crop and biomass transfer technologies for soil fertility improvement using farmer criteria, preference ranking and logit regression analysis. *Experimental Agriculture*, 40(1), 77-88.
- Obadina, A. O., Akinola, O. J., Shittu, T. A., & Bakare, H. A. (2013). Effect of natural fermentation on the chemical and nutritional composition of fermented soymilk nono. *Nigerian Food Journal*, 31(2), 91-97.
- Ochieng, J., Afari-Sefa, V., Lukumay, P. J., & Dubois, T. (2017). Determinants of dietary diversity and the potential role of men in improving household nutrition in Tanzania. *Plos One*, 12(12), e0189022.

- Oghbaei, M., & Prakash, J. (2016). Effect of primary processing of cereals and legumes on its nutritional quality: *A comprehensive review. Cogent Food & Agriculture*, 2(1), 1136015.
- Ojiewo, C., Rubyogo, J. C., Wesonga, J., Bishaw, Z., Abang, M. M., & Gelalcha, S. (2018). *Mainstreaming Efficient Legume Seed Systems in Eastern Africa: Challenges, Opportunities and Contributions Towards Improved Livelihoods*. Rome, Food and Agriculture Organization of the United Nations
- Olagunju, O. F., Ezekiel, O. O., Ogunshe, A. O., Oyeyinka, S. A., & Ijabadeniyi, O. A. (2018). Effects of fermentation on proximate composition, mineral profile and antinutrients of tamarind (*Tamarindus indica* L.) seed in the production of daddawa-type condiment. *LWT*, 90, 455-459.
- Omondi, O. S. (2011). *The potential for Njahi (Lablab Purpureus L.) in Improving Consumption Adequacy for Protein, Iron and zinc in Households: A Case for Nandi south District, Kenya [Doctoral Dissertation]*. University of Nairobi. <https://scholar.google.com>
- Onwurafor, E. U., Onweluzo, J. C., & Ezeoke, A. M. (2014). Effect of fermentation methods on chemical and microbial properties of mung bean (*Vigna radiata*) flour. *Nigerian Food Journal*, 32(1), 89-96.
- Østerberg, J. T., Xiang, W., Olsen, L. I., Edenbrandt, A. K., Vedel, S. E., Christiansen, A., Landes, X., Andersen, M. M., Pagh, P., Sandøe, P., & Nielsen, J. (2017). Accelerating the domestication of new crops: Feasibility and approaches. *Trends in Plant Science*, 22(5), 373-384.
- Osborn, T. C., Blake, T., Gepts, P., & Bliss, F. A. (1986). *Bean Arcelin*. <https://scholar.google.com>
- Owenya, M. Z., Mariki, W. L., Kienzle, J., Friedrich, T., & Kassam, A. (2011). Conservation agriculture (CA) in Tanzania: The case of the Mwangaza B CA farmer field school (FFS), Rhotia Village, Karatu District, Arusha. *International Journal of Agricultural Sustainability*, 9(1), 145-152.
- Padulosi, S., Thompson, J., & Rudebjer, P. (2013). *Neglected and Underutilized Species*. [www.bioversityinternational.org](http://www.bioversityinternational.org)
- Partridge, I. (2003). *Better Pastures for the Tropics: Lablab*. <https://www.tropicalgrasslands>.
- Paudel, K. S., Deng, W., Paudel, B., Khatiwada, J. R., Zhang, J., & Su, Y. (2017). Household livelihood strategies and implication for poverty reduction in rural areas of central Nepal.

- Pengelly, B. C., & Maass, B. L. (2001). *Lablab purpureus* (L.) Sweet—diversity, potential use and determination of a core collection of this multi-purpose tropical legume. *Genetic Resources and Crop Evolution*, 48, 261-272.
- Popoola, J., Ojuederie, O., Omonhinmin, C., & Adegbite, A. (2019). *Neglected and Underutilized Legume Crops: Improvement and Future Prospects. In Recent Advances in Grain Crops Research*. IntechOpen. <https://scholar.google.com>
- Purwanti, E., Prihanta, W., & Fauzi, A. (2019). The diversity of seed size and nutrient content of lablab bean from three locations in indonesia. *International Journal of Advanced Engineering, Management and Science*, 5(6), 395-402.
- Qamar, S., Manrique, Y. J., Parekh, H., & Falconer, J. R. (2019). Nuts, cereals, seeds and legumes proteins derived emulsifiers as a source of plant protein beverages: A review. *Critical Reviews in Food Science and Nutrition*, 0(0), 1–21.
- Rai, N., Kumar, A., Singh, P. K., Singh, M., Datta, D., & Rai, M. (2010). Genetic relationship among Hyacinth bean (*Lablab purpureus*) genotypes cultivars from different races based on quantitative traits and random amplified polymorphic DNA marker. *African Journal of Biotechnology*, 9(2), 137–144.
- Ramadoss, B. R., & Shunmugam, A. S. (2014). Anti-dietetic factors in legumes: Local methods to reduce them. *International Journal of Food Sciences and Nutrition*, 3(3), 84-89.
- Rick. D. S., Holloway, A., Mullins, D., Nchabeleng, L., & Ward, P. (2002). *Learning Aboutlivelihoods Insights from Southern Africa*. South Africa and Oxfam GB in the UK.
- Robotham, O., & Chapman, M. (2017). Population genetic analysis of the hyacinth bean (*Lablabpurpureus*(L.) Sweet, Leguminosae) indicates an East African origin and variation in drought tolerance. *Genetic Resources and Crop Evaluation*, 64(1), 139–148.
- Rohman, A., Helmiyati, S., Penggalih, M., & Setyaningrum, D. (2014). Rice in health and nutrition. *International Food Research Journal*, 21(1), 13-24.
- Rouf-Shah, T., Prasad, K., & Kumar, P. (2016). Maize: A potential source of human nutrition and health: A review. *Cogent Food & Agriculture*, 2(1), 1166995.
- Ruelle, M. L., Asfaw, Z., Dejen, A., Tewolde-Berhan, S., Nebiyu, A., Tana, T., & Power, A. G. (2019). Inter-and intraspecific diversity of food legumes among households and communities



in Ethiopia. *PloS One*, 14(12), e0227074.

