NUTRITIVE VALUE AND FARMERS PREFERENCE OF CHICKPEA (*Cicer arietinum L.*) VARIETIES FOR FOOD FEED TRAITS

MSc. Thesis

By

Etagegnehu Bzuneh

June, 2021

Debre Berhan, Ethiopia

NUTRITIVE VALUE AND FARMERS PREFERENCE OF CHICKPEA (*Cicer arietinum L.*) VARIETIES FOR FOOD-FEED TRAITS

A Thesis Submitted to the Department of Animal Science
College of Agriculture and Natural Resource Sciences, School of Graduate Studies
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In Partial Fulfilment of the Requirement for the Degree of Master of Science in Animal Production

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June, 2021

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SCHOOL OF GRADUATE STUDIES

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APPROVAL SHEET – I

This is to certify that the thesis entitled: **Nutritive value and farmers preference of chickpea (*Cicer arietinum L.*) varieties for food-feed traits** submitted in partial fulfilment of the requirements for the degree of Masters of Science with specialization in **Animal production** of the Graduate Program of the Department of **Animal Science**, College of Agriculture and Natural Resource Sciences, Debre Berhan University and is a record of original research carried out by **Etagegnehu Bzuneh, PGR/040/11**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during this investigation have been duly acknowledged. Therefore, I recommend that it can be accepted as fulfilling the thesis requirements.

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Certification of the final Thesis

I hereby certify that all the corrections and recommendation suggested by the Board of Examiners are incorporated in to the final Thesis

"Nutritive value and farmer's preference of chickpea (*Cicer arietinum L.*) Varieties for food-feed traits"

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support and valuable suggestion. Last but not least, I would like to thank my family and friends for all of their encouragement, love and support.

DEDICATION

This thesis is dedicated to my father **Bzuneh Belayneh**.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my genuine work and all sources of materials used for this thesis have been profoundly acknowledged. This thesis has been submitted in partial fulfilments of the requirements for MSc degree at Debre Berhan University and is deposited at the University Library to be made available to borrowers under the rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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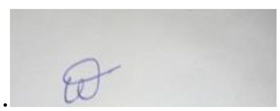
Name: **<u>Etagegnehu Bzuneh</u>** **Signature**. ……  ….………

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BIOGRAPHICAL SKETCH

The author was born in June 28, 1997, in Tarmaber Kebele, Mojana Wedera district, North Shewa Zone, Amhara National Regional State. She attended her primary education at Tarmaber Primary School and her secondary and preparatory education at Debre Sina General Secondary and Preparatory School. Then she joined Debre Berhan University, College of Agriculture and Natural Resources Sciences in the Department of Animal Science in 2016 and obtained her B.Sc. degree in Animal Science in June 2018. In the same year, she was hired at Debre Berhan University as a graduate assistant and she was joined the school of graduate studies at Debre Berhan University to attend her MSc degree in animal production in October 2019.

ABBREVIATIONS AND ACRONYMS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
BP	Biomass Production
BW	Body Weight
CSA	Central Statistical Agency
CP	Crude Protein
CPI	Crude Protein Intake
DA	Developmental Agents
DF	Days to 50% Flowering
DM	Dry Matter
DTM	Days to 90% Maturity
DMD	Dry Matter Digestibility
DMI	Dry Matter Intake
DZARC	Debre Zeit Agricultural Research Center
EE	Ether Extract
ED EIAR	Effective Degradability
FAOSTAT	Ethiopian Institute of Agricultural Research
FGD	Food and Agricultural Organization Statics
GY	Focus Group Discussion
	Grain Yield
HI	Harvest Index
HSW	Hundred Seed Weight
HY	Haulm Yield
ICARDA	International Center for Agricultural Research in Dry Areas
ILRI	International Livestock Research Institute
IVDMD	In vitro Dry Matter Digestibility
IVOMD	In vitro Organic Matter Digestibility

ABBREVIATIONS AND ACRONYMS (*Continued*)

ME	Metabolizable Energy
MEI	Metabolizable Energy Intake
MOA	Ministry of Agriculture
NFE	Nitrogen Free Extract
NIRS	Near-Infrared Reflectance Spectroscopy
NPB	Number of Primary Branches
NSB	Number of Secondary Branches
OM	Organic Matter
PH	Plant Height
PUI	Potential Utility Index Participatory
PVS	Variety Selection Randomized
RCBD	Complete Block Design Relative
RFV	Feed Value
SAS	Statistical Analysis System
SPSS	Statistical Package for Social Sciences
TDN	Total Digestible Nutrient

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NUTRITIVE VALUE AND FARMERS PREFERENCE OF CHICKPEA (*Cicer arietinum L*) VARIETIES FOR FOOD-FEED TRAITS

ABSTRACT

The study was conducted to evaluate the nutritive value of chickpea haulms from different varieties, to determine the relationship between the feed-food traits of chickpea and to assess farmers' knowledge and preference of chickpea varieties. The study involved field experiment, household survey and farmers' field day. For the field experiment, eight selected varieties of chickpea were used and planted on four farmers' fields. Agronomic parameters were recorded and subsequently, representative haulm samples were taken for nutritional analysis. Survey and farmers' field were used to assess farmers' knowledge and preferred traits as related to food- feed traits. Experimental data were analyzed by using analysis of variance (ANOVA) using Statistical Analysis System software (SAS, 2004) and survey data was analyzed using SPSS statistics tools. The result revealed that higher grain yield (GY) (1.47t/ha) ($P<0.001$) and haulm yield (HY) (2.49) ($P<0.05$) were obtained from Teketay variety. Relatively higher crude protein (CP) (5.12%) and in vitro organic matter digestibility (IVOMD) (50.63%) and metabolizable energy (ME) (7.44MJ/Kg ($p<0.01$) were obtained from Dz0058 variety. Higher dry matter degradability (DMD) ($p<0.001$) was recorded in Dz0058 except for 0, 6 and 24 hours of incubation in the rumen. Higher potential degradable fraction (PD) (61.99%) and effective dry matter degradability (EDMD) (46.79%) ($p<0.001$) were obtained from Dz0058.The GY was significantly ($p<0.001$) and positively associated with plant height (PH) (r=0.76), biomass production (BP), harvest index (HI) and HY. The survey showed that chickpea was the dominant legume grain produced in the study area as a result the haulm was used as livestock feed. The participatory variety selection (PVS) showed Teketay, Dalota and local were found to be the most preferred varieties based on selected criteria. These varieties were found to be good in terms of grain and straw yield hence could be recommended as suitable candidates for crop rotation with cereals in the study area in enhancing livestock production in addition to grain yield for human consumption.

Keywords: Chickpea haulm, dry matter degradability, grain yield, participatory variety selection

1. INTRODUCTION

Ethiopia is gifted with various agro-ecological zones suitable for the production of diversified crop and livestock species (Tolera Adugna *et al.*, 2012). It is believed to have the largest livestock population in Africa and the livestock sector has been contributing a considerable portion to the economy and still promising to rally round the economic development (Central Statistical Agency of Ethiopia (CSA, 2020). Livestock production ensures the availability of food (meat and milk and milk by-products, honey and egg), serves as the source of cash income, agricultural inputs for crop production and used as live banks in the rural community (Dereje Duressa *et al.*, 2014; Belay Beyene, 2017; CSA, 2020). Furthermore, livestock plays an important role in providing export commodities (live animals, hides and skins) to earn foreign exchanges to the country. On the other hand, draught animals provide power for the cultivation and crop long-distances, to convey their agricultural products to the market places and bring back threshing virtually all over the country and are also essential modes of transport to take holders and their families their domestic necessities. Livestock as well confers a certain degree of security in times of crop failure as they are a “near-cash” capital stock (CSA, 2020).

Though the country has large number of livestock and favourable environment, the contribution of livestock to the producers in particular and the national economy in general is below expected (Tolera Adugna, 2008). This is due to some interrelated factors such as feed scarcity in terms of both quality and quantity, the prevalence of diseases and parasites and poor genetic potential of the indigenous animals (Kassahun Gurmessa *et al.*, 2015; Hassanuur Hassan *et al.*, 2020). Among the constraints, shortage of feed in terms of quantity and quality is the major one hindering livestock production and productivity (Tolera Adugna *et al.*, 2012; Lelisa Diriba and Mengistu Urge, 2020; Bezabih Melkamu *et al.,* 2020).

In the highlands of Ethiopia, mixed farming system is dominated hence, the community depends on subsistence crop-livestock farming where livestock are integrally linked to the cultivation and complement each other (Belay Duguma *et al.*, 2012; Wuletaw Mekuria *et al*., 2018a). As a result of population pressure, communal grazing lands are in a decreasing trend (Hiwet Gebremedhin *et al.*, 2017). As a result, the provision of crop residues as livestock feed becoming more practical due to the shortage of alternative feed resources (Solomon Gizaw *et al.*, 2017). In this regard, crop residues provide a considerable quantity of dry season feed in the mixed farming system of Ethiopia (Ashenafi Miresa *et al.*, 2019); Lelisa Diriba and Mengistu Urge, 2020). As a result, its contribution exceeded 50% of the livestock feeds in cereal growing regions of the country (Solomon Gizaw *et al.*, 2017). Ashenafi Miresa *et al.* (2019) also indicated that crop residues including cereals and pulses are the main feed resource during the dry season which supplied about 77.41% of the annual dry matter (DM). However, studies showed that cereal straws and stovers are poor feed sources with low crude protein (CP), digestibility and higher fiber fractions (Mekuanint Gashaw and Girma Defar, 2017; Lelisa Diriba and Mengistu Urge, 2020). However, legume haulms have relatively better nutritional values (CP, metabolizable energy (ME) contents) and digestibility) compared to cereal straws (Lopeze *et al.*, 2005; Eyob Haile, 2017; Haule, 2017).

Grain legumes play an important role as a source of food and feed in smallholder mixed systems and they also contribute to soil fertility improvement through biological nitrogen fixation (Sisay Belete *et al.*, 2019). Among different legume grains, chickpea is a cool-season food-feed legume and grown as a winter crop in the tropics and as a summer or spring crop in temperate environments (FAOSTAT, 2012). It is a good source of protein, carbohydrates, minerals, and vitamins for human nutrition especially in developing countries (Sheleme Beyene *et al.*, 2015). It is relatively high in the content of CP and carbohydrate compared to some other legume grains (Sharma *et al.*, 2013). In addition to human nutrition, the chickpea by product and the haulm of chickpea used as animal feed because of their nutritional value (Bampidisa and Christodoulou, 2011). According to the report of Eyob Haile (2017), the residue of chickpea contains higher CP (10.67%) and ME (7.94 MJ/kg) than cereal straws. Ashiraf (2017) also indicated that the CP, in vitro organic matter digestibility (IVOMD) and ME of chickpea haulm ranged from 7.12-11.1%, 48.4-52.6% and 7.1-7.72 MJ/kg, respectively. Moreover, Tena Alemu (2016) indicated that the CP, IVOMD and ME of Desi type chickpea variety haulms ranged from 3.31-5.21%, 49.51-53.07% and 7.27-7.78 MJ/kg, respectively. The variation of the chemical composition of chickpea haulms is due to genetic as well as environmental factor (Jane *et al*., 2017a).

