

STRENGTHENING NUTRITION-SENSITIVE AGRICULTURE THROUGH BIO FORTIFICATION: INTRODUCING A COMPREHENSIVE FRAMEWORK BASED ON FINDINGS FROM A CANADIAN/ETHIOPIAN PROJECT

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Submitted: 2015-06-08

Accepted: 2015-10-15

Published online: 2016-06-30

Abstract

This paper examines the links between agriculture and nutrition as it seeks to address food and nutrition security in Southern Ethiopia. It draws on data from field research supported by the Canadian International Food Security Research Fund, through the International Development Research Center/Global Affairs Canada. The review aims to introduce a comprehensive framework linking pulse food productivity, bioavailability of micronutrients from pulses through household level processing, nutrition education, and marketing, and their leverage on nutrition security. The development of the framework and subsequent discussion are based on key findings of selected analysis of research conducted in two large pulse producing regions of Ethiopia (SNNPR and Oromia). In order to simplify the understanding of the pathways, 20 case studies conducted by independent research teams are cited and reviewed in the results section, and these are presented under four headings: 1) Agronomic practices and soil management; 2) Pulse based food processing; 3) Nutrition education; and 4) Gender and livelihood. It is noted that effective application of the framework creates an enabling environment for agriculture to become more nutrition-sensitive to respond to the growing concerns of hidden hunger and malnutrition among Ethiopian households.

Key words: agriculture; biofortification; bioavailability; gender; nutrition; pulse crops

INTRODUCTION

Agriculture is of fundamental importance to human nutrition, both as a direct determinant of household food consumption and through its role in livelihoods and food systems (IFPRI 2011, FAO 2012). There is a growing understanding that agricultural development provides an obvious entry point for efforts to improve nutrition. At the same time, agricultural investments targeted

at smallholder farmers are more likely to succeed if they address the human capital constraints of malnutrition.

According to the World Bank (2007), agriculture has the potential to greatly reduce poverty – a key contributor to poor health and undernutrition. In sub-Saharan Africa, for example, agriculture employs 65% of the labor force and generates 32% of growth in gross domestic product. Strong agricultural growth could raise the incomes of 75% of the world's poor

people who live in rural areas and help pull millions out of poverty. However, more needs to be learned about what kind of agricultural growth does most to reduce poverty and improve nutrition and health, especially given the budget constraints that countries face.

In the past several years, global agricultural research has paid much attention to increasing production with the view of feeding more people (Arsenault et al. 2015). Traditionally, agriculture has been driven largely by economic interest, focusing on production of staples food or for generation of income. Consequently, agricultural policy and related research in low income countries have focused on increasing staple food production to provide sufficient dietary energy to a growing population (Arsenault et al. 2015). The time has come to invest in other aspects of agriculture that are aimed at the poor (and their need for nutrition and good health). Thus, the question becomes how to reconcile the economic dimension of agriculture with the nutritional needs of households. Or alternatively, how to link agriculture to nutrition, without jeopardizing the economic objectives which are fundamental to agriculture, while meeting the nutritional needs of consumers. Socially excluded populations (women, children and the poor) often bear the highest burden of low agricultural productivity, poor health, and undernutrition. How can the nutrition and health needs of these groups be integrated into agricultural policies?

Given that the majority of the world's poor are women and children, there is a need to explore gender issues in agricultural production. Not only are women preparers of food and caregivers during illness, but in many countries, they are also the main agricultural producers. In South East Asia, for example, women supply up to 90% of the labor required for rice cultivation. In sub-Saharan Africa women produce up to 70% of the food that their households consume and sell (FAO and ILO 2010). This situation suggests that women can play key roles in leveraging agriculture for nutrition and health. Samuel and Dasmani (2010) explained that farm efficiency can improve, when traditions, culture, and other socioeconomic constraints that hinder women's participation are removed. Are there ways to take advantage of women's unique

role in order to enhance agriculture's benefits for nutrition and health – without unduly adding to the already heavy demands on women's time and labor?

Recently, there has been a growing understanding among researchers that agriculture must now not only produce more calories to reduce hunger, but also more nutrient-rich food to reduce hidden hunger. One promising approach is increasing the micronutrients of staple food through biofortification, a process of breeding nutrients into food crops to provide a comparatively cost-effective, sustainable, and long-term means of delivering more micronutrients. Biofortification improves the nutritional content of staple food crops by breeding varieties that are richer in three of the most limiting micronutrients (vitamin A, iron, and zinc) not found in conventional varieties (Saltzman et al. 2013). Varieties of biofortified staple food crops are bred to display desirable agronomic attributes, such as high yields, and consumption properties that match or outperform those varieties farmers currently grow. Biofortification targets the rural poor, who produce and consume staple food crops in significant quantities, and who may not have access to other nutrition interventions such as fortification, which mainly target urban populations that consume processed food (Ekin et al. 2015).

This approach will not only lower the number of severely malnourished people, but also help them to maintain improved nutritional status (Howarth et al. 2013). Moreover, biofortification provides a feasible means of reaching malnourished rural populations who may have limited access to commercially marketed fortified foods and supplements. Existing evidence suggests that biofortification is an efficacious and cost-effective strategy for alleviating micronutrient deficiency and public health intervention in rural areas of several developing countries (Stein et al. 2007, Meenakshi et al. 2010, Ekin et al. 2015).