- Giller, K. E., Franke, A. C., Abaidoo, R., Baijukya, F., Bala, A., Boahen, S., Dashiell, K., Kantengwa, S., Sanginga, J. M., Sanginga, N., & Simmons, A. (2013). *N2Africa: Putting Nitrogen Fixation to work for Smallholder Farmers in Africa*. In *Agro-Ecological Intensification of Agricultural Systems in the African Highlands* (pp. 156-174). Routledge. <http://www.google.com>
- Saaka, M., Mutaru, S., & Osman, S. M. (2021). Determinants of dietary diversity and its relationship with the nutritional status of pregnant women. *Journal of Nutritional Science*, 10(14), 1-8.
- Same District Council. (2018). *United Republic of Tanzania Office of the President Regional Administration and Local Government Same District Council*. <http://samedc.go.tz/>
- Sarma, B., Sarma, A., Handique, G. K., & Handique, A. K. (2010). Evaluation of Country Bean (*Dolichos Lablab*) landraces of North East India for Nutritive Values and Characterization through Seed Protein Profiling. *Legume Research*, 33(3), 184–189.
- Savitha, B. N. (2008). *Characterization of Avare (Lablab purpureus ( L .) Sweet ) Local Collections for Genetic*. <http://krishikosh.egranth.ac.in/bitstream/1/82563/1/th9751.pdf>
- Seville, D., Buxton, A., & Vorley, W. (2011). *Under what Conditions are Value Chains Effective Tools for Pro-Poor Development?*. <https://scholar.google.com>
- Shelef, O., Weisberg, P. J., & Provenza, F. D. (2017). The value of native plants and local production in an era of global agriculture. *Frontiers in Plant Science*, 8, 2069.
- Sherasia, P. L., Garg, M. R., & Bhandari, B. M. (2018). *Pulses and their By-Products as Animal Feed*. United Nations. <https://scholar.google.com>
- Shetto, R., & Owenya, M. (2007). *Conservation Agriculture as Practised in Tanzania: Three Case studies*. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations. <https://scholar.google.com>
- Shruthi, B. S. (2008). *Nutrient Composition, Product Development and Sensory Evaluation of Dolichos Bean (Lablab purpureus)*. <https://scholar.google.com>
- Siddique, K. (2016). *Pulses Contribution to Production and Dietary Diversity to Eradicate Hunger and Malnutrition*. <https://scholar.google.com>

- Singh-ackbarali, D., & Maharaj, R. (2014). Sensory Evaluation as a Tool in Determining Acceptability of Innovative Products Developed by Undergraduate Students in Food Science and Technology at The University of Trinidad and Tobago. *Journal of Curriculum and Teaching*, 3(1), 10–27. <https://doi.org/10.5430/jct.v3n1p10>
- Singh, A., & Abhilash, P. C. (2019). Varietal dataset of nutritionally important Lablab purpureus (L.) sweet from Eastern Uttar Pradesh, India. *Data in Brief*, 24, 103935.
- Smith, A. D., Emmett, P. M., Newby, P. K., & Northstone, K. (2013). Dietary patterns obtained through principal components analysis: The effect of input variable quantification. *British Journal of Nutrition*, 109(10), 1881-1891.
- Nkhata, S. G., Ayua, E., Kamau, E. H., & Shingiro, J. B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food Science & Nutrition*, 6(8), 2446-2458.
- Smith, S. M. (2013). *Determining Sample Size. How to Ensure You Get the Correct Sample Size* [<https://www.ndsu.edu/gdc/wp-content/pdf/Determining-Sample-Size.pdf>]
- Soetan, K. O. (2012). Comparative evaluation of phytochemicals in the raw and aqueous crude extracts from seeds of three Lablab purpureus varieties. *African Journal of Plant Science*, 6(15), 410-415.
- Soetan, K. O., & Oyewole, O. E. (2009). The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds: A review. *African Journal of Food Science*, 3(9), 223–232. Retrieved from <http://www.academicjournals.org/AJFS>
- Sonali, A., & Vishwakarma M. K. A. (2015). Comparative Study of Indian Varieties of Lablab and Field Bean for Phenotypic and Nutritional Traits Sonali Legume Genomics and Genetics. *Legume Genomics and Genetics*, 6(3), 1–7. <https://doi.org/doi: 10.5376/lgg.2015.06.0003>
- Sridhar, K. R., & Seena, S. (2006). Nutritional and antinutritional significance of four unconventional legumes of the genus Canavalia: A comparative study. *Food Chemistry*, 99(2), 267-288.
- Suárez-Martínez, S. E., Ferriz-Martínez, R. A., Campos-Vega, R., Elton-Puente, J. E., De La Torre Carbot, K., & García-Gasca, T. (2016). Bean seeds: Leading nutraceutical source for human health. *Journal of Food*, 14(1), 131–137.
- Subuola, F., Widodo, Y., & Kehinde, T. (2012). Processing and utilization of legumes in the