Even though crop residues make a substantial contribution as a source of livestock feed in mixed crop-livestock production systems, different crop improvement programs like fertilizer applications, variety selection, etc. were focused on grain production with no consideration of yield and nutritive value of crop residues and evaluation and selection of ‘’improved variety without farmer participation. Improvement of crop residues through the collaboration of crop and livestock scientists in multidimensional crop and feed improvement initiatives are necessary. In this attempt, International Center for Agricultural Research in Dry Areas (ICARDA) has initiated multidisciplinary research together with its Ethiopian national partners to produce grain legume cultivars. By increasing crop coverage and production, increasing crop residues production and thus maximization of crop residues utilization is very essential. Moreover, promoting the improved cultivars and associated crop production technologies to farmers through participatory evaluation and selection approaches are very imperative.

Participatory varietal selection (PVS) is the selection made by farmers on their fields of finished or near-finished products from plant breeding programs including released cultivars and varieties in advanced stages of testing (Astawus Esatu *et al.*, 2018). In PVS the users are allowed to participate in selecting appropriate technologies by employing their indigenous knowledge, as a result, it is an effective tool in facilitating the adoption and extension of the improved technologies (Obsa Chimdesa *et al.*, 2018). According to Molla Fantie and Tsedalu Jemberu (2012), PVS has a significant role in technology adaptation and dissemination in a short time than the conventional approach. In smallholder crop-livestock production systems, the improvement of crop straw yield implies an increase in livestock production and productivity. By involving farmers in variety selection, it can be possible to develop and popularize varieties of chickpea crops having high yield (both grain and straw) and better in nutritional content and other agronomic traits.

Thus, the objectives of the present study were

- To evaluate the nutritive value of chickpea haulms from different varieties
- To evaluate the relationship between the feed-food traits of chickpea
- To assess farmer preferences and knowledge related to food-feed traits of chickpea

2. LITERATUR REVIEW

2.1. Overview of Livestock Feed Resources in Ethiopia

Crop-livestock mixed farming systems are the mainstay of smallholders by integrating crops and livestock. Rising populations, together with increasing livestock density and grain production pressure exerts considerable pressure on land resources tend to increase these systems (Wuletaw Mekuria *et al*., 2018b). Livestock act as a live bank and insurance in times of crop failure, as they are a "near-cash" capital stock as well as a vital source of dietary protein (CSA, 2020). The major livestock feed supply in the highlands is based on crop residues, natural pasture and crop aftermath (Derbie Alemu *et al*., 2019; Habte Abebaye *et al.*, 2019; Lelisa Diriba and Mengistu Urge, 2020). Crop residues (including stems, leaves and chaff) refer to the portion of the harvested crop, which remains after the grain portion of the crop is removed. However, the area of grazing land has declining due to the expansion of cropping to meet the food demand of the ever-increasing human population. As a result, ruminants depend largely on crop residues (Fekede Feyissa, 2011; Mekete Bekele *et al.,* 2018).

Straws (from teff, wheat and barley), stovers (from maize and sorghum) and haulms (from pulses) are the major crop residue having an important role in livestock feed provision (Andualem Tonamo *et al*., 2015; Kassahun Gurmessa *et al*., 2016; Mekuanint Gashaw and Girma Defar, 2017). Food feed crops produce large quantities of crop residues (straws, stovers, and haulms) in addition to grain thus which are considered as dual-purpose crops (Fekede Feyissa, 2011). They are important for smallholder farmers in the mixed crop-livestock systems to mitigate feed shortage and provide human food with a balanced diet (Sisay Belete *et al.*, 2019). Grain and crop residues of various cereal and pulse crops are contributing substantial roles equally to the livelihoods of smallholder farmers (Blummel *et al*., 2010).

2.2. Crop Residues

The crops grown are mainly used as food for humans as well as a means of income whereas residues from cereal and pulse crops are the major source of livestock feed (Dawit Assefa *et al.*, 2013). Crop-residues result from the expansion of crop production which provides a considerable quantity of dry season feed in most farming areas of Ethiopia especially in the highland and mid-altitude agro-ecologies (Derbie Alemu *et al.,* 2019; Ararsa Derara and Amanuel Bekuma, 2020). They have an important role in fulfilling feed gaps during periods of acute feed shortage (Kassahun Gurmessa *et al.*, 2015). Although the dominant use of crop residues is as livestock feed, they have also other alternative uses such as for construction, fuel and as sources of cash income under the Ethiopian context (Fekede Feyissa, 2011). Furthermore, they are an important source of soil mulch in the mixed cropping-livestock systems (Ashiraf, 2017).

Studies showed that crop residues had higher total DM production shares relative to other feed resources and the contribution is greater than 50% of the livestock feeds in the mixed crop-livestock production system (Solomon Gizaw *et al.*, 2017; Ashenafi Marisa *et al.,* 2019; Getahun Belay and Tegene Negesse, 2019). The availability of crop residues is closely related to the farming system, the type of crops produced and the intensity of cultivation (Solomon Gizaw *et al.,* 2017). The utilization of crop residues is soon after the main crop harvest and threshed and by conservation for next dry and wet seasons mostly stalked in the open air (Kassahun Gurmessa *et al.*, 2016; Kasa Biratu and Saba Haile, 2017).

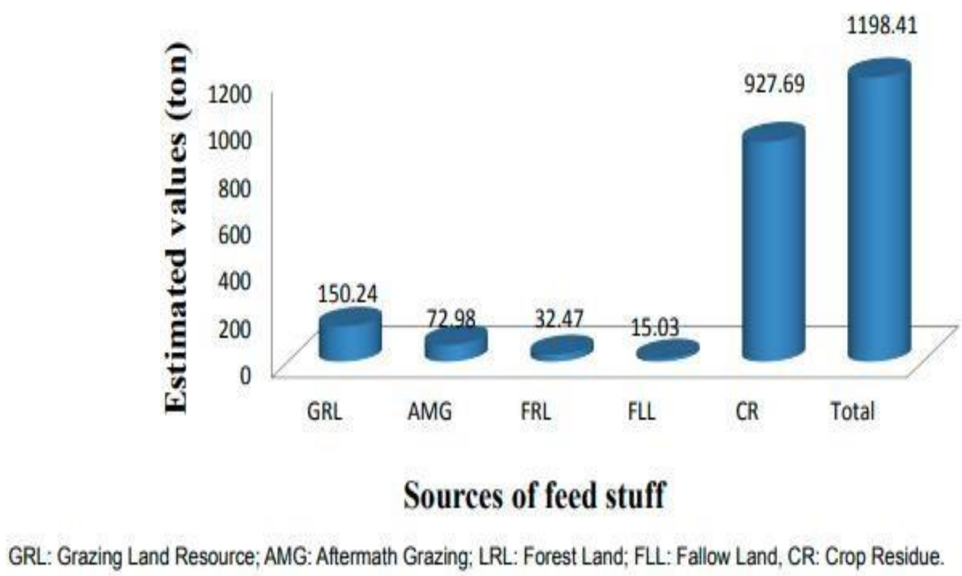

Figure 1. Total DM production shares of different feed resources in selected kebeles of Bedele district, Oromia, Ethiopia Source. (Ashenafi Miresa *et al.,* 2019)

2.2.1. Nutritional value of crop residues

Crop residues are the sources of energy feed; hence up to 80% of their DM is made up of polysaccharides. They vary greatly in chemical composition and digestibility depending on species, varietal differences and agronomic practices. They are fibrous feed characterized by high cell wall content and lower digestibility and CP content specifically cereal straw and stover (Deribe Gemiyo *et al.,* 2013; Lelisa Diriba and Mengistu Urge, 2020). According to Blümmel *et al.* (2010), low CP had a major limitation to the feeding value of cereal residues, particularly when it fed without supplementation. Derbie Alemu *et al.* (2019) also indicated that cereals straws had less CP required for optimum microbial rumen function. Consequently, feeding of straw and stovers without supplementation resulted in low intake, digestibility and utilization.

The variation in the nutritional value of crop residues is due to the differences in the proportion of botanical fractions within and between the crop residues (Eyob Haile, 2017), genotype, agro ecology (Derbie Alemu *et al.,* 2019), species (Mekuanint Gashaw and Girma Defar, 2017), maturity (Rambau *et al.,* 2016). Legume residues have relatively higher nutritional value (higher ME, CP, digestibility) than cereals straws and stovers (Lopeze *et al.*, 2005; Ashiraf, 2017; Eyob Haile, 2017). Under limited resources in the households, better utilization of crop residue could be achieved by maximizing the use of legume residue as feed and optimizing the use of cereal residue as soil mulch (Ashiraf, 2017). Furthermore, Eyob Haile *et al.* (2017) indicated that the effective degradability of dry matter (ED) and organic matter digestibility (OMD) values were higher for legume residue than for cereal crop residues.

According to Lelisa Diriba and Mengistu Urge (2020), even though, legumes residues had high cell wall contents, they had significantly higher CP than cereal crop residues. Lopeze *et al.* (2005) also indicated legume haulms had better feeding value and they were degraded in the rumen at a faster rate, resulting in a higher extent of degradation. Furthermore, according to Mekuanint Gashaw and Girma Defar (2017), pulses straws contain higher CP and in vitro dry matter digestibility (IVDMD). Derbie Gemiyo *et al.* (2013) also indicated that the CP and IVDMD content of crop residues were lower than browses and grasses.

The nutritive value of the crop residues is enhanced through physical and/or chemical treatment and/or supplementation with agro-industrial byproducts or forage legume. According to Fitsum Abera *et al.* (2018), treatment with urea and urea-molasses with concentrate mix is a considerable option for improving the utilization of maize stover. Ashiraf (2017) also indicated that urea treatment results in a considerable enhancement of the nutritive value of chickpea, faba bean and lentil straw by increasing CP, IVOMD, ME, dry matter intake (DMI), crude protein intake (CPI) and metabolizable energy intake (MEI) and decreasing fiber constituents. Moreover, Teklu Wegifeyisa (2016) reported that supplementation of faba bean straw with concentrate resulted in higher potential value as animal feed.