However, many questions remain to be answered. Under what conditions will farmers grow biofortified crops, and will consumers accept the biofortified varieties which may look different from those they are used to? How will the availability of biofortified crops affect the nutrition of those who are most

often malnourished – women and children? Other opportunities for improving nutrition and reducing health risks surely exist along the value chain. For example, what is the best way to reduce health risks – including food and water safety risks – stemming from agricultural production and processing? How can the nutritional quality of foods be enhanced during processing? How can consumers be encouraged to accept, and even seek, more nutritious foods, and how can such foods be made available and affordable?

This paper aims to answer some of the questions raised in the preceding section by highlighting the strategies adopted and applied in the ongoing Canadian International Food Security Research Fund (CIFSRF) project embarked upon by the University of Saskatchewan, Canada, in partnership with Hawassa University, Awassa, Ethiopia. The project takes the position that in order to ensure adequate nutrition there is a need to facilitate the ability of households to provide mothers and young children (e.g. complementary feeding) access to sufficient nutritious food that would enable a healthy life and livelihood.

Food/nutrition security among Ethiopian households

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Coates et al. 2007). At the household level, food security is understood as access to sufficient food all the time for an active, healthy life (Maxwell and Frankenberger 1992). The definition of food security at the household level has also been extended to include the related concepts of accessibility, sufficiency, security and sustainability (Maxwell and Frankenberger 1992, Gittlesohn et al. 1998).

In Ethiopia, both chronic and transitory (seasonal) food insecurity are severe. According to FAO (2006), much of Ethiopia's rural population live in a state of chronic food insecurity. Recurrent drought, degradation of natural resources and rapid population growth are among the main causes of declining per capita food production. In Ethiopia, 44%, 29% and 10% of children under age five are stunted (short for the age), wasted (low weight for the

given height) and underweight, respectively (CSA and ORC Macro 2011).

In line with the high prevalence of food insecurity at the household level, Ethiopia faces one of the world's highest rates of maternal and child malnutrition. About 27% of women in Ethiopia are malnourished with a Body Mass Index (BMI) of less than 18.5 (CSA and ORC Macro 2005), which is one of the highest levels in Africa (Macro International 2008). In a study by Abuye and Berhane (2007), it was reported that in addition to low BMIs, approximately 22% of mothers had different degrees of vitamin A deficiencies, 26% had anemia, and 35.8% had goiter reflecting iodine deficiency. One of the most serious and long-lasting impacts of maternal malnutrition is increased child malnutrition and usually subsequent death. Recent systematic reviews have demonstrated that Behaviour Change Intervention (BCI) has the potential to improve child feeding practices and nutritional status (Imdad et al. 2011, Bhutta et al. 2013).

The majority of the nutritionally vulnerable populations in both regions are dependent in some way upon agriculture as a primary source of livelihood. Given this, and the fact that household food security is a critical underlying determinant of nutritional well-being, the agriculture sector and wider agrifood system are considered to be central to sustained progress in reducing undernutrition. While agriculture has the potential to be a strong driver of reductions in undernutrition, the sector is currently not realizing this potential, and also, not enough is known about how to realize this potential (Gillespie et al. 2015).

In Ethiopia, pulses (faba beans, field peas, chick peas, haricot beans, lentils), also called grain legumes, occupy 13% of Ethiopia's cropland and are the second most important food source in the national diet, providing a principal protein source (Tefera 2014). Combining pulses with other plant based foods such as cereal increases protein quality and provides more micronutrients generally not found when it is eaten in isolation (Berhanu et al. 2014).

While some efforts were made to enhance food security at a household level, none of these efforts accounted for addressing the link between agriculture and nutrition through

biofortification strategies. The CIFSRR project is an ongoing collaborative project between Hawassa University (HwU) and the University of Saskatchewan (UofS) aimed at reducing protein-calorie malnutrition in Ethiopia by promoting the adoption of pulse technologies and nutrition interventions at a household level, especially in young children and women.

The CIFSRR project uses a biofortification strategy which linked agriculture and nutrition by spanning the spectrum from improved pulse crop agronomy (with an emphasis on chickpea and bean and including Zn and Fe fertilization), isolation of superior *Rhizobium* strains (nitrogen-fixing bacteria), to the utilization of household-level pulse processing strategies (dehulling, soaking, germination, fermentation, etc.). Also, improved micro-nutrient (Zn and Fe) profile of processed chickpea and bean flours in turn were used to produce pulse-cereal complementary food products. These nutritious pulse foods along with the nutrition education of mothers have led to increased weight gain in young children, a key indicator of nutrition outcome in young children (CIFSRR 2014).

In the CIFSRR biofortification program, the major activities include plant breeding of chickpea, haricot and faba beans to develop varieties that combine the best nutritional and agronomic traits in each crop. A biofortification approach is believed to bring about multiple advantages which include: consistent and large amounts of food staples consumed by all family members, seeds that fortify themselves once developed which reduces costs, a feasible means of reaching undernourished populations in relatively remote rural areas, and delivering naturally fortified foods to people with limited access to commercially marketed fortified foods that are more readily available in urban areas.