- tropics. *Trends in Vital Food and Control Engineering*, 77, 1-18.
- Tadele, Z. (2009). Role of Orphan Crops in Enhancing and Diversifying Food Production in Africa. *Journal*, 6(3/4), 9–15.
- Tadesse, B., & Bakala, F. (2018). Value Chain Analysis of Potato: The Case of Sheka Zone, Southwest Ethiopia. *International Journal of Horticulture & Agriculture*, 3(1), 1–10. <https://doi.org/10.15226/2572-3154/3/1/00117>
- Tamás, B. (2005). Estimation of marginal effects using margeff. *The Stata Journal*, 5(3), 309–329.
- Tefera, T. (2006). Towards improved vegetable use and conservation of cowpea and lablab: Atronomic and participatory evaluation in northeastern Tanzania and genetic diversity study. *Cuvillier*, 49(0), 0–9.
- Tsaju, V. S., Bouba, A. A., & Yanou, N. N. (2021). Technological potential of under-utilized starches from eight varieties of legumes grown in Cameroon. *Brazilian Journal of Biology*, 81(1), 1–10. <https://doi.org/doi.org/10.1590/1519-6984.195234>
- Agrawal, A., Pandey, A., Varaprasad, K. S., Tyagi, R. K., & Khetarpal, R. K. (2018). Regional expert consultation on underutilized crops for food and nutrition security in Asia and the Pacific. *Indian Journal of Plant Genetic Resources*, 31(2), 194-195.
- UN. (2015). *The World Population Prospects 2015 Revision Latest Major Publications: United Nations Department of Economic and Social Affairs*. <https://scholar.google.com>
- UNICEF and TANZANIA. (2016). *Tanzania Joint Multi-Sectoral Nutrition Review* [https://www.unicef.org/tanzania/media\\_18904.html](https://www.unicef.org/tanzania/media_18904.html)
- UNICEF, FAO, IFAD, UNICEF, WFP & WHO. (2018). *The State of Food Security and Nutrition in the World 2018. Building Climate Resilience for Food Security and Nutrition*. Rome, FAO. Licence: CC BY-NC-SA 3.0 IGO. <https://scholar.google.com>
- URT. (2015). *National Nutrition Strategy*. <https://scholar.google.com>
- Minde, J. J., Matemu, A. O., & Venkataramana, P. B. (2022). Contribution of the Dolichos Lablab value chain to farmer's household livelihood assets in Tanzania. *Heliyon*, 8(11), 1-11.
- Kalpanadevi, V., & Mohan, V. R. (2013). Nutritional and anti nutritional assessment of under utilized legume D. lablab var. vulgaris L. *Bangladesh Journal of Scientific and Industrial*

- Venkatesha, S. C., Gowda, M. B., Mahadevu, P., Rao, A. M., Kim, D. J., Ellis, T. H. N., & Knox, M. R. (2007). Genetic diversity within *Lablab purpureus* and the application of gene-specific markers from a range of legume species. *Plant Genetic Resources*, 5(3), 154-171.
- Vidigal, P., Duarte, B., Cavaco, A.R., Caçador, I., Figueiredo, A., Matos, A. R., Viegas, W., & Monteiro, F. (2018). Preliminary diversity assessment of an undervalued tropical bean (*Lablab purpureus* (L.) Sweet) through fatty acid profiling. *Plant Physiology and Biochemistry*, 132, 508-514.
- Fathonah, S., Amalia, B., & Humaizah, S. (2020). The formulation of alternative gluten-free mung bean biscuits. *Journal of Physics: Conference Series*, 1444(1), 012004.
- Von, O. (2014). *Food and Nutrition Security. The Concept and its Realization. Pontifical Academy of Sciences, Scripta Varia 125, Vatican City 2014.* www.pas.va
- Weinberger, K., & Msuya, J. (2004). *Indigenous Vegetables in Tanzania: Significance and Prospects.* <https://doi.org/10.1017/CBO9781107415324.004>
- Weingärtner, L. (2000). Assessment Instruments and Intervention Strategies Lioba Weingärtner *The Concept of Food and Nutrition Security*, 1, (I), 1–28.
- WHO. (2017). *The State of Food Security and Nutrition in the World 2017.* [http:// www. who. int/ nutrition/ publications/foodsecurity/state-food-security-nutrition-2017-inbrief-en.pdf?ua=1](http://www.who.int/nutrition/publications/foodsecurity/state-food-security-nutrition-2017-inbrief-en.pdf?ua=1)
- Wijk, M. V., Hammond, J., Frelat, R., Fraval, S., Teufel, N., Tavenner, K., & Henderson, B. (2018). *Smallholder Farmers, Food Security, and Livelihoods: Exploring Trade Offs and Synergies Using Farm Household Characterization Data.* Rome, Italy: CGIAR Independent Science & Partnership Council (ISPC) Secretariat.
- World Bank. (2008). *World Development Report 2008 Agriculture for Development World Development Report.* <https://doi.org/doi.org/10.1596/978-0-8213-6807-7>
- Xiao, J., & Bai, W. (2019). Bioactive phytochemicals. *Critical Reviews in Food Science and Nutrition*, 59(6), 827–829. <https://doi.org/10.1080/10408398.2019.1601848>
- Zotor, F. B., & Amuna, P. (2017). The food multimix concept: Harnessing and promoting local composite complementary diets. *Proceedings of the Nutrition Society*, 76(4), 535-542.
- Zotor, F. B., Ellahi, B., & Amuna, P. (2015). Applying the food multimix concept for sustainable

and nutritious diets. *Proceedings of the Nutrition Society*, 74(4), 505-516.

## APPENDICES

### Appendix 1: Questionnaire for farmers and consumers at household level

#### Potentials of underutilized Dolichos Lablab (*Lablab Purpureus*) Seeds in improving nutritional quality and livelihood in Tanzania

##### Part A: Background information

Q1. Date of Interview: \_\_\_\_/\_\_\_\_/\_\_\_\_

Q2. Questionnaire No.: \_\_\_\_

Q3. Region: \_\_\_\_\_

Q4. District: \_\_\_\_\_ Village: \_\_\_\_\_

Q5. Phone number (mobile, if available): \_\_\_\_\_

| Social and Demographic Status of Respondents |  | Tick appropriate  |
|--|--|---|
| 6.   | Gender:  | 1. Male 2. Female   |
| 7.   | Interviewee's age:   | 1=12-20, 2=21-30, 3=31-40, 4=41-50, 5=51-60, 6= Over 60         |
| 8.   | Marital status   | 1=Single 2=Married 3=Separated 4=Divorced 5=Widow/widower       |
| 9.   | Education background:  | 1=Primary 2=Secondary/<br>3=College/University/ 4=other specify |
| 10.  | Household composition:   | 1=no. males 2= no. females (with their ages)                    |
|  |  |   |
|  |  |   |
|  |  |   |
| 11.  | Occupation other than cultivation of lablab<br>With average income per month | 1=<br>2=<br>3=<br>4=  |