Table 1. Chemical composition and nutritional value of some legume residues

Sources	Residues	CP (%)	ME(MJ /kg)	IVDMD (%)	NDF (%)	ADF (%)	ADL (%)
Kassahun Gurmessa *et al.* 2016	Field pea haulm	5.33	8.48	49.86	67.51	47.94	13.56
	Faba bean haulm	4.71	9.12	54.68	66.89	48.13	15.64
Haule (2017)	Common bean haulm	8.79	8.9	55.9	61.8	48.3	-
	Cow pea haulm	13.9	10.4	65.3	60.1	44.2	-
	Pigeon pea haulm	10.1	8.98	53.8	57.6	33.6	-
Eyob Haile (2017)	lentil haulm	9.4	8.39	-	52.0	32.5	
Asemahegn Mersha and Debissa Lemessa (2020)	Lentil haulms	7.20	8.09	-	50.51	36.77	-

CP= crude protein, ME= metabolizable energy, IVDMD= in vitro dry matter digestibility, NDF= neutral detergent fiber, ADF= acid detergent fiber, ADL= acid detergent lignin

Table 2. Chemical composition and nutritional value of some cereal residues

Sources	Crop residue	CP (%)	ME(MJ/kg)	IVDMD (%)	NDF (%)	ADF (%)	ADL (%)
Mekuanint Gashaw and Girma Defar (2017)	Wheat Straw	3.22	-	41.92	77.72	49.51	10.30
	Barley Straw	4.01	-	48.31	75.26	48.45	8.97
	Teff Straw	3.78	-	46.84	74.17	49.63	9.22
	Barley Straw	4.44	-	-	79.57	60.22	17.68
Derbie Alemu *et al.* (2019)	Wheat Straw	2.44		-	81.72	62.33	17.69
Andualem Tonamo *et al.* (2015)	Teff Straw	4.26	-	50.68	76.10	46.25	5.24
	Maize Straw	3.67	-	40.90	78.23	53.94	5.66
Bezabih Melkamu *et al.* (2018)	Wheat Straw	4.63	6.67	46.2	76.5	50.57	6.30
	Maize stover	5.67	-	59.42	72.55	26.62	
Gashu Geremew *et al.* (2017)	Teff Straw	5.56	-	45.08	77.5	39.39	-
	Barely Straw	4.1	-	52.1	76	42	-
Kassahun Gurmessa *et al.* (2016)	Teff Straw	4.20	9.80	59.56	67.16	32.65	3.54
	Wheat Straw	3.60	9.71	58.56	68.65	37.35	5.33
	Barley Straw	4.08	9.08	53.51	68.77	36.97	6.61
Haule (2017)	Sorghum Stover	8.24	8.86	51.9	69.1	35.9	-

CP= crude protein, ME= metabolizable energy, IVDMD= in vitro dry matter digestibility, NDF= neutral detergent fiber, ADF= acid detergent fiber, ADL= acid detergent lignin

2.3. Food Legume Crops and their Roles

Food legumes are species of the plant family Leguminosae whose seeds are consumed directly by humans. They have an important role in global food and nutrition especially in the dietary pattern of low-income groups of people in developing countries. They are also the source of nitrogen in organic cropping systems as it fixes atmospheric nitrogen and effectively bringing new nitrogen into the soil system (Sharon *et al.*, 2020). They are the second most-produced crop in Ethiopia next to cereals and cultivated on more than 1.5 million hectares of land annually, mainly by smallholder farmers in the mixed crop-livestock farming system for food, feed and soil fertility improvement through symbiotic biological nitrogen fixation (CSA, 2015; Sisay Belete *et al.*, 2019). In addition to contributing directly to food security, food legumes also play an important role as a source of feed for livestock thus indirectly contributing to food security. Besides, grain by products of legumes play an important role as sources of dry fodder for livestock (Sharasia *et al.*, 2017).

In Ethiopia, the production of food legumes covered 12.73% (1,620,497.30 ha) of the grain crop area next to cereal crops and 9.54% (about 30,113,480.57 quintals) of the grain production was drawn from the same crops. Faba beans, haricot beans (white), haricot beans (red) and chickpeas (white) were planted to 3.87% (about 492,271.60 ha), 0.69% (about 88,302.71 ha), 1.57% (about 200,334.52 ha) and 1.28% (about 163,067.24 ha) of the grain crop area, respectively. The production obtained from faba beans, haricot beans (white), haricot beans (red) and chickpeas (white) was 3.30%, 0.48%, 1.07% and 1.05% of the grain production, respectively (CSA, 2019).

2.4. Chickpea and its Roles

Chickpea (*Cicer arietinum L.*) is one of the self-pollinating legume crops with a diploid set of chromosomes (2n=16) (Varshney *et al.*, 2013) cultivated for its edible seeds in almost all part of the world. It has a highly digestible protein content (23%) and also rich in carbohydrates (64%), starch (47%), fiber (6%), and minerals (phosphorus, calcium, magnesium, iron and zinc). Its Lipid fraction is also high in unsaturated fatty acids (Jukanti *et al.*, 2012). According to Mamta *et al.* (2021), chickpea seed contain 22.1 -24.42% protein, 0.15-1.25 sulphur-containing amino acid and 0.63-1.38% Tryptophan. In addition, it fixes atmospheric nitrogen through bacteria (rhizobium) present in their roots, which in turn improves soil fertility hence the crops sown succeeding the chickpea are also benefited. Due to the tap root system, they open up the soil and the extensive leaf drop increases the organic matter in the soil (Lijalem Korbu *et al.,* 2016).

Chickpea is quick-growing, branched and reaches a height between 20 and 60 cm, even up to 1 m. It has a deep taproot and many lateral secondary roots exploring the upper layers of the soil, as a result, it can use residual moisture and it allows farmers to harvest two crops in a growing season (cereal followed by chickpea) thereby improving their food supply and income (Yasin Goa *et al.*, 2017). Based on distinct botanical or morphological features and molecular diversity analysis, chickpea is primarily classified into Desi and Kabuli type. Desi-type chickpea is characterized by small seeds size, pods, leaflets, plantlets and darker colored and smooth or wrinkled seed coat. On the other hand, the Kabuli type is characterized by large seeds, pods, leaflets, plantlets and white to cream-colored seed coat color (Sheleme Beyene *et al.*, 2015).

2.4.1. Chickpea production in Ethiopia

Chickpea is one of the major pulses grown in Ethiopia, mainly by subsistence farmers usually under rain-fed conditions (Getachew Tilahun *et al.,* 2015) and largely produced next to faba bean, haricot bean and field pea (CSA, 2020). Ethiopia is the sixth largest producer of chickpea in the world and the leading producer in Africa (FAOSTAT, 2016). In Ethiopia chickpea is usually grown on black vertisols with minimum tillage and such soils are known for its excess water and drainage problem during the main rainy period (June–August). Thus, to overcome this problem, farmers plant chickpea late in the season (September–October) commonly on residual moisture (Legesse Dadi *et al.*, 2005) which gives farmers opportunities to engage in double cropping. This allows more intensive and productive use of land, particularly in areas where land is scarce (Sheleme Beyene *et al.,* 2015). Amhara and Oromia regions are the larger producer of chickpea in Ethiopia (Sheleme Beyene *et al.,* 2015) (Figure 3). In Ethiopia, chickpea production contributes significantly to household consumption and cash income generation (Tewodros Tefera, 2014). Apart from this, because of its ability to fix atmospheric nitrogen, it can reduce the risk of pests and diseases associated with mono-cropping hence used in crop rotation with cereal crops like wheat, teff and barley (MoANR, 2016).

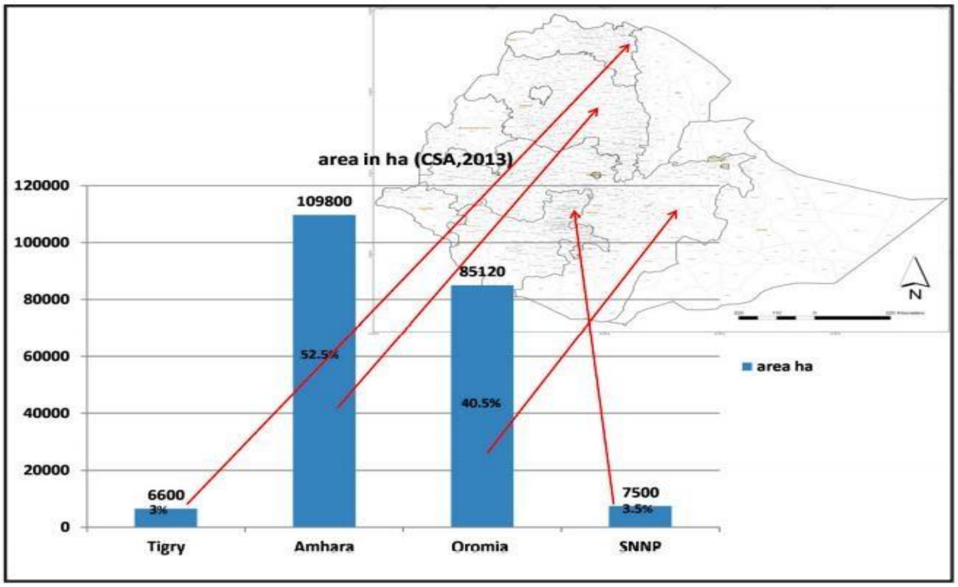

Figure 2. Major chickpea growing region in Ethiopia (Sheleme Beyene *et al.*, 2015)

2.4.2. Yield and yield components of chickpea

Yield is a complex trait controlled by several simply inherited traits. The correlation coefficients highlight the pattern of association among such yield components and determine how a complex trait such as yield can be improved, so it is essential in determining selection criteria (Shanmugam and Kalaimagal, 2019). Hundred seed weight (HSW), pods per plant, plant height (PH) and harvest index (HI) are important indicators in grain yield (GY). Mostly, pods and the number of seeds in pods influence GY in legume crops. According to Tena Alemu (2016), biomass production (BP) is positively and significantly ($p<0.001$) correlated to days to 50% (DF), days to maturity (DTM), HSW, PH, GY, HI and haulm yield (HY).

Rahimi *et al.* (2013) also reported GY exhibited a significant positive correlation with the number of pods. Fasil Hailu (2019) indicated that HI and BP had a significant and positive association with grain yield. Tibebu Belete *et al.* (2017) also reported that grain yield showed a highly significant association with biomass yield and similarly biomass yield showed a significant positive association with the number of primary branches per plant, biomass production rate, seed growth rate and grain yield. These indicate that correlated traits had an association with grain yield and they have an important role in determining these complex traits.

Therefore, consideration should be given while practicing selection aimed at the improvement of grain yield.

The yield and yield components of chickpea are affected by genotype (Bazvand *et al*., 2015) inter and intra-row spacing (Melak Agajie, 2018), sowing date (Regassa Ayana *et al*., 2014; Bazvand *et al.*, 2015; Husnain *et al*., 2015; Ray *et al.*, 2017; Amrinder et al., 2019) and genotype by location interaction (Fasil Hailu, 2019). Jane *et al*. (2017) and Tena Alemu (2016) also indicated that genotype had a significant effect on grain and haulm yield of chickpea.

2.5. Chickpea Haulm as Livestock Feed Resource and its Nutritive Value

Chickpea is one of the leguminous plants which is a less labor-intensive crop compared to cereals crop. It is an important crop in mixed crop-livestock systems in Ethiopia. It is cultivated as a food-feed crop, where the grain provides food for humans and the haulm for the livestock (Besufekad Belayneh *et al.*, 2018).