MATERIALS AND METHODS

Pulse crops are commonly grown in three of the most populous regions of Ethiopia, namely, Amhara, Oromiya and Southern Ethiopia (SNNPR). The major varieties of pulses grown in Ethiopia, faba bean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.), and lentil (*Lens*

esculenta L.) are categorized as highland pulses and grown in the cooler highlands. While haricot bean (*Phaseolus vulgaris* L.) and mung bean (*Phaseolus radiates* L.) are predominantly grown in the warmer and lowland parts of the country. The Southern Nations Nationalities and Peoples Regional (SNNPR) state contribute faba beans (10%), field peas (18%), chickpeas (3%), and haricot beans (15%) (CSA 2008).

The development of the framework of agriculture-nutrition and subsequent discussion is based on the key findings of selected analysis of CIFSRR studies conducted across six districts in two regions of Ethiopia (SNNPR and Oromiya) between 2011 and 2015. These independent studies fall under four major themes: 1) agronomic practices and soil management; 2) pulse food processing for improved micronutrients; 3) nutrition education; and 4) gender and livelihood dimensions.

Studies under the first theme have used field experiments and trials with various target groups. The studies include both greenhouse and field experiments and aim to cover various aspects of soil management practices, including micronutrient deficiencies, micro-nutrient adsorption, intercropping and crop rotation.

Under the second theme, studies on pulses food preparation and processing examined strategies that degrade antinutrients, such as phytate and polyphenols in order to enhance the bioavailability of Fe and Zn for improved nutritional quality. Two studies are included in this cluster, both dealing with improving the bioavailability of pulses by decreasing phytate and other anti-nutritional factors through soaking and germination.

Studies in the third theme (nutritional education) have examined the impact of nutrition education on the quality and quantity of pulse rich food consumed, as well as on the nutritional status of children. The reference population considered for these studies were mothers who had eligible young children (age 6 months to 23 months) and were residents of the study target areas for more than six months. The sample size of each individual study was determined using a single population with random sampling techniques to select mother-child pairs. Almost all of the studies in this cluster used

a survey questionnaire to collect the required data.

The last theme, the gender and livelihood studies, focused mainly on analyzing the role of gender and other socioeconomic factors

on pulse production and consumption. The analysis employed a wide range of tools and variables. Four studies are included under this theme.

Table 1. Studies related to agronomy practices and soil management, Ethiopia, 2011 to 2014

Study, date	Region/zone/district	Villages sampled	Design	Main objective
Woldesenbet et al. (2013)	SNNPR	Taba and Halaba	factorial experiment	Examine the responses of chickpea to N and P fertilizers
Beyene et al. (2013)	SNNPR and Oromia	Huletegna Choroko, Taba, and Jole Andegna kebeles	experimental	Examine the effects of NP and Zn and Fe fertilization on yield and quality of different haricot bean varieties
Tefera et al. (2013)	SNNPR	Huletegna Choroko and Taba	factorial experiment	Test the responses of five chickpea genotypes to four rates of phosphorus (P) fertilizer applications
Bushaka and Haile (2013)	SNNPR	Hallaba and Taba	random control block design	Evaluate the response of chickpea to <i>Rhizobium</i> inoculation, phosphorus fertilizer and their combined application under farming conditions
Hirpa (2014a)	SNNPR	Hallaba and Taba	experiment	Determine the effects of intercrop row arrangements on the performances of maize and haricot bean
Hirpa (2014b)	SNNPR	Hallaba and Taba	field studies	Determine the effects of intercrop row arrangements and staggered intercropping of haricot bean on the performance of maize crop

Table 2. Studies related to pulse preparation and processing, Ethiopia, 2011 to 2014

Study, date	Region/zone/district	Villages sampled	Major pulse crops	District population	Type	Sample (n)
Berhanu et al. (2014)	Hawassa Zuria district, Sidama Zone, SNNPR	NA	haricot bean	139,654	experimental design	Laboratory based
Kebebu et al. (2013)	Hula, Sidama Zone SNNPR	Titecha	broad bean (fava bean)	130,433	cross-sectional survey	169 mother child pairs (age 6–23 months)

Table 3. Studies related to nutrition education, Ethiopia, 2011 to 2014

Study, date	Region/ zone/district	Villages sampled	Pulse crops	District population in 2007	Type	Sample (n)
Zebdewos et al. (2015)	Damot Gale District, Wolaita Zone, SNNPR	Taba and Gacheno	haricot bean	154,610	quasi experimental	80 mothers child pair (age 6–23 months)
Negash et al. (2014)	Hula, Sidama Zone SNNPR	Titicha and Debicha	broad bean (fava bean)	130,433	cross- sectional survey	197 mother child pairs (age 6–23 months)
Mulualem et al. (2016)	Damot Gale district, SNNPR	Taba and Gacheno	haricot bean	154,610	quasi- experimental	160 mother- child pairs

Table 4. Gender, marketing and socioeconomic studies, Ethiopia, 2011 to 2014

Study date	Region/ zone/district	Villages sampled	Major pulse crops grown	District population	Type	Sample (n)
Tsegaye et al. (2015)	Dale district, Sidama zone, SNNPR	12 villages	haricot beans	242,000	cross sectional survey	665 mothers child pair (age 6–23 months)
Tefera (2014)	Wolayita and Halaba Zones SNNPR	Huletegn Choroko, Taba and Jole Andegna	haricot bean	130,433	cross- sectional survey	183 farmers
Bezabih et al. (2013)	Wolaita district/ SNNPR	Taba	haricot bean	154,600	cross sectional	218 households
Tadesse et al. (2013)	Hawassa Zuria District, SNNPR	2 Villages	haricot bean	139,654	cross sectional	140 male and female headed households

RESULTS

In the CIFSRF project, improving food security and nutrition begins with efforts in increasing pulse production through soil management and improved seed varieties. Once good quantity of pulse production is made possible, the next important issues are how households prepare/process, consume and/or market the pulses. While the preparation aspect is mainly affected by the nature and depth of nutrition education, the latter has a direct bearing on household income, which ultimately improves livelihood if all household members equally benefit from the sale of pulses. Indeed, the

gender dimension connects the production, preparation/consumption and marketing behaviors in different ways (Fig. 1). Therefore, the following few paragraphs discuss the key research findings and enumerate agriculture-nutrition links under four interrelated headings.