##### Part B: Lablab production

| Investigation of lablab farmers' production practices |  | Please tick that appropriate  |
|---|--|---|
| 12.   | What is your land tenure status?   | 1= Land owned 2= Land rented 3= Other (Specify) _____   |
| 13.   | Through which means did you acquire land?                                  | 1= Inheritance from parents 2= Purchased 3= Gift 4= Other (Specify) _____   |
| 14.   | What is your land area under crop production (hectares)?                   | 1= Larger farmer (farm greater than 5 hectares)<br>2= Medium farmer (farm greater than 2 and less than/equal to 5 ha) 3= Small farmer/Marginal farmer (farm less than/equal to 2ha) |
| 15.   | When did you start cultivating lablab                                      | Year _____  |
| 16.   | Do you annually harvest?   | 1=Yes 0=No 3=Other specify _____  |
| 17.   | Please estimate the space occupied by Lablab production in your farm land. | 1= ≤ 10% 2= 11-20% 3= 21-30% 4= 31-40% 5= 41-50% 6= ≥ 50%   |
| 18.   | What cropping system applied in your farming activities?                   | 1= Pure stand 2= Intercropping 3= _____   |
| 19.   | Where do you get your seeds for planting?                                  | 1=friends 2=relatives 3=buy kg _____ and Tshs _____   |
| 20.   | Mention Lablab accessions do you cultivate                                 | 1=<br>2=<br>3=  |
| 21.   | Why do you grow Lablab?<br>Please tick that appropriate (main reason)      | 1= Auto-consumption 2= Contract grower 3= Available market 4= Other (specify) _____   |

|     |   |  |
|-----|---|--|
| 22. | How many years have you been growing Lablab? (Years of experience)  | 1= 0-5 years 2= 6-10 years 3= 11-15 years 4= 16-20 years 5= >20 years  |
| 23. | Have you change your farm over the years  | Year_____ 1= _____(Ha) 2= yield_____   |
| 24. | Do you think this structure will change for 2018? If yes, please confirm the change:  | 1= Yes by _____<br>0=No  |
| 25. | At what period of the year do you grow lablab?  | 1=Farming in dry season 2= Farming under rain-fed conditions 3= Both   |
| 26. | Please list tillage tools used for land preparation in the production of Lablab.  | 1=Axe 2= Hoe 3= Machete 4= Wheel barrow 5= Ox-plough cultivation 6=Tractor 7= Other (specify)_____   |
| 27. | Do you apply inputs in lablab production?   | 1= Yes 0= No   |
| 28. | If yes, please tick all that apply (Inputs used)  | 1=Improved seeds 2= Inorganic fertilizer 3= Organic fertilizer 4= Pesticides 5= None   |
| 29. | If pest control is among your farming activities, what kind of pesticide do you use in lablab cultivation?                          | Mention  |
| 30. | If you don't apply pesticide, give reasons.   | 1= Spray cause health problems 2= Spray is harmful to environment 3= Lack of knowledge on the use of pesticides 4= Pesticides are costly 5= Other (Specify)_____   |
| 31. | Do you buy the inputs?  | 1= Yes 0= No   |
| 32. | If Yes, from where do you buy them? Please tick all that apply.   | 1= Agro-chemical dealers 2= Market 3= Other (specify)_____   |
| 33. | If No, how do you get them? Source of supply  | 1= Other farmers 2= Cooperatives 3= NGOs 4= Government subsidies 5= Other (specify)_____   |
| 34. | Which water supply system do you apply in Lablab production?  | 1= Rain-fed farming 2= Watering can irrigation 3= Sprinkler irrigation 4= Drip or trickle irrigation 5= Other specify_____   |
| 35. | Does climate change affect your activities of Lablab production?  | 1=Yes 0= No  |
| 36. | If yes, what is the effect of climate change on your produce?   | 1= Frequent floods 2= Soil erosion 3= Wind erosion 4= Soil degradation/depletion 5= Drought 6= Plant diseases  |
| 37. | Which main methods do you use for Lablab harvesting?  | 1= Uprooting the crop 2= Harvesting of leaves 3= Harvesting of leaves and stem tops 4. Dried seeds 5= Green beans 6= Other (specify)_____                          |
| 38. | How do you handle your harvest?   | State  |
| 39. | How do you package your harvest product?  | 1= Plastic bag 2= Jute bag 3= Polythene bag 4= Basket 5= Plastic crate 6= Cardboard box 7= Metal box 8= Wooden box 10= Other (specify)_____                        |
| 40. | Do you sell processed lablab?   | 1= Yes 0= No   |
| 41. | If yes, what processing/preservation techniques do you apply to Lablab product?   | 1= Simple sun-drying 2= Sun-drying & grinding into powder 3= solar drying technology 4= Other (specify)_____   |
| 42. | Destination of sales  | 1=Domestic 2=Foreign 3=Amount (kg) _____ 4=Price (1/Quintal) _____   |
| 43. | Have you used contracts when selling Lablab? If Yes, specify types of contracts and amount sold throughout these contacts (Quintal) | 1=amount sold _____<br>2=price _____   |
| 44. | Which main transport facility used in your Lablab product? Transport facility   | 1= Head 2= Wheelbarrow/= Animal 4. Bicycle 5= Motorbike 6. Van/pickup 7= Lorry 8= Daladala/bus 9= No transport needed (middlemen collect) 10= Other (specify)_____ |