2.5.1. Chemical composition

Chickpea haulm is the by-product produced after chickpea grain threshing which can be used as a ruminant feed. Previous research showed that it has relatively higher CP and ME (Bampidis and Christodoulou, 2011; Kafilzadeh and Maleki, 2011; Golshani *et al.,* 2012; Eyob Haile, 2017). Lardy and Anderson (2009) also indicated that chickpea haulm had higher nutritive value than cereal straws (about 44-46% total digestible nutrient (TDN) and 4.5-6.5% CP). Furthermore, Ashraf (2017) reported that the CP and ME contents of the chickpea haulm ranged from 7.12-11.1% and 7.1- 7.72 MJ/kg DM which indicates, it have better feeding value. Fikadu Dereje *et al.* (2010) also showed chickpea haulm has a chemical composition of DM (91.5-92), Ash (8.67-9), CP (6.19-6.36), NDF (55.1-57.5), ADF (40.5-41.4) and ADL (8.04-8.52). On the other hand, Abdel-Magid *et al.* (2008) indicated that chickpea haulm had lower nutritive value compared to pea haulm and berseem hay when fed to growing male sheep.

Moreover, chickpea haulm is also a good source of minerals, such as calcium, phosphorus, magnesium, iron and potassium (Carla *et al.*, 2013). According to Jane *et al.* (2017a), chickpeas haulms are a good source of calcium. The nutritional value of chickpea haulm is variable depending on the crop variety, the content of anti-nutritional factors (e.g. tannins), stage of harvest, length of storage, leaf to stem ratio, storage conditions, location, soil fertility and fertilizer application (Kafilzadeh and Maleki, 2011).

Table 3. Chemical composition and nutritional value of chickpea haulms

Parameters (%)	Kafilzadeh and Maleki (2012)	Golshani *et al.* (2012)	Numan *et al.* (2017)	Ashraf (2017)	Jane *et al*. (2017a)
DM	-	92.18	89.4-90.3	-	-
OM	92.08-92.93	92.00	81.2-81.8	-	-
CP	2.81-3.58	6.05	6.40-7.42	7.12-11.1	4.82- 5.99
NDF	59.86-64.54	-	63.7-67.0	64.4- 73.2	71.6- 75.0
ADF	45.92- 47.34	-	51.3-56.0	42.9- 48.9	-
ADL	-	-	-	11.3- 13.0	-
IVOMD	-	-	-	48.4- 52.6	47.7- 49.9
ME(MJ/kg)	5.59- 6.21	-	5.96- 7.37	7.1- 7.72	-

DM= dry matter, OM= organic matter, CP= crude protein, NDF=neutral detergent fiber, ADF= acid detergent fiber, ADL= acid detergent lignin, IVOMD=in vitro organic matter digestibility, ME= metabolizable energy

2.5.2. Dry matter degradation kinetics

Dry matter degradability (DMD) of chickpea haulm is lower than that of other legume straw due to its higher cell wall content (Golshani *et al.*, 2012). Kafilzadeh and Christodoulou (2011) reported that DM digestibility and rumen degradability of chickpea haulm was about 10 and 42% which was higher than cereal straw, respectively. Golshani *et al.*(2012) reported that organic matter (OM) and CP degradation of chickpea haulm at initial incubation times (0- 12 hours) increased considerably, while degradation rate increments after 12 hours of incubation were slow and the 72 hours incubation degradation percentage for OM and CP of chickpea haulm were 60.0% and 73.3%, respectively. Naser *et al.* (2011) also showed that the dry matter degradation of chickpea haulm at initial (washing loss. 0 h) and final (72 hours) incubation times were 18.14 and 60.09%, respectively. Eyob (2017) indicated that the OM and CP degradation characteristic of chickpea haulm were high and the values of DM, OM and CP degradation characteristics were dependent on the content and the composition of the cell walls of the straw.

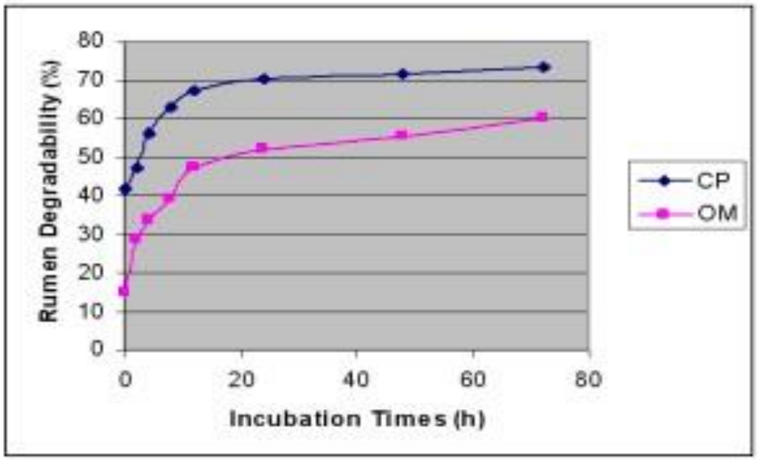

Figure 3. Ruminal organic matter and crude protein degradation of chickpea haulm at different incubation times (Golshani *et al.*, 2012).

Table 4. Ruminal DM degradation characteristics of chickpea haulms

Parameter (%)	Soares *et al.* (2000)	Naser *et al.* (2011)	Eyob Haile (2017)	Numan *et al.* (2017)
a	16.7	19.00	24.8.4	19.16
b	28.7	38.60	32.36	37.68
c	0.041	0.152	0.044	0.0114
a+b	45.4	58.10	57.20	56.84

a= immediately soluble fraction, b= insoluble but slowly degradable fraction, c= constant rate for the degradation of fraction b (degradation rate), a+b = potential degradability

Table 5. Ruminal NDF, OM and CP degradation characteristics of chickpea haulms

Parameter (%)	Soares *et al.* (2000)	Numan *et al.*(2017)	Eyob Haile (2017)	Golshani *et al.* (2012)	Eyob Haile (2017)	Golshani *et al.* (2012)
	NDF		OM		CP	
a	6.6	-	16.36	17.50	18.11	40.80
b	32.7	76.40	36.89	39.20	54.95c	31.20
c	0.028	0.0176	0.042	0.116	0.079	0.153
a+b	39.3	56.84	53.25	56.70	73.06	72.00

a= immediately soluble fraction, b= insoluble but slowly degradable fraction, c= constant rate for the degradation of fraction b (degradation rate), a+b = potential degradability

2.6. Relationship between Food- Feed Traits of Chickpea

The relationship between food-feed trait components is essential in determining selection criteria hence improving one trait may increase the other. Grain yield is the primary trait targeted in the chickpea improving program. So, the efforts to increase the yield and nutritive value of chickpea haulm do not depress grain yield (Ashiraf, 2017). According to Rahimi *et al.* (2013) and Tena Alemu (2016), the correlation between haulm and grain yield was significantly positive which indicated the possibility of increasing both yields simultaneously.

According to Tena Alemu (2016), grain and haulm yield were significantly and negatively correlated with ash, CP, ME and IVOMD and positively correlated with NDF, ADF and ADL. However, Ashiraf (2017) showed that correlations between CP, NDF, ADF, ADL and ME content of chickpea haulm and grain yield were weak which presents a good opportunity for increasing straw/grain yield without affecting straw fodder quality and vice versa. Tena Alemu (2016) in his result showed that DTM was significantly and positively correlated with NDF, ADF and ADL hence as the days increases for plant maturity, at the same time the fiber content increases. However, the DTM is significantly and negatively correlated with ash, CP, ME and IVOMD (Tena Alemu, 2016). As the number of days increases for crop maturity, the CP percentage reduces mainly due to the dilution effect by rapid accumulation of cell wall content ((McDonald *et al.*, 1995; Wubetie Adnew *et al.*, 2018).

2.7. Participatory Variety Selection

Participatory variety selection (PVS) has evolved as one of the innovative approaches to complement the conventional variety development and dissemination process (Keshab, 2012; Daniel Tadesse *et al.,* 2014; Tokuma Legesse *et al.*, 2019). It is a selection among varieties that do not segregate in the next generation by farmers under the target environment. It is a simple way for breeders and agronomists to learn which varieties perform well on-farm and preferred by farmers (Ceccarelli, 2012). Hence, farmers can select well-adapted and preferred varieties under their circumstances using their criteria (Berhanu Fentie and Mesfin Fenta, 2021). Participating farmers in the process of crop improvement and variety evaluation fasten variety identification and adoption, increase variety diversity, yield and farmers' income, facilitate farmers learning and empowering and strengthen collaboration between breeders and farmers (Almekinders and Elings, 2001).

Teame Gerezeir *et al.* (2018) showed that PVS has been projected as an alternative to the problem of fitting the crop to the target environments and users' preferences. The inclusion of farmers in the variety selection and perception enabled them to select the best variety/cultivar and/or hybrid of the new crop according to their experiences, which performed well in their local environments. It has three phases to identify preferred cultivars. Identifying farmers' needs; searching for suitable material to test with farmers; and experimentation on farmers' fields (Witcombe *et al.,* 2003). Participatory variety selection has many advantages and some of them include strengthening farmers' autonomy and increasing their freedom to select varieties, increasing adoption of new improved varieties by the farmer, to know more precisely farmers' varietal selection preferences and criteria to include them in breeding objectives and to increase the dissemination of new varieties in farmer field condition (Sié *et al.*, 2010).

3. MATERIALS AND METHODS

3.1. Cultivation of Different Varieties of Chickpea

3.1.1. Description of the study area

The experiment was conducted on four farmers' fields at Adadi Gole kebele, Gimbichu District East Shewa Zone of central Oromia region from the beginning of October 2019 to the end of March 2020. The locations were purposively selected for their potential for chickpea production in the central highlands of Ethiopia. Adadi Gole kebele is one of the urban kebele of Gimbichu district. It is geographically located at 08 ° 59' 950'' N, 39° 07' 652'' E at an elevation of 2430 m.a.s.l. The area is characterized by one cropping season. Heavy clay soil textural class and Eutric Vertisol soil types dominate the area. The area receives a mean annual rainfall of 843mm. Rainfall distribution is bimodal, usually the long rains (Meher) and the period of the short rains (Belg). The annual minimum and maximum temperature are 7 ^{o}c and 26^{o}c respectively. The dominant crops grown on the area include wheat and teff (from cereal crops) and chickpea, grass pea and lentil (from legume grains).