Improving agronomy and soil management practices

Six studies conducted related to agronomy and soil management are depicted in Table 1. A number of the studies in the first theme showed that at three locations (Huletegn Choroko, Taba, and Jole Andegna kebeles),

experiments on the effects of nitrogen (N), phosphate (P) and Zn and Fe fertilization on yield and quality of different haricot bean varieties showed significant differences in leaves and grain N contents (e.g. Beyene et al. 2013).

Another study focusing on close examination of the responses of chickpea (*Cicer arietinum* L.) to N and P fertilizers (Woldesenbet et al. 2013), revealed that N applications had varying effect on the biomass and grain yields of chickpea over the two locations (Taba and Halaba). More grain yield and biomass was obtained with increased N application at Taba than Halaba, where grain yield increased by 61% in the control (Taba), but only 34% in Halaba.

Researchers (Tefera et al. 2013) examined the response of five chickpea (*Cicer arietinum* L.) genotypes to four rates of phosphorus (P) fertilizer applications at Huletegn Choroko and Taba sub districts, southern Ethiopia, during the 2013 cropping season. The experiment was a factorial of chickpea genotypes (Ejeri, Mastewal, Naatoli, Habru and local) and P fertilizer rates (0, 26, 46 and 66 kg ha⁻¹) in a randomized complete block design with three replications. The team collected data on plant growth parameters (plant height, dry matter, number of pod bearing branches) and yield and yield components (number of pods per plant, number of seeds per pods biological yield, straw yield, Harvest index (HI), 100-seed weight, seed yield at harvest). Chickpea genotypes and P fertilizer rates showed highly significant differences ($P \leq 0.001$) for all yield and yield components studied except plant height and seed pod-1 which was significant at $P \leq 0.05$. The interaction effects of chickpea genotypes with P fertilizer rates, chickpea genotypes and locations, and P fertilizer rates and locations were significant for Pod plant-1, biological straw and seed yield, and Harvest index ($P \leq 0.05$), except for seed yield and Harvest index which were not affected by P fertilizer rates and locations interaction. The highest yield (2.22 tons ha⁻¹) was achieved by the genotype Mastewal with 46 kg P ha⁻¹ at Taba, with a yield of 31.4% over control treatment. The lowest yield (1.16 tons ha⁻¹) was by the local check without P application. Genotype Ejeri gave the highest yield (0.84

tons ha⁻¹) at Huletegn Choroko with an advantage of 23.9%.

As part of meeting the best performing variety selection, the efficacies of indigenous Ethiopian *Rhizobium* strains were compared to elite national and imported commercial inoculants from Canada. The most efficient *Mesorhizobium* strain, Cp41, with 60 kg/ha Diammonium phosphate (DAP) significantly improved growth and productivity of chickpea across four districts (Damot Gale, Meskan Sodo and Halaba) using two newly introduced varieties (Habru and Arerti).

Another experiment evaluated the response of chickpea to *Rhizobium* inoculation, phosphorus fertilizer and their combined application under farming conditions (Bushaka and Haile, 2013). For this purpose, three strains of *Mesorhizobium ciceri* and two concentration levels of phosphorus with three replications were tested in a farm experiment by using Randomized Control Block design. It was noted that *Mesorhizobia* inoculants and P fertilizer were found to have significantly affected the biomass and grain yields of chickpea ($p < 0.001$). All of the three inoculants produced a significantly higher yield than the control ($p < 0.001$). However, the highest biomass and grain yields of chickpeas were obtained from plots inoculated with strain CP41.

Two studies focused on determining the effects of intercropping and row arrangement on haricot bean (*Phaseolus vulgaris* L.) production. A study conducted by Tamiru (2014) determined the effects of intercrop row arrangements and staggered intercropping of haricot bean on the performance of maize (*Zea mays* L.) crop at Hallaba and Taba areas, Southern Ethiopia. The study found significant effects of cropping patterns and staggered interseeding of the legume component on growth and yield components of maize crop. This indicates that increased trends of Leave Area Index (LAI) of maize crop as interseeding of haricot bean was delayed for 3 weeks after maize (WAM) that stabilized during the 6 WAM interseeding time. Maize stover production was significantly high at 1:2 row ratio and delaying of the undersowing haricot bean in the already established maize crop for 6 weeks, 10.94 and 11.39 t ha⁻¹, respectively. Maize grain yield showed

a significant variation with respect to the staggered sowing of haricot bean, whereby the highest (3.99 t ha⁻¹) being recorded when haricot bean intercropping was delayed for 21 days after maize planting.