|     |   |  |
|-----|---|--|
| 45. | Do you employ permanent and casual workers in your farm?  | 1= Yes 0= No   |
| 46. | If Yes, how many permanent and casual workers employed in your farm?  | 1= Permanent employees 2= Casual workers<br>1= how many_____ 2= payment per month_____Tshs   |
| 47. | Where do you sell your harvest? (Farm fresh produce outlet)   | 1= In the field 2= At home 3= Roadside markets 4= Local markets 5= Supermarkets 6= Cooperatives 7= Processors/industry 8= Middlemen 9= Retailers 10= Other (specify)_____  |
| 48. | Please state how far from your home is in km:   | 1= Nearest market; 2= Nearest Agrovet shop.<br>Km_____ Km_____   |
| 49. | Who has been advising you in the cultivation and plantation of your Lablab  | 1= Yourself without any information<br>2= Your perception of the market<br>3= Your perception that in this way you can earn more money<br>4= Advisory services in the area<br>5= Representatives of enterprises processing<br>6= Family members<br>7= Other (specify)_____ |
| 50. | Have you received any information related to the Lablab?  | 1= Yes 0= No   |
| 51. | If yes, by whom:  | 1= Myself 2= Expert 3= Family members<br>4= Executives 5= Other (Specify)_____   |
| 52. | Type of information received  | 1=Input supplies (seeds, etc.) 2=Market info (prices, trends, buyers, suppliers) 3=Financial services (credit, savings or insurance) 4=Support for product development and diversification   |
| 53. | Have you ever experienced problems in Lablab production?  | 1= Yes 0= No   |
| 54. | If Yes, what main constraints do you experience in Lablab production? *Rank: 1= Most serious 2= Fairly serious 3= Least serious | 1= Access to farm inputs 2= Pests and diseases 3= Lack of preservation and processing technologies 4= Lack of market access 5= Other (specify)_____  |
| 55. | Have you received any training on underutilized foods production in general and Lablab in particular?                           | 1= Yes 0= No   |
| 56. | If No, are you willing to attend a farmers' training?   | 1= Yes 0= No   |
|     | If Yes, in what particular area?  | Mention_____   |
|     | If No, what is the reason?  | Give_____  |
| 57. | What is your target in the Lablab production in the future 5 years? Please tick ALL that apply.                                 | 1= Double production quantities 2= Purchase new land to extend production 3= Set up agro-processing unit for Lablab crop 4= Open link with supermarkets to supply lablab 5=Other (specify)_____  |
| 58. | Suggest the way forward to improve the production and utilization of Lablab in Tanzania. Please tick ALL that apply.            | 1= Improving availability of inputs 2= Quality planting seeds 3= Training of Lablab producers 4= Awareness on the potential of lablab 5= Farm Land use consolidation for Lablab production 6= Other (specify)_____   |

| Home uses of Lablab (put a tick) |             | Human food | Animal feed | Soil conservation |
|----------------------------------|-------------|------------|-------------|-------------------|
| 59.                              | Leaves      |            |             |                   |
| 60.                              | Green seeds |            |             |                   |
| 61.                              | Dried seeds |            |             |                   |
| 62.                              | Whole plant |            |             |                   |

| Other crops cultivated/ keeping cattle (mention) |  | Within lablab farm1=yes | Not within2=no | Productions (Quintal) | Uses (if sold put price) |
|--|--|-------------------------|----------------|-----------------------|--------------------------|
| 63.  |  |                         |                |                       |                          |
| 64.  |  |                         |                |                       |                          |



|     |  |  |  |  |  |
|-----|--|--|--|--|--|
| 65. |  |  |  |  |  |
| 66. |  |  |  |  |  |

**Knowledge questions were poorly framed for you to have a proper assessment.**

**Part C: Investigation on Farmers' Understanding about the Potential of Lablab. Please rate the following questions in regard to your understanding about the potentials value of Lablab**

| Knowledge on Lablab Nutritive Value                        |   | True     | False    | Don't know |
|--|---|----------|----------|------------|
| 1.   | Lablab contain high protein   |          |          |            |
| 2.   | Lablab contain essential vitamins, particularly A, B and C, and minerals (such as calcium and iron)           |          |          |            |
| 3.   | The high protein and vitamin contents in Lablab can eliminate deficiencies among children, women and the poor |          |          |            |
| 4.   | Lablab are nature's food and it is that naturalness in them that makes them healthy and nutritious            |          |          |            |
| 5.   | Lablab complete food with maize/rice  |          |          |            |
| 6.   | Lablab have nutritional value more than other legumes   |          |          |            |
| 7.   |   |          |          |            |
| Knowledge on Medicinal Value and Health Benefits of lablab |   |          |          |            |
| 1.   | Lablab have health healing properties   |          |          |            |
| 2.   | Lablab is used for stomach problems   |          |          |            |
|  | <b>Other uses mention and rate in the space below:</b>  |          |          |            |
| 3.   |   |          |          |            |
| 4.   |   |          |          |            |
| 5.   |   |          |          |            |
| Knowledge on Agronomic Advantages of Lablab                |   |          |          |            |
| 1.   | Lablab are well adapted to harsh climatic conditions and disease infestation                                  |          |          |            |
| 2.   | Lablab are easier to grow in comparison to domesticated legumes   |          |          |            |
| 3.   | Lablab add nutrient to the soil   |          |          |            |
| 4.   | Lablab are annually grown in semi desert areas  |          |          |            |
| 5.   | Lablab prevent soil erosion   |          |          |            |
|  | <b>Other mention and rate in the space below:</b>   |          |          |            |
| 6.   |   |          |          |            |
| 7.   |   |          |          |            |
| Knowledge on economic importance of Lablab                 |   |          |          |            |
| 1.   | Lablab are important commodities in household food security   |          |          |            |
| 2.   | Lablab provide employment opportunities   |          |          |            |
| 3.   | Lablab generate income for the rural population   |          |          |            |
| 4.   | Give monthly estimate of income from Lablab   | ≥100,000 | ≥200,000 | ≤200,000   |

| Portraying Consumers' Attitudes (appreciation/perception) against Lablab                   | Strongly agree (5) | Agree (4) | Neutral (3) | Disagree (2) | Strongly disagree (1) |
|--|--------------------|-----------|-------------|--------------|-----------------------|
| 1. Lablab farming is a women's activities/business   |                    |           |             |              |                       |
| 2. Lablab is poor people's food, traditional lifestyle, and food of the older generation   |                    |           |             |              |                       |
| 3. Lablab consumption may cause health problems  |                    |           |             |              |                       |
| 4. Lablab are animal feeds   |                    |           |             |              |                       |
| 5. Lablab are soil conservation  |                    |           |             |              |                       |
| 6. Lablab are unfashionable and not trendy compared to common consumed legumes             |                    |           |             |              |                       |
| 6. Lablab are time consuming to process and to prepare compared to common consumed legumes |                    |           |             |              |                       |
| 7. Lablab are not good for human   |                    |           |             |              |                       |