3.1.2. Experimental design

Eight chickpea varieties were used as the planting material (Table 6). A randomized complete block design (RCBD) was used to layout the experiment. Four farmers from a specific location were selected based on the representativeness of the farm and the willingness of farmers to allocate land for the trial. The farmers were allowed to grow all the eight chickpea varieties. The individual plot size was 25m^2 (5m x 5m) for each genotype. Row planting was implemented with 0.3 and 0.1m spacing between rows and plants, respectively as per research recommendation and the space between the plots were 1m. The row length was 5 m and the numbers of rows per plot were 17. The seeding and fertilizer rates were 120 and 100 kg ha^{-1} as per research recommendation. Crop husbandry practices were done by farmers under the close supervision of the researchers and development workers until the crops reached maturity for grain harvesting.

3.1.3. Description of experimental materials

A total of eight chickpea varieties (i.e. three Desi type released, three Kabuli type released, one local variety and one advanced line) obtained from Debre Zeit Agricultural Research Center (DZARC) were used as the experimental materials.

Table 6. Description of the chickpea varieties used in the experiments

Variety	Year of release	Breeder/Maintainer	Type	Status
Teketay	2013	DZARC	Desi	Released
Dalota	2013	EIAR/ DZARC	Desi	Released
Minjar	2010	EIAR/ DZARC	Desi	Released
Hora	2016	EIAR/ DZARC	Kabuli	Released
Ejerie	2005	EIAR/ DZARC	Kabuli	Released
Arerti	1999	DZARC/EIAR	Kabuli	Released
DZ0058	–	DZARC	Desi	Advanced line
local	–	_	_	Local variety

Source (MoANR, 2016)

3.1.4. Agronomic parameter evaluation and sample collection

The agronomic characteristics include DF (days), DTM (days), PH (cm), number of the primary branch (NPB), number of the secondary branch (NSB), HSW (g), GY (t/ha), HI (GY/BP), BP (t/ha) and HY (t/ha). The DF was recorded as the number of days from planting to a stage where 50% of the plants in a plot bear flower. Days to maturity were recorded as the number of days from planting to a stage where 90% of the plants in a plot produce matured pods. Plant height was measured in centimeters from the ground level to the tip of the plant from 10 randomly selected plants at physiological maturity and the average heights were taken. Number of primary branches was recorded by counting the number of branches which were primarily produced from the main stem from 10 randomly selected plants at physiological maturity and the average was taken as NPB.

Number of secondary branches (NSB) was recorded by counting the number of secondarily produced branches from the primary branch from 10 randomly selected plants in a plot and the averages were taken as NSB. Hundred seed weight was determined by weighing hundred randomly taken seeds from each plot after threshing by using a sensitive balance after adjusting the moisture content to 10- 12%.

Grain yield was determined from the middle rows of the plant after threshing and yield per plot was converted to per hectare basis. Harvesting index was determined as the ratio of GY to BP. The BP was recorded by weighing the total above-ground biomass harvested from each experimental plot at the time of harvesting and then yield per plot converted to yield per hectare basis. Haulm yield was determined by calculating the difference between BP and GY and finally yield per plot converted to per hectare basis. Finally, representative samples of whole plant haulm composed of stems, leaves and pod husks (500-800 g) were collected into sample bags for each plot separately and labeled with necessary information.

3.2. Laboratory Evaluation

3.2.1. Chemical composition

The representative haulm samples were transported to ILRI Animal Nutrition Laboratory, Addis Ababa for laboratory analysis. The samples were given laboratory numbers and ground to 1mm mesh size using Wiley mill and packed into paper bags. Near-Infrared Reflectance Spectroscopy (NIRS) prediction was employed for the analysis of the nutritional value of haulm samples. The NIRS instrument, Foss Forage Analyzer 5000 with the software package WinISI II in the 1100-2498nm spectral ranges were used to scan chickpea haulm samples for the prediction of DM, Ash, N, ME, IVOMD and fiber fractions (NDF, ADF and ADL), by using predictive equations developed based on previously conducted conventional analyses. For scanning purposes, the already ground sample was dried overnight at 60°C in an oven to standardize the moisture conditions and then the partially dried sample was filled into NIRS cup and scanned. The Crude CP was calculated as N × 6.25.

Hemicellulose and cellulose content was determined using the following equations.

$$\mathrm{Hemicellulose}(\%) = \mathrm{NDF} - \mathrm{ADF},\ \mathrm{Cellulose}(\%) = \mathrm{ADF} - \mathrm{ADL}$$

The value of NDF and ADF also were used to calculate dry matter intake (DMI), dry mater digestibility (DMD) and relative feed value (RFV) according to the formula developed by Rohweder *et al. (*1978);

$$\mathrm{DMD}\% = 88.9 - (0.779 \times \%\,\mathrm{ADF},\quad \mathrm{DMI}\,\%\ \mathrm{of\ BW} = 120\,/\,\%\mathrm{NDF}\ \text{ then}$$

$$\mathrm{RFV} = \frac{\%\mathrm{DM}\ \ \mathrm{D}\times}{1.29}$$

3.2.2. In situ ruminal incubation

Rumen degradability of samples straw of chickpea varieties was determined by incubating samples in nylon bags in three rumen fistulated Boran- Holstein Frisian steers just before the morning meal. Chickpea haulm samples were grounded to pass 2mm screen and 3g of each sample on air-dry basis were transferred into each nylon bag and then incubated for 0, 6, 12, 24, 48, 72 and 96 hours. After each incubation period, the bags were removed from the rumen of the animals and immediately put in water to stop the microbial activity and then hand-washed under running tap water until the water becomes clear. Afterward, the bags with residues were oven-dried at 65 ^{o} C for 72 hours and again weighed to determine the dry matter content of residues. Washing loss (“0-hour” degradability of soluble nutrients) was determined by washing haulm samples in the water tank for 30 minutes and then the bags were dried in the same way to determine DM contents of the haulm samples.

The ruminal in situ degradability of DM (DMD) was determined for each incubation time using the following formula (Ørskov and McDonald, 1979).

$$\mathrm{DMD}(\%) = \frac{\mathrm{DM\ \ in\ haulm\ sample} - \mathrm{DM\ in\ residue}}{\mathrm{DM\ in\ residue}} \times 100$$

Digestion kinetics of DM was found by fitted the DMD data into the exponential equation

$$\mathrm{P} = \mathrm{a} + \mathrm{b}\,(1 - \mathrm{e}^{-\mathrm{ct}}$$

Where, P = degradation of DM (%),

a= Washing loss or soluble fraction (%),

b= the rumen-insoluble, but slowly degradable fraction (%)

a + b = potential degradability (%)

c = fractional degradation rate (hr^{-1}) and t = time (hr)

e = (2.7182) base for natural logarithm

Potential degradation (PD) was estimated as $(a + b)$ and effective degradability (ED) of DM was estimated using the formula. ED = $a + b \times (c/(c + k))$ where a, b and c are described above and k is rumen outflow rate, which is assumed to be 0.03/hr for roughage feeds (Ørskov and McDonald, 1979).

3.3. Haulms Dry Matter Yield and Potential Utility Index

The haulm dry matter yield (kg/ha) (HDMY) was calculated according to the formula developed by Tarawali *et al.* (1995);

$$\text{HDMY (t/ha)} = \frac{\text{DM(\%)} \times \text{ HY (t/ha)}}{100}$$

Potential utility index (PUI) integrates grain yield within in-vitro organic matter digestible haulm of the different chickpea varieties and was calculated according to the formula developed by (Fleischer *et al.*, 1989).

$$\text{PUI} = \frac{\text{GY(t/ha)} + \text{IVOMD(\%)}\ \ \text{HY(t/ha)}}{\text{BP(t/ha)}}$$

3.4. Evaluation of Farmer Preferences and Knowledge

3.4.1. Selection of survey kebeles and household data collection

A survey was conducted in three kebeles of Gimbichu district, East Shewa Zone of central Oromia region. A multi-stage sampling procedure was followed to select the sites for the study. The first stage was a purposive selection of three kebeles from the district based on the potential for chickpea production. The second stage was a random selection of two villages from each kebeles and the last stage was a random sampling of 25 mixed crop-livestock farmers from each of the selected villages. Eventually, a total of 150 household farmers were considered for the collection of household data. During the survey, information was mainly gathered on demographic and socioeconomic characteristics on crop production, livestock and land holding, chickpea production, feed resources and feeding strategies.

3.4.2. Farmer field day

A field day was organized in the experimental site to identify farmer's preferred varieties for food feed traits. The varieties were separately evaluated at the flowering stage by developmental agents (DAs) and a group of 36 farmers at each experimental site. The farmers were selected based on their experience in chickpea production. A pair-wise ranking of the farmer’s selection criteria was made to rank the selection criteria to determine the most important preferred trait. Before the evaluation, farmers were made to familiarize with the selection criteria and process. Then, farmers gave a 1-5 scale rank (Very good (5), good (4), average (3), poor (2) and very poor (1)) based on some selected criteria.

3.5. Statistical Analysis

Data obtained from the predicted value of NIRS, agronomic and DM disappearances were analyzed by analysis of variance (ANOVA) using SAS, 2004, version 9.0.Correlation analysis was also done between different agronomic parameters and chemical compositions. The statistical significance of the differences between means was tested using Duncan’s multiple range tests (DMRT).The following mathematical linear model for randomized complete block design was used to analyze the data

$Y_{ij}= \mu +R_i+G_i+E_{ij}$

Where: Yij= the observed value of the trait Y for the i^{th} genotype in j^{th} replication/ block

μ = the general mean of trait Y;

R_j, the effect of j^{th} replication/ block

G_i= the effect of i^{th} genotypes and

E_{ij} = the experimental error associated with the trait y for the i^{th} genotype in j^{th} replication

The DM disappearances and the degradation characteristics such as a, b, c, PD and ED were estimated using nonlinear regression procedures of SAS. The means and percentages of the survey data were analyzed using SPSS version 16.

4. RESULTS AND DISCUSSION

4.1. Food -Feed Traits of Selected Chickpea Varieties

4.1.1. Grain and haulm yield

Grain yield, haulm yield, haulm dry matter yield, harvest index and potential utility index are indicated in (Table 7). In the current study, grain yield differed significantly ($p < 0.001$) among the evaluated varieties.This is comparable with the previous study by Getachew Tilahun *et al.* (2015), Jane *et al.* (2017a), Fasil Hailu *et al.* (2020) and Amare Tsehaye *et al.* (2020) who reported significant variation for GY in different chickpea varieties. The variation among varieties could be due to genetic effects. Significantly higher GY was obtained from Teketay (1.47t/ha) followed by local (1.26t/ha) and Dalota (1.24t/ha), respectively while the least value of GY (0.45t/ha) recorded from DZ-0058. The yield advantage of Teketay over that of local variety was 16.7%. The least grain yield recorded for DZ-0058 might be due to low field emergence and sparse plant density.The overall GY (1.03 t/ha) in the present study is lower than the value of 2.063, 1.197 and 1.67t/ha reported by Getachew Tilahun *et al.* (2015) and Yasin Goa, Mathewos Ashamo (2016) and Tena Alemu(2016) respectively.