A similar farm based study (Hirpa 2014a, b) also determined a 15.5% yield reduction in maize when the number of haricot bean rows introduced between two maize rows increased from one to three, which is attributable to the aggravation of interspecific competition in the latter case. In the case of haricot bean crop, compared to the sole stand intercropping of one, two and three rows of haricot bean between two rows of maize had resulted in yield reductions of 56, 44.5 and 28.2%, respectively. The total N content of the residual soil also showed significant improvement due to the introduction of the leguminous haricot bean into the cropping system.

Pulse food processing for micronutrient improvement

There are two main analyses in this section. The first one deals with pulse consumption: formulation of chickpea-incorporated bread and sensory acceptability of bread among pre-school children in Southern Ethiopia (Tafese et al. 2013). The study undertook the formulation of chickpea-incorporated bread to enhance protein, iron and zinc content. Flat bread was made from maize dough containing 25%, 30% and 35% processed chickpea after fermentation for 19 hours. This increased protein, ash, iron and zinc content by 1.46–3.39%, 0.13–1.27%, 4.94–5% and 0.29–0.42%, respectively when compared to control bread. There was a significant increase in iron and zinc with an increase in proportion of chickpea flour, significant decrease in all flat bread in their phytate content and significant difference between all chickpea-incorporated and maize based bread in their sensory attributes ($p < 0.05$). The consumption of pulse food was practiced by 56.4% of children and the majority (70%) of the children in the study had a moderate dietary diversity score.

The micronutrient levels of pulse flours were subjected to various food processing and preparation techniques (roasting, boiling, soaking, fermentation and germination) to improve nutrient bioavailability. Measures of community consumer acceptability and sensory analysis were also completed. House-

hold food processing methods were carried out to enhance iron and zinc bioavailability in formulated haricot beans and chickpea and maize complementary food and common household dishes in 2 studies in two of the study sites. Soaking and roasting methods were used in the preparation of maize flours, and germination (for 48 or 72 hours) and roasting were used in the laboratory treatment of haricot bean flour. Proximate nutrient analysis conducted on processed and unprocessed flours using standard methods revealed that there was no significant difference in iron ($p = 0.114$), and zinc ($p = 0.326$) between 48 and 72 hours germinated white haricot beans. However, processed products showed a significant reduction of phytate ($p = 0.001$). An acceptability test with 36-mother-child pairs showed no significant differences among the porridge sampled for sensory attribute. This study showed that pulse-cereal porridge is suitable, as pulse processing methods such as germination are necessary to improve bioavailability of iron and zinc (Berhanu et al. 2014).

In the studies mentioned above, the sensory evaluations were done following the acceptable norm to reduce potential bias such as proper selection of panelists, brief trainings of the panelists, observation of food samples under controlled conditions, adequate sampling (between 5–30) and proper analysis of data.

Taken together, processing methods have demonstrated improvement in the micronutrient profile of new specialized nutritional foods made of pulse-cereal blend and introduced them into the diet of young children. Nutrients from these pulse-cereal blends were more easily absorbed (fewer anti-nutrients) and well liked than ones made from local varieties bought at the market. This is noteworthy in that baseline studies indicated that pulse consumption was low in the study areas and that germination and fermentation methods of traditional food preparation were not commonly used.

Improving consumption of pulse based food through nutrition education

The fourth issue surrounding linking agriculture and nutrition rests on the education of the community members about pulse preparation and consumption, as it was

initially believed that the poor consumption of some pulses is usually related to knowledge and attitudes of the farming households. Nutrition education strategies such as recipe-based complementary feeding practice also led to an improved knowledge and practice of mothers with young children in the Hula district, Southern Ethiopia. Based on the participation of 200 randomly selected mother–child (aged 6 to 23 months) pairs in the 6 month intervention, mothers received education sessions consisting of eight specific messages using Alive and Thrive posters, demonstration and tasting of a local barley and maize porridge recipe containing 30% broad beans, with follow-up visits to their homes to address food preparation and other concerns related to the project. The control group lived in a different area and there was no intervention. Results showed that at 6 months, knowledge and practice scores regarding complementary feeding were significantly improved ($p < 0.001$) in the intervention group, but not in the control group. The intervention resulted in the improvement of children's dietary diversity, as well as the mean intake of energy and selected nutrients, compared with children in the control group. Using multiple learning modes (recipe demonstration, taste testing, action oriented messages and follow-up visits) is an effective approach to improving KAP for mothers and nutrition outcomes for young children (Negash et al. 2014). A follow-up study from Mulualem et al. (2016) confirmed these findings.

Evidence from the above studies suggests that nutrition education programs can make significant contributions to improving dietary behaviours when integrated with appropriate tools and resources.

Gender and livelihood dimensions of pulse based food production and consumption

Gender has been identified as the “key element” in the linkage between agriculture and nutrition. While several issues are involved around gender, the project has focused on the key elements related to pulse production, consumption and marketing, which includes women's constraints in accessing resources and agricultural inputs;

intra-household gender relations impact on farm productivity, distribution of benefits, and the market opportunities for women. In addressing the project's gender dimension of pulse production, consumption and marketing, four independent analyses were carried out using different samples from the study area. The results of these analyses drew similar conclusions.