|  |   |                                 |                       |                      |                         |                                   |
|--|---|---------------------------------|-----------------------|----------------------|-------------------------|-----------------------------------|
| 8.   | Lablab are believed to be poison  |                                 |                       |                      |                         |                                   |
| 9.   | There are scientific facts to be poisonous  |                                 |                       |                      |                         |                                   |
| <b>Please rate your degree of preference of lablab versus common consumed bean</b> |   |                                 |                       |                      |                         |                                   |
| 1.   | The taste, appearance and quality of lablab foods are not as good as that of common consumed bean |                                 |                       |                      |                         |                                   |
| 2.   | Lablab are cheap to produce and maintain compared to common consumed bean                         |                                 |                       |                      |                         |                                   |
| <b>Please rate the frequency of Lablab consumption in your household.</b>          |   | <b>Always (5)</b>               | <b>Often (4)</b>      | <b>Sometimes (3)</b> | <b>Seldom (2)</b>       | <b>Never (1)</b>                  |
| 1.   | How often do you eat lablab in your household?  |                                 |                       |                      |                         |                                   |
| 2.   | Give reasons for the answer above   | Reasons:                        |                       |                      |                         |                                   |
| <b>Please rate your acceptability of attributes of Lablab recipes.</b>             |   | <b>Extremely acceptable (5)</b> | <b>Acceptable (4)</b> | <b>Neutral (3)</b>   | <b>Unacceptable (2)</b> | <b>Extremely unacceptable (1)</b> |
| 1.   | Colour  |                                 |                       |                      |                         |                                   |
| 2.   | Smell   |                                 |                       |                      |                         |                                   |
| 3.   | Texture   |                                 |                       |                      |                         |                                   |
| 4.   | Taste   |                                 |                       |                      |                         |                                   |

**Please rate your consumption intent in regard to Lablab recipes.**

|                          |                              |  |   |   |  |  |                         |
|--------------------------|------------------------------|--|---|---|--|--|-------------------------|
|                          | I would eat it every day (7) | I would eat it very often (twice a week) (6) | I would eat it frequently (once a week) (5) | I would eat it now and then/occasionally (once a month) (4) | I would eat it if available but would not go out of my way (3) | I would eat it when no other food is available (2) | I will never eat it (1) |
| Food action rating scale |                              |  |   |   |  |  |                         |

|  |  |  |
|--|--|--|
| <b>Please rate the barriers of Lablab consumption.</b> |  | Rank: 3= Most serious 2= Fairly serious 1= Least serious |
| 1.   | Lack of knowledge and skills in lablab preparation and nutrition information   |  |
| 2.   | Lack of knowledge transfer between generations for younger generation's beliefs and pickiness  |  |
| 3.   | Urbanization and modernization have changed eating habits and induced a lack of the interest regarding lablab knowledge by the youth |  |
| 4.   | Lack of knowledge transfer from research institutions on lablab nutritional benefits   |  |
| 5.   | 5. Other (specify).....  |  |

**Part D: Food and nutrition security**

| No. | Question  | Response options   | Code |
|-----|---|--|------|
| 1   | In the past four weeks, did you worry that your household would not have enough food? | 0 = No (skip to Q2)<br>1=Yes   |      |
| 1A  | How often did this happen?  | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |      |

|    |  |  |  |
|----|--|--|--|
| 2  | In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?  | 0 = No (skip to Q3)<br>1=Yes   |  |
| 2A | How often did this happen?   | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |  |
| 3  | In the past four weeks, did you or any household member have to eat a limited variety of foods (less kinds of food on the plate) due to a lack of resources?                     | 0 = No (skip to Q4)<br>1=Yes   |  |
| 3A | How often did this happen?   | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |  |
| 4  | In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food? | 0 = No (skip to Q5)<br>1=Yes   |  |
| 4A | How often did this happen?   | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |  |
| 5  | In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?                                   | 0 = No (skip to Q6)<br>1=Yes   |  |
| 5A | How often did this happen?   | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |  |
| 6  | In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?  | 0 = No (skip to Q7)<br>1=Yes   |  |
| 6A | How often did this happen?   | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |  |
| 7  | In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?  | 0 = No (skip to Q8)<br>1=Yes   |  |
| 7A | How often did this happen?   | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |  |
| 8  | In past four weeks, did you/any household member go to sleep hungry because there wasn't enough food?  |  |  |
| 8A | How often did this happen?   | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |  |
| 9  | In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?                                      | 0 = No (questionnaire is finished)<br>1=Yes  |  |
| 9A | How often did this happen?   | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) |  |