Haulm yield was significantly ($p<0.05$) differed among the tested varieties. This is comparable with the previous works by Tamiru Meleta and Girma Abera (2019), Tesfahun Mekuanint *et al.* (2018) and Jane *et al.* (2017a) who reported the presence of significant variation of HY among different chickpea varieties. In this regard, significantly higher but statistically similar HY values 2.57, 2.49, 2.28 and 2.11 t/ha were recorded for Minijar, Teketay, Local, and Ejerie varieties, respectively, whereas the least value (1.75t/ha) was recorded for Dz0058. The presence of variability among genotypes could be essential for the improvement in crop straw yield which in turn brings an increase in livestock production and productivity (Jane *et al.*, 2017b). The overall mean HY (2.15) in the present study is lower than the value of 2.94 t/ha reported by Tena Alemu (2016).

Relatively low yields (grain and haulm) observed in the present study might be attributed to the late time of sowing, wet seedbed and disease prevalence. At the time of sowing, there was heavy rain thus the experimental site was affected. Previous studies indicated that grain and haulm yield of chickpea reduced gradually due to the effects of delayed sowing (Regassa Ayana, 2014; Sikdar *et al.*, 2015; Ray *et al.*, 2017; Bezabih Woldekiros and Lake Mekonnen, 2018; Amrinder *et al.*, 2019). Generally, late planting was observed to expose the plants for drought stress conditions which resulted in lower vegetative growth that in turn resulted in low yield.

Table 7. Average grain yield, haulm yield, haulm dry matter yield, harvest index and potential utility index of eight chickpea varieties

Varieties	GY (t /ha)	HY (t /ha)	HDMY (t/ha)	PUI (%)	HI (%)
Ararti	1.01^{c}	2.04^{bcd}	1.86	51.72	34.15^{abc}
Dalota	1.24^{b}	2.10^{bcd}	1.90	51.52	37.23^{a}
Dz0058	0.45e	1.75^{d}	1.58	45.17	21.07^{d}
Ejerie	0.80^{d}	2.11^{abcd}	1.91	44.55	28.63^{bc}
Hora	0.98^{cd}	1.86^{cd}	1.69	52.35	34.65^{ab}
Local	1.26^{b}	2.28^{abc}	2.06	47.50	35.75^{a}
Minijar	1.00^{c}	2.57^{a}	2.33	42.00	28.25^{c}
Teketay	1.47^{a}	2.49^{ab}	2.25	49.68	37.43^{a}
Mean	1.03	2.15	1.93	48.06	32.01
SEM (±)	0.058	0.07	0.07	0.01	0.01
CV (%)	12.19	13.49	17.30	13.79	12.17
Sig	***	**	ns	ns	***

$^{a-e}$ means within columns followed by the same letter (s) are not significantly different ($P < 0.05$), ns = not significant, ** = significant at $P \leq 0.01$, *** = significant at $P \leq 0.001$, GY=grain yield, HY=haulm yield, HDMY= haulm dry matter yield, HI=harvest index, PUI= potential utility index, SEM=standard error of the mean, CV=coefficient of variation, Sig.= significant level

4.1.2. Haulm dry matter yield, harvest index and potential utility index

There was no significant (p>0.05) difference between the varieties for HDMY and PUI in the present study (Table 7). Contrary to this, Tena Alemu (2016) reported significant variation for HDMY and PUI of chickpea haulms.

The highest HDMY and PUI were recorded from Teketay (2.25 t/ha) and Ararti (52.35%) while the least value was recorded from Dz0058 (1.58 t/ha) and Minijar (42.00%), respectively. Potential utility index integrates grain and digestible dry matter. So, it is a good parameter in measuring food-feed crops (Fleischer *et al.*, 1989). However, in the present study varieties with higher IVOMD were not found to be higher in PUI due to the lower grain yield of such varieties.

Harvest index differed significantly ($p<0.001$) among the tested varieties (Table 6). The yield of a crop is the function of biomass production and harvest index therefore, HI is an important selection criterion in plant breeding. Significantly higher HI was recorded from Teketay (37.43), Dalota (37.23), local (35.75) and Ararti (34.15), whereas, the least (21.07) was obtained from Dz0058. The lower HI in the present study might be might be due to the late time of sowing, disease prevalence and presence of wet seedbed. Generally, previous studies indicated lower HI of chickpea crop at late sowing compared to the optimum time of sowing (Regassa Ayana, 2014; Husnain *et al.*, 2015).

4.1.3. Chemical composition of chickpea varieties haulms

4.1.3.1. Dry matter and ash contents

Significant difference ($p>0.05$) was not observed among the tested varieties in the content of DM of chickpea haulms (Table 8). The DM content of chickpea varieties haulms were ranged from 90.26 in Ejerie to 90.60 % in Minijar. The overall mean value of DM (90.46%) in this study is lower than the previous findings reported by Golshani *et al.* (2012) (92.18) and Eyob Haile (2017) (91.64%) in chickpea haulms while higher than the result of 90.0% reported by Numan *et al.* (2017) in chickpea haulm. This variation possibly might arise from variation in variety and samples drying methods.

A significant ($p<0.05$) varietal difference was observed in the ash content of chickpea varieties haulms (Table 8).Higher ash content was obtained from Dz0058 (9.08%) and lower from Minijar (7.43%). The average mean of ash (8.18%) obtained in the present study is lower than the previous values of 8.50% in chickpea lines haulms and 8.65% in Desi type chickpea varieties haulms, respectively by Numan *et al.*(2017) and Tena Alemu(2016). This variation might be due to the variation in variety and location. The ash content is the concentration of minerals in the forages which play an important role in the body function of the overall animal production and productivity activity (Rasby *et al.*, 2011). The higher ash content indicates a high concentration of minerals (Fantahun Dereje, 2016).

4.1.3.2. Cell wall contents

A significant ($p<0.05$) varietal difference was observed in the NDF content of chickpea varieties haulms (Table 8). Higher NDF was obtained from Minijar (59.41%) and lower from Dz0058 (52.12%).The overall mean NDF content (55.42%) in this study is lower than the result of 58.32-65.55% in different chickpea varieties haulms (Kafilzadeh and Maleki, 2012; Tena Alemu, 2016; Numan *et al.*, 2017).On the other hand, it is higher than 52.11% in chickpea haulm varieties grown in low moisture areas reported by Tena Alemu (2016). The NDF contents of all tested varieties were relatively lower than the upper limit of 60% of which voluntary feed intake and feed conversion efficiency are decreased due to longer rumination time. The relatively low content of fiber among varieties may facilitate the colonization of the feed by the microbial rumen population, which in turn might increase fermentation rate and thus improving digestibility and feed intake (Van Soest, 1994).

A significant ($p<0.05$) varietal difference was observed in the ADF content of chickpea varieties haulms (Table 8). The overall mean of ADF content (44.49%) is higher than the value of 38.93% in chickpea varieties haulms in low moisture area and 42.67% in Desi type chickpea varieties in potential environment reported by Tena Alemu (2016). On the other hand, it is lower than 46.70% and 53.0% in chickpea haulm and different chickpea varieties and lines haulm reported by Kafilzadeh and Maleki (2012) and Numan *et al.* (2017), respectively. This variation might be coming from variation in location, genotype, soil fertility and maturity. The ADF is the percentage of indigestible and slowly digestible material in a feed (McDonald *et al.,* 2002).

A significant ($p<0.05$) varietal difference was observed in ADL content among the tested varieties haulms (Table 8). The overall mean ADL (10.26%) content of chickpea varieties haulms is relatively comparable with the result of 9.89 and 9.82% in Desi and Kabuli type chickpea varieties haulms, respectively in the potential environment. On the other hand, it is higher than 8.81% in Kabuli type chickpea varieties in low moisture stress area reported by Tena

Alemu (2016). This might be due to the time required for maturity is shorter in low moisture areas and similarly, the cell wall content of the haulm is also lower because of the residue harvested after the crop maturity. Tena Alemu (2016) showed that agro ecology had a significant effect on the ADL of chickpea varieties haulms. In the present study, the lignin content of the haulm was high as compared to the maximum level of 7%, which limits DM intake and digestibility. Digestibility of the feed decreased with increasing maturity and this could be linked with an increased fiber concentration in plant tissue and increased lignification during plant development (Wilson *et al.,* 1991). Significant (p>0.05) difference was not observed in hemicellulose and cellulose content among the tested varieties of chickpea haulms (Table 8). The hemicellulose content was ranged from

Table 8. Dry matter, ash and cell wall contents of chickpea varieties on experimental sites

Varieties	DM (%)	Ash (%)	Hemicellulose (%)	Cellulose (%)	NDF (%)	ADF (%)	ADL (%)
Ararti	90.48	8.52^{ab}	10.93	32.74	53.74bc	42.81^{b}	10.07^{bc}
Dalota	90.52	8.07^{cb}	10.85	34.42	55.71^{abc}	44.86^{ab}	10.44^{ab}
Dz0058	90.36	9.08^{a}	9.99	32.45	52.12^{c}	42.14^{b}	9.69^{c}
Ejerie	90.26	8.30^{abc}	11.10	33.34	54.68^{bc}	43.59^{b}	10.24^{bc}
Hora	90.49	7.88bc	10.78	34.03	55.00bc	44.29b	10.19bc
Local	90.51	8.50^{ab}	11.42	35.31	56.95^{ab}	45.53^{ab}	10.22^{bc}
Minijar	90.64	7.43c	11.43	36.97	59.41a	47.98a	11.02a
Teketay	90.41	7.67bc	10.97	34.47	55.71abc	44.74ab	10.28bc
Mean	90.46	8.18	10.93	34.22	55.42	44.49	10.26
SEM (±)	0.05	0.19	0.19	0.53	0.69	0.65	0.14
CV (%)	0.19	7.60	9.90	5.69	4.85	5.12	4.18
Sig.	ns	*	ns	ns	*	*	*

[a-c] means within columns having different superscript are significantly different at*= P<0.05, **=P<0.01, DM= Dry matter, , NDF=neutral detergent fiber, ADF= acid detergent fiber, ADL=acid detergent lignin, SEM=standard error of mean, CV= coefficient of variation, Sig.= significant level

4.1.3.3. Crude protein

Significant ($p>0.05$) difference was not observed in the CP contents of chickpea varieties haulms in the present result (Table 9). The overall mean CP content (4.07%) in this study is relatively consistent with the value of 4.15% in Desi-type chickpea varieties reported by Tena Alemu (2016) while it is higher than the value of 3.23% reported by Kafilzadeh and Maleki (2012) in chickpea haulm. On the other hand, it is lower than the result of 6.05 to 6.45% reported for different varieties of chickpea haulms (Golshani *et al.,* 2012; Numan *et al.,* 2017). This variation might be coming from variation in location, maturity, variety and management conditions among the different studies.