The first study was conducted in four districts in the southern region based on data collected from 665 sample households. This analysis indicated that 69% of the households were headed by males while the remaining 31% were headed by females. The majority of the households (45%) had a size of 4–6 members followed by 7+ (44.4%) and only 10.7% reported having a size of six and above, culminating in a mean household size of 6.27 for the sample households. The data revealed that about 60% of the respondents could not read or write. When the data was disaggregated by sex, more than 68% of female respondents, compared to 54% of male respondents, fell into this category. A market-oriented study of 183 pulse crop producers, conducted by Tefera (2014) in SNNPR, indicated the differences in the educational attainment of the members of male and female-headed households. That was statistically significant at a level of 1%, which is normally the case in Ethiopia, i.e., men are more literate than women, having had better educational opportunities. According to the findings, about 78% of female-headed household (FHH) members had no formal education, compared to only 39% of male headed household (MHH) members.

The findings of the study (Tsegaye et al. 2015) revealed that female-headed households own much less land, livestock and other important strategic resources compared to male-headed households, which has implications for their level of involvement in pulse production. A good proportion of female headed households (33.1%) own 0.5 to 1 hectare, and 25.7% own less than a half hectare, and another 38% of them own more than one hectare. The landless households were very small (3.5%). The analysis revealed that some of the female-headed households transferred their land to others on a temporary basis because of a lack of ownership of oxen and labor to execute demanding agricultural activities.

Overall, the study indicated that the production of pulses by small holder farmers is negligible. The main pulse produced in the study area is haricot bean, although chickpea is also produced by a small number of households. Based on 183 farmers sampled from three districts, Tefera (2014) estimated that 73% of households produce haricot beans (close to 56% was sold); chickpea was produced by 26.8% of the households (69.5% was sold) indicating that chickpea is an even more important cash crop. The average level of market orientation index computed for the two crops were 0.4 and 0.53, respectively. The author attributed the difference to the education level of household heads, access to credit and land per capita (Tefera 2014).

The gender studies have also noted that MHH and FHH have different preferences, with the former usually preferring to produce crop varieties that have high market demands and prices, and the latter opting for crops which are mainly used for domestic consumption. A study conducted by Aregu et al. (2011) in Hallaba, Dale and Ada Liben districts indicated that where chickpeas and haricot beans are considered to be priority commodities, men prefer to produce their improved varieties while women prefer the local variety (Dima), which is more suitable for household use.

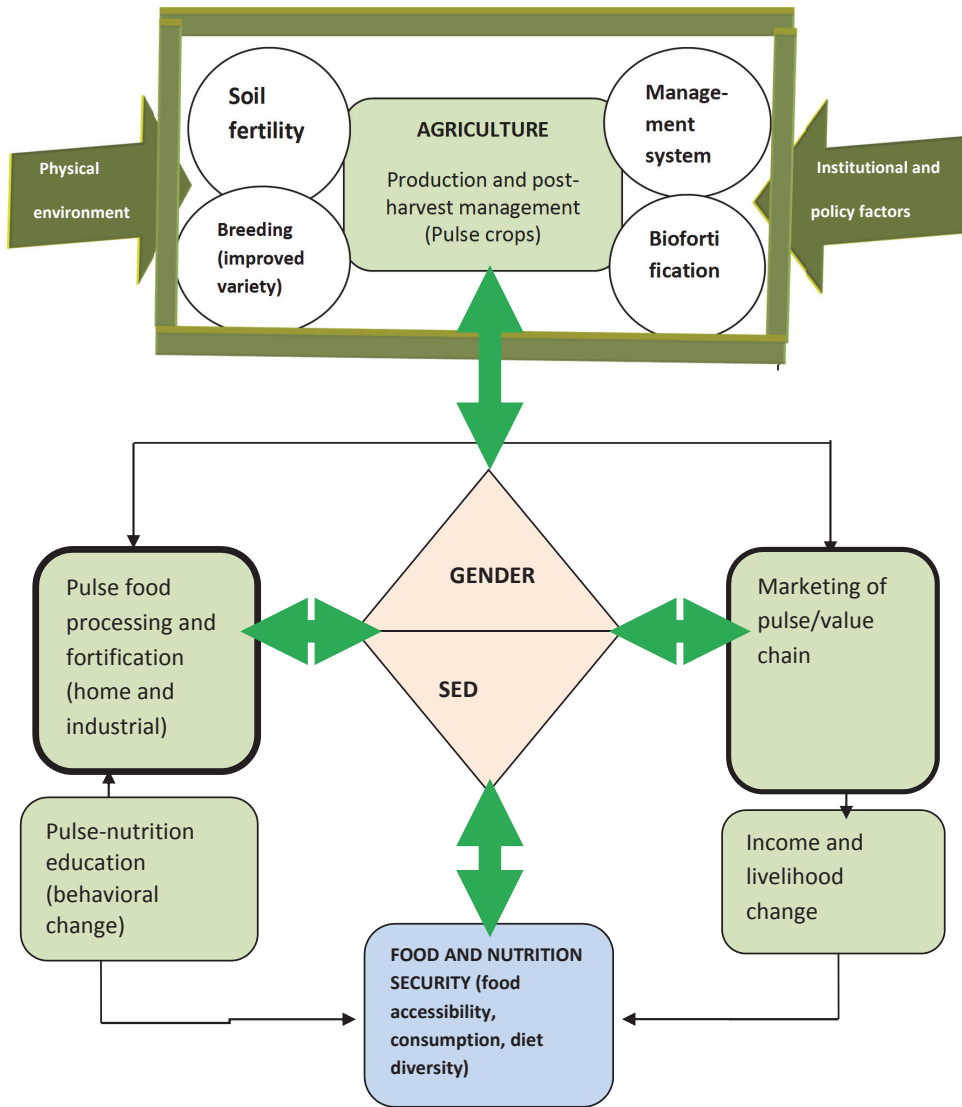
Women own much less livestock in all four study districts, which corroborates with the small land ownership noted above. Owning less land implies two things: firstly, the village community usually views such FHHs as weak farmers, and consequently they receive little or no attention during land allocation and limited extension advice on the uses of agricultural input and technologies. A gender related analysis of the same population (Tadesse et al. 2013) indicated that the perception by extension agents of female and male farmers was a challenge to women in MHHs in accessing agricultural extension service. Likewise, extension agents' attitude as well as cultural biases towards FHHs were major challenges for women in FHHs. Secondly, a lack of oxen forces women to engage in share-cropping arrangements, men in the community bring their labor and oxen for harvesting the lion share of the produce, leaving the female-headed households with food insecurity. The CIFSRF project study