**Part E: Minimum Dietary Diversity for Women of reproductive age (15-49) (MDD-W)**

|    | <b>Food categories</b>                      | <b>Foods items commonly consumed in the survey area(s) (yesterday)</b>   | <b>Consumed<br/>Tick one</b> |
|----|---|--|------------------------------|
| 1. | Foods made from grains                      | Porridge, bread, rice, pasta/noodles or other foods made from grains   | yes (1)<br>no (0)            |
| 2. | White roots and tubers and plantains        | White potatoes, white yams, manioc/cassava/yucca, cocoyam, taro or any other foods made from white-fleshed roots or tubers, or plantains | yes (1)<br>no (0)            |
| 3. | Pulses (beans, peas and lentils)            | Mature beans or peas (fresh or dried seed), lentils or bean/pea products, including hummus, tofu and tempeh                              | yes (1)<br>no (0)            |
| 4. | Nuts and seeds                              | Any tree nut, groundnut/peanut or certain seeds, or nut/seed “butters” or pastes   | yes (1)<br>no (0)            |
| 5. | Milk and milk products                      | Milk, cheese, yoghurt or other milk products but NOT including butter, ice cream, cream or sour cream                                    | yes (1)<br>no (0)            |
| 6. | Organ meat                                  | Liver, kidney, heart or other organ meats or blood-based foods, including from wild game   | yes (1)<br>no (0)            |
| 7. | Meat and poultry                            | Beef, pork, lamb, goat, rabbit, wild game meat, chicken, duck or other bird  | yes (1)<br>no (0)            |
| 8. | Fish and seafood                            | Fresh or dried fish, shellfish or seafood  | yes (1)<br>no (0)            |
| 9. | Eggs  | Eggs from poultry or any other bird  | yes (1)<br>no (0)            |
| 10 | Dark green leafy vegetables                 | List examples of any medium-to-dark green leafy vegetables, including wild/foraged leaves  | yes (1)<br>no (0)            |
| 11 | Vitamin A-rich vegetables, roots and tubers | Pumpkin, carrots, squash or sweet potatoes that are yellow or orange inside (vitamin A-rich vegetables)                                  | yes (1)<br>no (0)            |
| 12 | Vitamin A-rich fruits                       | Ripe mango, ripe papaya (vitamin A-rich fruits)  | yes (1)<br>no (0)            |
| 13 | Other vegetables                            | List examples of any other vegetables  | yes (1)<br>no (0)            |
| 14 | Other fruits                                | List examples of any other fruits  | yes (1)<br>no (0)            |

**Thank You!**

# THE NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY

## Appendix 2: Questionnaire for trader/agents/middleman

### Potentials of underutilized Dolichos Lablab (*Lablab Purpureus*) Seeds in improving nutritional quality and livelihood in Tanzania

#### Part A: Background information

Q1. Date of Interview: \_\_\_\_/\_\_\_\_/\_\_\_\_

Q2. Questionnaire No.: \_\_\_\_

Q3. Region: \_\_\_\_\_

Q4. District: \_\_\_\_\_ Village: \_\_\_\_\_

Q5. Phone number (mobile, if available): \_\_\_\_\_

| Social and Demographic Status of Respondents |  | Tick appropriate  |
|--|--|---|
| 6.   | Gender:  | 1. Male 2. Female   |
| 7.   | Interviewee's age:   | 1=12-20, 2=21-30, 3=31-40, 4=41-50, 5=51-60, 6= Over 60       |
| 8.   | Marital status   | 1=Single 2=Married 3=Separated 4= Divorced<br>5=Widow/widower |
| 9.   | Education background:  | 1=Primary 2=Secondary/ 3=College/University/ 4=other specify  |
| 10.  | Household composition:   | 1=no. male 2= no. female (with their ages)                    |
|  |  |   |
|  |  |   |
| 11.  | Occupation other than lablab business<br>With average income per month | 1=<br>2=<br>3=<br>4=  |

#### Part B: Lablab business

| Investigation of Lablab business practices |  | Please tick that appropriate  |
|--|--|---|
| 12.  | Have you ever attended some training on business administration?                     | 1=Yes 0=No, 3=If yes where/why?<br>_____  |
| 13.  | Do you collect other crops apart from lablab?  | 1= Yes 0=No 3= If yes mention them?<br>_____  |
| 14.  | Which system/s do you use when collecting lablab crops from farmers?                 | 1= Pay in advance 2= Cash on delivery 3=On credit   |
| 15.  | What measurements do you use when buying the lablab crops?                           | Mention=  |
| 16.  | How do you package your collected product?   | 1= Plastic bag 2= Jute bag 3= Polythene bag 4= Basket 5= Plastic crate 6= Cardboard box 7= Metal box 8= Wooden box 10= Other (specify)_____ |
| 17.  | Where do you collect them? (Farm fresh produce outlet)                               | 1= In the field 2= At home 3= Roadside markets 4= Local markets 5= Supermarkets 6= Cooperatives 7= Other (specify)_____                     |
| 18.  | Destination of sales   | 1=Domestic 2=Foreign 3=Amount (kg)<br>4=Price (1/Quintal) _____   |
| 19.  | Do you use some standard measurement when selling them?                              | 1=Yes 2=No 3=Other specify_____   |
| 20.  | Where did you obtain your first capital on this business?                            | Mention:  |
| 21.  | Offering in terms of price per unit for the season 2017/18 and 2018/19 respectively. | Mention:  |

|     |  |   |
|-----|--|---|
| 22. | Any comment of the above prices as you compare to the cost of production                       | Comments:   |
| 23. | Do you also grow lablab?   | 1= Yes 0=No<br>3= Give reasons for any answer chosen  |
| 24. | Do you think this business is profitable?  | 1-Yes 0=No<br>3= If yes how much did you earn in the season 2017/18 and 2018/19 respectively<br>4= If No why doing it |
| 25. | How many years have you been doing this business? (Years of experience)                        | Mention=  |
| 26. | From your earnings, what are the most uses of them?  | Mention=  |
| 27. | What are farmers' perceptions on your business?  |   |
| 28. | Do you keep records of this business?  | 1= Yes, which type of data you are keeping<br>0= No, why?   |
| 29. | Do you have a list of potential farmers that you treat them as your loyal customers/suppliers? | 1= Yes, how do you make communication with them<br>0= No, why?  |
| 30. | How do you communicate with your farmer in general?  |   |
| 31. | Do you think the way you communicate has positive impact on your business?                     | 1= Yes 0= No, why?  |
| 32. | What are things needed to help your business to run in a profitable manner?                    | 1= from you<br>2= farmers<br>3= government  |
| 33. | Does your business have any contribution to farmers apart from buying their crops?             | 1= Yes, which type of contribution<br>0= No, why?   |
| 34. | Do government do the same business at your area?   | 1= Yes 0= No  |
| 35. | Give suggests to the government base on 34   |   |
| 36. | Do you think farm gate price is good for the farmers?  | 1= Yes, why?<br>0= No, why?   |
| 37. | What are your future suggestions to this business?   | Suggestions=  |