The CP content is one of the most important criteria to determine the nutritional quality of livestock feeds since as the level of CP increases, the dry matter intake by livestock and rumen microbial growth would also increase (Chanthakhoun *et al.*, 2012). However, the mean CP content of chickpea varieties haulms in this study is lower than the critical value of 7% for normal rumen microbial action and feed intake (Van Soest, 1982). Therefore, the sole feeding of residue from these varieties will not supply adequate ammonia levels required for rumen microbial activity (Sultan *et al.,* 2007). The lower CP content in this study might be related to the longer time required for the maturity of the plant that induces dilution of CP and increasing lignification. Reddy *et al.* (2003) indicated that water-stressed plants had higher nitrogen content and digestibility.

4.1.3.4. Metabolizable energy

A significant ($p<0.01$) difference was observed in ME content among the tested varieties haulms (Table 9). Higher ME content was obtained from Dz0058 (7.44) and lower from Minijar (6.71 MJ/kg). The overall mean ME content (7.16 MJ/kg) is relatively consistent with the value of 6.84 MJ/kg for different chickpea lines haulms reported by Numan *et al.* (2017). On the other hand, it is slightly lower than 7.54 - 7.94 MJ/kg for different chickpea varieties haulms reported by Tena Alemu (2016). On the other hand, it is higher than 6.02 to 6.84 MJ/kg for different varieties and line haulms (Kafilzadeh and Malek, 2011; Numan *et al.,* 2017). The range of ME in the present study is lower than 7.10 -7.72MJ/kg reported by Ashraf (2017). This variation might be due to genetic, environmental and management factors. The values of ME in each genotype of chickpea varieties haulms in the present study were above the lower limit of tropical forage legumes 6.50 MJ/kg DM (Evitayani *et al.,* 2004).

4.1.3.5. In vitro organic matter digestibility

A significant ($p<0.01$) difference was observed in IVOMD among the tested varieties with the range of 45.99 (Minijar) to 50.63% (Dz0058) (Table 9). This is relatively consistent with the range of 47.7- 49.9% reported by Jane *et al.* (2017a) while lower than the range of 51.45 to 54.3 (Tena Alemu, 2016) for different chickpea varieties haulms. This variation might be related to genetic and environmental variation. All the tested varieties haulms had less than 50% IVOMD except Dz0058.

4.1.3.6. Relative feed value

No significant ($p>0.05$) difference was observed in the RFV among the tested varieties (Table 9). The RFV of chickpea varieties ranged from 87.41 in Minijar to 101.22 in Dz0058. Higher RFV was recorded from Dz0058 might be due to its lower contents of ADF and NDF. A relative feed value index is proposed to reflect how well an animal will eat and digest a particular forage species when it is feed as the only source of energy (Kazemi *et al.,* 2012). Its value is a relative indicator of the digestible dry matter intake potential of forage as it is estimated from the product of potential intake based on NDF content and dry matter digestibility based on ADF.

Table 9. Crude protein, metabolizable energy, in vitro organic matter digestibility and relative feed value of chickpea varieties on experimental sites

Varieties	CP (%)	ME (MJ/Kg)	IVOMD (%)	RFV
Ararti	4.00	7.40^{ab}	50.29^{ab}	93.62
Dalota	3.94	7.01^{bc}	47.97^{bc}	90.48
Dz0058	5.12	7.44^{a}	50.63^{a}	101.22
Ejerie	4.26	7.26^{ab}	49.51^{ab}	94.57
Hora	3.83	7.30^{ab}	49.55^{ab}	92.38
Local	3.57	7.05^{abc}	48.09^{bc}	87.59
Minijar	3.70	6.71^{c}	45.99^{c}	87.41
Teketay	4.17	7.10^{ab}	48.46^{ab}	92.52
Mean	4.07	7.16	48.81	92.47
SEM (±)	0.22	0.07	0.42	2.21
CV (%)	15.96	3.33	2.94	8.16
Sig	ns	**	**	ns

$^{a\text{-}c}$ means within column having different superscript are significantly different at*= P<0.05, **=P<0.01, CP= crude protein, ME=metabolizable energy, IVOMD= in vitro organic matter digestibility, RFV=relative feed value, SEM=standard error of mean, CV= coefficient of variation, Sig= significant level

4.1.4. Dry matter degradability and degradability characteristics

The ruminal DMD of chickpea varieties haulms at different incubation times for different varieties under investigation is illustrated in (Table 10) and (Figure 5). The ruminal dry matter degradation was significantly ($p<0.001$) different among the chickpea varieties haulms in all incubation times. This might be associated with the difference in the chemical composition of chickpea varieties.

The degradability of chickpea varieties haulm was increased with increasing time of incubation. At 24 hours of incubation over 40% of the DM in most of the chickpea varieties haulms had been degraded and more than 50% degraded at 96 hours of incubation. At 0 hours of incubation higher dry matter disappearance ($p<0.001$) was recorded in Hora (22.30%) while lower from Dalota

(17.03%). The high initial disappearance in Hora variety haulm might indicate the relatively higher content of dusty and small particles during sample grinding even in the same equipment and screen size, which could easily pass from the bags, rather than a greater solubility. At 6 and 12 hours of incubations Ararti, Dz0058 and local were more ($p<0.001$) degradable than other varieties haulms. The overall mean dry matter degradability of 12 hours of post-incubation is lower than the value of 50.82% in chickpea haulm reported by Naser *et al.* (2011).

The overall mean 24 hours DMD in the present study is lower than 55.28 and 47.05% in chickpea haulm reported by Naser *et al.*(2011) and Eyob Haile (2017), respectively. At 48 hours post-incubation, higher rumen DMD was recorded in Ararti (56.03%) and Dz0058 (55.59%) and lower from Dalota (32.51%). The overall mean of 48 hours degradability is relatively consistent with the previous result by Eyob Haile (2017) (52.83%) while lower than 58.47% by Naser *et al.* (2011) in chickpea straw. At 72 and 96 hours of incubation higher rumen DMD were recorded from Dz0058 (59.88 and 65.56%) while lower from Dalota (46.52 and 46.92%), respectively. The overall means of 72 and 96 hours of incubation degradability are higher than 56.11 and 56.85%, respectively in chickpea haulm reported by Eyob Haile (2017).

Table 10. In situ dry matter degradability of chickpea varieties haulms (%DMD)

	Time of incubation in the rumen (hours)						
Varieties	0	6	12	24	48	72	96
Ararti	18.15^{ef}	36.34^{a}	40.01^{a}	46.05^{b}	56.03^{a}	59.83^{a}	62.46^{b}
Dalota	17.03^{g}	19.59^{d}	29.62^{c}	32.51^{d}	43.82^{d}	46.52^{f}	46.92^{g}
Dz0058	19.15^{d}	34.67^{ab}	41.98^{a}	47.72^{a}	55.59^{a}	59.88^{ab}	65.56^{a}
Ejerie	20.43^{c}	28.65^{c}	36.14^{b}	41.25^{c}	51.05^{b}	55.25^{dc}	56.26^{b}
Hora	22.30^{a}	28.02^{c}	29.93^{c}	45.66^{b}	51.51^{b}	53.28^{d}	55.28^{b}
Local	18.76^{de}	31.55^{abc}	38.52^{ab}	49.17^{a}	55.40^{a}	56.84^{bc}	58.74^{c}
Minijar	21.18^{b}	31.10^{bc}	34.88^{b}	45.59^{b}	48.58^{c}	50.75^{e}	52.73^{e}
Teketay	17.77^{f}	23.23^{d}	26.73^{c}	42.55^{c}	47.56^{c}	48.06^{f}	49.80^{f}
Mean	19.35	29.15	34.73	43.81	51.19	53.70	55.97
SEM	0.36	1.18	1.12	1.03	0.88	0.99	1.24
CV	1.83	9.17	5.82	1.94	2.54	2.43	2.35
Sig	***	***	***	***	***	***	***

$^{a\text{-}g}$ means within column having different superscript are significantly different at*** = P<0.001; SEM= standard error of mean, CV= coefficient of variation, Sig= significant level

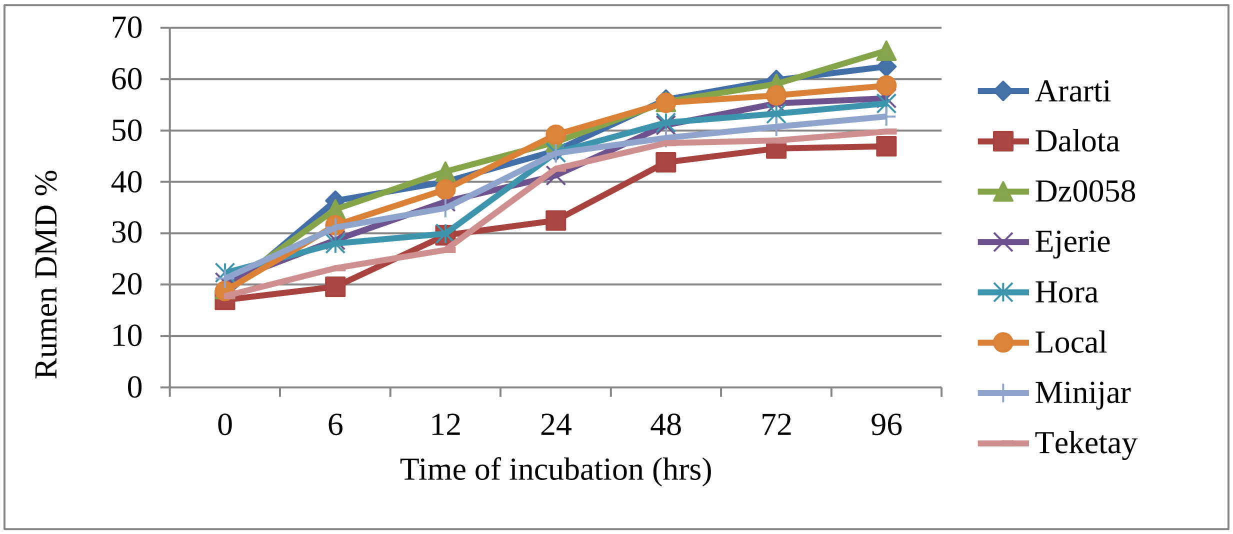

Figure 4. A graphical pattern of ruminal DMD of chickpea haulm at different incubation time

The results for the rapidly soluble fraction (a), insoluble but fermentable fraction (b), potentially degradable fraction (PD), rate of degradation of b fraction (c) and effective degradability (ED) were significantly ($p<0.001$) different among the tested varieties haulms (Table 11). The soluble DM fraction (a) ranged from 16.06 in Dalota to 21.45% in Dz0058. The overall mean soluble DM fraction (a) is consistent with the previous result of 19.00% for chickpea haulm reported by Naser *et al.* (2011). On the other hand, it is higher than 16.7% reported by Soares *et al.* (2000) while lower than 24.84% reported by Eyob Haile (2017) for chickpea haulm.