further indicates the gender differentials in decision-making on production, consumption and marketing. Only an insignificant proportion of the women respondents in MHH participate in selling, transporting and spending the income generated from pulses (10.2%, 10.1% and 10.2% respectively).

There is also evidence of differences in intra-household food distribution (Tsegaye et al. 2015), which translates to some household members having better access to specific food items than others. For instance, 75% of the respondents reported that haricot bean is consumed more, or given priority by male household members. Haricot bean is consumed at least once a day by 62.3% of the households, and usually prepared in sauce form 76.1% of the time. On the contrary, there appears to be no significant difference in household members' consumption of chickpeas; about 59% did not respond to the inquiry and 37% reported no difference. However, chickpeas are less commonly consumed compared to haricot beans.

DISCUSSION

As it experiences one of the highest rates of child and maternal malnutrition, Ethiopian agriculture is to respond and address several challenges through comprehensive and sustainable approaches. While some efforts have been made to enhance food security at the household level, none of these efforts accounted for addressing the framework for agriculture and nutrition link through biofortification strategies. One of very few promising efforts that seeks to link agriculture and nutrition for improved household food security is the CIFSRF project. As stated earlier, the project is an ongoing collaboration between Hawassa University (HwU) and the University of Saskatchewan (UofS), aimed at reducing protein-energy malnutrition in Ethiopia by promoting the adoption of pulse technologies and nutrition interventions at a household level, especially in young children and women. The project was implemented over a three year period between 2011 and 2014. The project implemented an integrated agriculture-nutrition-marketing approach aimed at improving access to planting material or seed, increase demand, enhance



SED = sociodemographic

Fig 1. Pathways of agriculture and nutrition linkages for improving household food security, 2015

knowledge and practices through extension; increase bioavailability of iron and zinc through pulse based food preparation and processing, increase acceptability pulse food through nutrition education; increase income through market development and then scale up the practices.

The analysis of the 20 field and laboratory studies were based on data gathered from two of the main pulse producing regions (SNNPR and Oromia). Fig. 1 depicts the operational linkages developed to answer some of the outstanding research questions identified. These include, under what conditions will

farmers grow biofortified crops? How will the availability of biofortified crops affect the nutrition of population groups who are most often malnourished-women and children? What are the most common gender and socioeconomic constraints along the value chain? How can the nutritional quality of foods be enhanced during processing? How can consumers be encouraged to accept, and even seek, more nutritious foods, and how can such foods be made available and affordable?

As depicted in the framework (Fig. 1), all four agricultural activities have a direct bearing on pulse production. The agronomy and soil management aspect of the project starts with a biofortification strategy, which sought to place micronutrient-dense traits in those varieties that already have preferred agronomic and consumption traits, such as high yield. In a nutshell, the agronomy and breeding studies have shown that there is variation in grain yield and biomass with increased N application, varying across different genotypes. Land preparation methods and sowing seasons influence yield and yield components of chickpea and other pulses. Cropping patterns and staggered interseeding of pulses impacts growth and yield.

Following the agronomic practices, increasing the bioavailability of the micronutrients (iron and zinc) during household and/or industrial processing of the pulse based foods is another important dimension addressed in the framework of linking agriculture and nutrition. With regards to the preparation of pulse food stuffs (such as bread), there was a significant increase in iron and zinc with increases in the proportion of chickpea flour. The micronutrient levels of pulse flours were subjected to various food processing and preparation techniques (roasting, boiling, soaking, fermentation and germination) to improve nutrient bioavailability.

Processing such as germination of pulses crops is necessary for improved bioavailability of micronutrients necessary for complementary pulse-based foods (Berhanu et al. 2014). Increasing the bioavailability of micronutrients was not an end in itself, as the success of biofortified staple crops depends on whether they are accepted and consumed by target populations. The studies

measured consumer acceptance in terms of their sensory evaluation and economic valuation compared to the conventional ones. Therefore, in addressing the bioavailability of pulse based crops or any staple grain, the two most important questions future researchers should address are a) will target consumers (for instance, children and women) accept the taste, odor and other traits of the biofortified foods? and b) what are the effective mechanisms to maximize target consumers' acceptance of biofortified foods? It is important to mention that prior to the implementation of any such consumer acceptance study, ethical issues should be considered.