**Thank You!**

# THE NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY

## Appendix 3: Questionnaire for sensory attributes and acceptability of the Lablab cookies

Questionnaire no: \_\_\_\_\_ Date: \_\_\_\_\_ Time: \_\_\_\_\_

Age: \_\_\_\_\_ Sex: \_\_\_\_\_ District: \_\_\_\_\_ Mobile no: \_\_\_\_\_

You are presented with samples of baked cookies. Please give a score as given in the table for each parameter. The scores are explained in the table below.

| 1                 | 2                 | 3                | 4                | 5                        | 6             | 7             | 8              | 9              |
|-------------------|-------------------|------------------|------------------|--------------------------|---------------|---------------|----------------|----------------|
| Dislike extremely | Dislike very much | Dislike moderate | Dislike slightly | Neither like nor dislike | Like slightly | Like moderate | Like very much | Like extremely |

Please put your selection number here

| Sample no. | Parameter  |             |            |       |       |
|------------|------------|-------------|------------|-------|-------|
|            | Appearance | Texture     |            | Aroma | Taste |
|            |            | crunchiness | sponginess |       |       |
| 818        |            |             |            |       |       |
| 776        |            |             |            |       |       |
| 456        |            |             |            |       |       |
| 882        |            |             |            |       |       |
| 272        |            |             |            |       |       |
| 457        |            |             |            |       |       |
| 750        |            |             |            |       |       |
| 661        |            |             |            |       |       |
| 591        |            |             |            |       |       |
| 150        |            |             |            |       |       |
| 670        |            |             |            |       |       |
| 114        |            |             |            |       |       |
| 171        |            |             |            |       |       |
| 672        |            |             |            |       |       |
| 530        |            |             |            |       |       |
| 104        |            |             |            |       |       |
| 841        |            |             |            |       |       |
| 615        |            |             |            |       |       |
| 727        |            |             |            |       |       |
| 601        |            |             |            |       |       |
| 138        |            |             |            |       |       |
| 721        |            |             |            |       |       |
| 475        |            |             |            |       |       |
| 299        |            |             |            |       |       |
| 487        |            |             |            |       |       |
| 675        |            |             |            |       |       |
| 649        |            |             |            |       |       |
| 154        |            |             |            |       |       |
| 243        |            |             |            |       |       |
| 620        |            |             |            |       |       |
| 825        |            |             |            |       |       |
| 522        |            |             |            |       |       |
| 238        |            |             |            |       |       |

How much are you willing to pay per sample if you decide to buy?.....

Please give any comment:.....

**Thank you**

## RESEARCH OUTPUTS

### (i) Publications

Minde, J. J., Venkataramana, P. B., & Matemu, A. O. (2021). Dolichos Lablab-an underutilized crop with future potentials for food and nutrition security: A review. *Critical Reviews in Food Science and Nutrition*, 61(13), 2249-2261.

Minde, J. J., Venkataramana, P. B., & Matemu, A. O. (2021). Dolichos lablab (*Lablab purpureus*): Smallholder Farmers Knowledge, Attitude and Practices in relation to Food and Nutrition Security in Tanzania. *International Journal. Biosciences*, 19(5), 122-136. DOI: <http://dx.doi.org/10.12692/ijb/19.5.122-136>

Minde, J. J., Matemu, A. O., & Venkataramana, P. B. (2022). Contribution of the Dolichos Lablab value chain to farmer's household livelihood assets in Tanzania. *Heliyon*, 8(11), 1-11.

### (ii) Poster Pesentation

Dolichos research status at NM-AIST on 10/27/2021 at NM-AIST, Arusha, Tanzania

### (iii) Showcase

- Lablab cookies presentation at the East African Business Council (EABC) in collaboration with the Nelson Mandela African Institution of Science and Technology (NM-AIST) which conducted an Academic-Public-Private Partinership Forum (APPPF) on 20/04/2022 at Gran Melia Hotel in Arusha, Tanzania
- Innovation exhibitions of Nutritious Lablab Cookies in MAKISATU organized by Tanzania Commission for Science and Technology (COSTECH) on 16/05/2022 at Dodoma in Tanzania.
- Lablab cookies presentation at the Eastern and Southern Afrrica Higher Education Centres of Excellence – ACE II on 14<sup>th</sup> -16<sup>th</sup>, 2022 in Arusha, Tanzania.



## Poster Presentation

# Nutritious Lablab Cookies

**Josephine J. Minde, Pavithravani B. Venkataramana and Athanasia O. Matem**  
 School of Life Sciences and Bioengineering, Nelson Mandela African Institution of Science and Technology (NM-AIST), P.O. Box 447, Arusha, Tanzania.  
 Department of Community Economic Development, The Open University of Tanzania, P.O. Box 517, Moshi, Tanzania.  
 corresponding author email: [jminde@nmaist.ac.tz](mailto:jminde@nmaist.ac.tz)

### Background

- ❖ Lablab (*Lablab purpureus*) is an underutilized legume with great potential for food, income generation, and environmental conservation.
- ❖ It is popularly known as *Ngwara* in Tanzania
- ❖ Rich in genetic resource worldwide and at NM-AIST more than 300 germplasm is available.
- ❖ Rich in protein (45.5%) and minerals (Zn, Mg, Fe and Ca).
- ❖ Source of livelihood for smallholder farmers.
- ❖ Contains antinutrients.
- ❖ Least preferred as a source of nutrients, as it's tedious in preparation (raw seeds) and takes a long time to cook.
- ❖ The study intends to have an impact on friendly processing method and expose the possibility of diversifying Lablab beans into convenience food products to improve consumption and income.

**Some Lablab accessions**



### Fermentation of Lablab seeds



### Lablab cookies



- Rich in protein and minerals
- Reduced anti-nutrients
- Improved consumer acceptability
- Contribution to SDG's

**1 NO POVERTY**



**2 ZERO HUNGER**



**3 GOOD HEALTH AND WELL-BEING**



**15 LIFE ON LAND**



**Acknowledgments:** NM-AIST & Centre for Research, Agricultural Advancement, Teaching Excellence and Sustainability in Food and Nutrition Security (CREATES-FNS)



A poster and containers with Lablab cookies presented at MAKISATU in Dodoma, Tanzania