The studies have also shown that nutrition education interventions can make significant contributions to improving dietary behaviours when integrated with appropriate tools and resources (Negash et al. 2014, Mulualem et al. 2016). Moreover, using multiple learning modes (recipe demonstration, taste testing, action oriented messages and follow-up visits) is a more effective approach to improving KAP for mothers and nutrition outcomes for young children (Negash et al. 2014). The fact that the nutrition education component is affected by gender and other socioeconomic factors (Negash et al. 2014, Mulualem et al. 2016), means that any intervention of this nature should address female headed households and women farmers. These are usually the poorer section of communities in regards to resource acquisition such as land, oxen, agricultural input, labor and credit services (Tefera 2014, Tsegaye et al. 2015).

Pulse crop marketing and income generation are key components housed within the framework for improved nutrition. In Ethiopia, on average, pulse crops contribute to 15% of the total protein intake, account for 13% of the cultivated land and 8.5% of the total crop production (Chilot et al. 2010). In recent years, however, the pulse sector has shown some increase in the total volume of production (Tefera 2014) creating a good opportunity to maximize the role of marketing components of pulse crops in the nutrition-agriculture framework. In one of the case studies, market orientation was addressed (Tefera 2014) as an important option for increasing the production of nutrient-rich pulse-based foods. The study found that

chickpea has a higher market orientation index than the haricot bean, and such a difference was attributed to the difference in the education level of household heads, access to credit and land per capita (Tefera 2014). A related study conducted in Wolaita zone reported that over 91.7% of households faced challenges in pulse marketing due to involvement of brokers, low price and distance to better markets, while 46% of households were confronted with a lack of transportation and low market price (Bezabih et al. 2013).

The studies mentioned in this review have shown that the dimension of gender along with other socio-demographic variables, play a central role in significantly affecting the nutritional outcomes of the target groups. The pathway indicated in Fig. 1 places gender at the core of the framework, indicating that the other major components (agronomic practices, processing, and marketing and nutrition education) may pass through the gender dimension in order to influence nutritional/health outcomes. That is one of the reasons that the gender studies conducted under the auspices of the project addressed pulse production/consumption and marketing from a gender perspective. The studies documented that female-headed households own much less land, livestock and other important resources; have less participation in selling, transporting and spending of the income generated from pulses. All these have clear implications for food and nutrition security.

Previous studies conducted in the study areas indicated that such factors easily exposed FHH to food insecurity compared to male-headed households (Hailu and Regassa 2006, Mengistu et al. 2009). Other studies conducted in the same districts have also documented additional gender related constraints and challenges related to pulse production and consumption such as problems related to the use of technology, credit, saving and attitudinal factors. The analysis carried out by Fikre et al. (2013) based on 181 randomly selected households from two villages in the Halaba District indicated that the major constraints in pulse crops technologies were identified as low participation in extension programs and other social activities, poor access to credit, low access and ownership of media instruments, less involvement in any activities of formal and informal organizations

and less support from extension agents as a source of information. A study based on 218 randomly selected households from Wolaita zone (Bezabih et al. 2013) revealed that female-headed households had less access to extension services, production packages, plowing oxen and credit services in the production of pulses. There was a disparity between male and female-headed households in credit arrangement, seed and fertilizer purchase, land allocation, and marketing of pulses (Bezabih et al. 2013).

Despite its importance, there still seems to exist a huge gap among researchers and policy makers in understanding the critical role gender dimensions play. A recent study conducted in selected East African countries (Ethiopia included) showed that agriculture, as a major employer of poor rural women generating other non-food pathways to nutrition, is not commonly understood among policy makers. In the same study, respondents in Pakistan suggested that most aspects of the food system are controlled by men, which is why nutrition does not receive priority (Gillespie et al. 2015).

Overall, in a broader sense, the contributions of the framework developed and introduced into the Canada-Ethiopia collaborative project are three-fold. First, it can help to improve the knowledge and perception of undernutrition and its link to agriculture for policy makers and program managers, allowing them to be more pro-nutrition instead of merely focusing on the production and supply of agriculture. Second, the agriculture-nutrition linkages bring together the multispectral bodies for addressing nutrition challenges. Third, the framework can be applied to other countries and regions wishing mainstreaming nutrition interventions into agricultural activities.

CONCLUSION

The research may give an understanding of an operational framework on linking agriculture and nutrition for improved nutrition and household wellbeing in Ethiopia. The framework is based on empirical evidence from studies conducted through a Canada-Ethiopia CIFS RF project. The project brought together several components: agronomy

and soil management for improved pulse productivity, bioavailability of iron and zinc through household level pulses food processing, nutrition education; and gender dimensions at the core of the nutrition-agriculture linkages. The research also highlights critical issues that may hinder efforts to operationalize the agriculture-nutrition linkages. It further highlights the progress made within this CIFSRRF project to operationalize agriculture-nutrition linkages.

The effective application of this framework is likely to create an enabling environment for agricultural practices to become more nutrition-sensitive in order to respond to the growing concerns of hidden hunger and malnutrition among Ethiopian households. This can be achieved by tackling some of

the limitations and challenges such new innovative approaches may face.

CONFLICT OF INTEREST

The authors have no conflict of interest to disclose.

ACKNOWLEDGEMENTS

The research project is funded by the Canadian International Food Security Research Fund, through the International Development Research Center/Global Affairs Canada. The authors would like to express their heartfelt thanks for the financial support.

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