The insoluble but fermentable fraction (b) was ranged from 30.45 in Minijar to 40.54 in Dz0058%. The overall mean fermentable fraction in the present study is higher than the previous result of 28.70 and 32.36% reported by Soares *et al.* (2000) and Eyob Haile (2017), respectively while lower than 38.10% reported by Naser *et al.*(2011) in chickpea straw. In the present study, the higher insoluble but fermentable fraction (b) of Dz0058 may be explained by the lower content of cell wall fraction in this variety. The overall mean rate of degradation (c) was 0.05 per hour which is higher than the previous result of 0.041 and 0.044 per hour reported by Soares *et al.* (2000) and Eyob Haile (2017), respectively in chickpea haulm. On the other hand, it is lower than 0.152 per hour reported by Naser *et al.* (2011). Higher PD was recorded from Dz0058 (61.99) while lower from Dalota (49.02%) with an overall mean of 55.72%. The mean of PD is lower than 58.10, 56.84 and 57.20 % reported by Naser *et al.* (2011), Numan *et al.* (2017) and Eyob Haile (2017), respectively. In the present study, the potentially degradable fraction of most of the chickpea haulms was above 50% except Dalota. The average ED was 41.47% ranged from Dalota (33.54) to Dz0058 (46.79%). Relatively higher ED in Dz0058 may be related to its lower contents of cell wall fraction.

Generally, the difference in DMD and ruminal degradability characteristics of the present study from previous studies might be due to differences in varieties, chemical composition, leaves to stems proportion, stage of maturity and impurity and technical variation such as bag pore size, washing procedures, grinding size, the diet of experimental animal, species of animal and washing method (Golshani *et al.*, 2012; Anjum *et al.*, 2014).

Table 11. In situ dry matter degradability characteristics of chickpea haulm

Varieties	Parameters				
	a	b	c /hour	PD	ED
Ararti	21.06^{a}	39.88^{ab}	0.05^{abc}	60.94^{ab}	46.11^{a}
Dalota	16.06^{b}	32.96^{c}	0.03^{d}	49.02^{d}	33.54^{d}
Teketay	16.08^{b}	34.49^{bc}	0.05^{bcd}	50.57^{d}	36.80^{c}
Dz0058	21.45^{a}	40.54^{a}	0.05^{abc}	61.99^{a}	46.79^{a}
Ejerie	21.01^{a}	36.11^{abc}	0.04^{cd}	57.11^{bc}	41.30^{b}
Hora	20.83^{a}	35.47^{abc}	0.04^{cd}	56.30^{c}	40.88^{b}
Local	19.02^{ab}	38.99^{ab}	0.06^{a}	58.02^{abc}	45.04^{a}
Minijar	21.37^{a}	30.45^{c}	0.06^{ab}	51.82^{d}	41.30^{b}
Mean	19.61	36.11	0.05	55.72	41.47^{b}
SEM(±)	0.52	1.02	0.00	0.70	0.39
Sig	***	***	***	***	***

$^{a–d}$ means within the same column with different superscripts are significantly different at ***P= < 0.001; a = soluble fraction, b = slowly degradable fraction, c = rate of degradation, PD = potential degradability, ED = effective degradability, SEM= standard error of mean, Sig= significant level

4.1.5. Correlation among food-feed traits of chickpea

Pearson correlation coefficients of chickpea haulm nutritional values and agronomic traits are presented in Table 12. Plant height was significantly (p<0.05) and negatively correlated with the ash content. Similarly, such a significant and negative association of PH and ash was observed by Tena Alemu (2016). The days to flowering was significantly and negatively associated with ash (P<0.001), CP, ME, RFV (p<0.05) and IVOMD (p<0.01). On the other hand, DF was significantly and positively correlated with NDF, ADF (p<0.05) and ADL (p<0.01). This is comparable with Tena Alemu (2016) who indicated that days to 50% flowering was negatively and significantly correlated with ash, CP, ME and IVOMD while positively and significantly associated with cell wall fractions.

The days to maturity also negatively and significantly associated with ash (p<0.05), CP (p<0.01), ME, IVOMD and RFV (P<0.001) while significantly and positively associated with NDF, ADF (p<0.01) and ADL (P<0.001). The positive and significant association between days to maturity and cell wall fractions might be possibly an indication of a high level of cell wall resulted from the accumulation of insoluble carbohydrates due to later stages of maturity.

The CP content was negatively and significantly correlated with HY and BP (p<0.01). On the other hand, it was non significantly correlated with grain yield and harvest index which indicated that no decline in CP is expected as a result of any increase in grain yield. This may offer an opportunity to select chickpea varieties having better CP without compromising GY and HI. Similarly, no such significant association between GY and CP was reported by Ashraf (2017) in chickpea. In contrast to this, Tena Alemu (2016) observed a significant and negative association between CP and GY.

Grain yield was associated with all feed quality traits (ash, cell wall fraction, ME, IVOMD and RFV) insignificantly (p>0.05). Consistently, absence of significant association between grain yield and NDF, ADF, ADL, IVOMD and ME was observed by Ashraf (2017) in chickpea. Haulm yield was significantly and negatively correlated with ash (P<0.001), CP, ME, IVOMD and RFV (p<0.01) while positively associated with NDF, ADF (p<0.01) and ADL (P<0.001). Similarly, such a significant association was observed by Tena Alemu (2016) in chickpea.

The CP was positively and significantly correlated (P<0.001) with ash, ME, IVOMD and RFV. This indicates haulm with higher CP could supply adequate protein for microbial growth and thus improves digestibility of the feed. The IVOMD was negatively and significantly correlated with NDF, ADF and ADL (P<0.001). Similarly, a significant and negative association of IVOMD and cell wall fraction was observed by Tena Alemu (2016) in chickpea. This negative correlation might be due to the fact that cell wall fraction causes depression in digestibility by inhibiting the activity of rumen microbial activity (Dereje Andualem *et al.,* 2016). The ME had significantly and positively associated with IVOMD (P<0.001). This might indicate that high organic matter digestibility supplies high metabolizable energy. Absence of a significant correlation of GY and PH with chemical composition results in a good opportunity for increasing these traits simultaneously.

Table 12. Pearson correlation between food feed traits of chickpea

	Ash	CP	NDF	ADF	ADL	ME	IVOMD	RFV
PH	-0.43*	-0.22	0.13	0.16	0.21	-0.27	-0.28	-0.17
DF	-0.60***	-0.39*	0.37*	0.41*	0.48**	-0.44*	-0.46**	-0.40*
DTM	-0.40*	-0.51**	0.74***	0.74***	0.67***	-0.71***	-0.71***	-0.76***
GY	-0.04	-0.26	0.22	0.13	0.18	-0.20	-0.20	-0.23
HY	-0.60***	-0.55**	0.53**	0.52**	0.57***	-0.52**	-0.53**	-0.55**
HI	0.02	0.05	-0.07	-0.17	-0.13	0.08	0.10	0.10
HSW	0.15	0.27	-0.24	-0.28	-0.22	0.34	0.36*	0.26
BP	-0.58***	-0.49**	0.46**	0.42*	0.48**	-0.44*	-0.46**	-0.48**
CP	0.62***	-	-0.86***	-0.84***	-0.87***	0.63***	0.70***	0.92***
NDF	-0.56**	-	-	0.96***	0.90***	-0.84***	-0.87***	-0.90***
ADF	-0.56**	-	-	-	0.91***	-0.90***	-0.90***	-0.91***
ADL	-0.68***	-	-	-	-	-0.80***	-0.84***	-0.88***
ME	0.58**	-	-	-	-	-	0.99***	0.74***
IVOMD	0.60***	-	-	-	-	-	-	0.80***
RFV	0.52**	-	-	-	-	-	-	-

* P<0.0**5,**** P<0.01 levels of probability, DM= dry matter, Ash, CP=crude protein, NDF=neutral detergent fiber, ADF= acid detergent fiber, ADL=acid detergent lignin, ME=metabolizable energy, IVOMD= in vitro organic matter digestibility, PH= plant height (cm), NPB= number of primary branch, NSB= number of secondary branch, DF=days to 50% flowering, DTM= days to 90% maturity, HSW=hundred seed weight(gm), BP=Biomass production (t/ha), GY= Grain yield(t/ha), HI= harvest index, HY= haulm yield (t/ha)

4.1.6. Correlation between yield and yield-related traits

The association between agronomic traits of the selected chickpea varieties is presented in Table 13. The result of correlation analysis revealed that GY had significant and positive correlations with PH, BP, HI ($p<0.001$), HY ($P<0.01$), DF ($P<0.05$). This indicates that varieties with high PH, DF, BP, HY and HI produce high GY and vice versa. Therefore, any improvement of these characters would result in a substantial increment in GY. In agreement with the present study Megersa Tadesse *et al.* (2016), (Fasil Hailu (2019) and Amare Tsehaye *et al.* (2020) showed that GY had a significant and positive association with BP, PH, HI and DF. In agreement with the present result Tena Alemu (2016) showed that GY was significantly and positively correlated with PH and BP. Moreover, Megersa Tadesse *et al.* (2018) and Asmare Zerfu (2021) also reported that a significant correlation between DF and GY.

In the present study, a significant and positive relationship was obtained between GY and PH ($P<0.05$). Contrary to the present result, absence of significant association was recorded for GY and PH (Megersa Tadesse *et al.*, 2018). On the other hand, a significant correlation of GY with the NSB is reported by Amir *et al.* (2018) and with HSW reported by Bazvand *et al.* (2015) and Mahamaya *et al.* (2017), which were not observed in the present study.

Strong associations were recorded for BP with PH ($r=0.70$), BP with GY ($r=0.82$), BP with HY ($r= 0.80$) and HI with GY ($r= 0.78$) at $p<0.001$ significant level. The HY had positively and significantly ($p<0.001$) correlated to BP ($r= 0.90$). It also positively associated with PH ($r=0.47$), DTM ($r=0.41$), DF ($r=0.47$), GY ($r=0.47$) ($p<0.01$). Similar results were reported previously by Tena Alemu (2016) who indicated that HY was positively correlated with PH, BP, GY, DTM, DF and HI. This indicates that chickpea high with the above-mentioned traits provide more HY and thus selection for those traits will bring an increase in haulm yield.

Table 13. Correlation among yield and yield components in chickpea varieties in the study area

	PH	NPB	NSB	DF	DTM	GY	HY	BP	HI	HSW
PH	1.00									
NPB	0.07	1.00								
NSB	0.05	0.21	1.00							
DF	0.46**	0.24	0.25	1.00						
DTM	0.21	0.24	0.39*	0.38*	1.00					
GY	0.76***	0.11	0.13	0.38*	0.26	1.00				
HY	0.47**	0.19	0.19	0.47**	0.41*	0.47**	1.00			
BP	0.70***	0.20	0.34	0.50**	0.40*	0.80***	0.90***	1.00		
HI	0.49**	-0.03	-0.02	0.21	-0.05	0.78***	-0.14	0.29	1.00	
HSW	-0.12	-0.02	-0.02	-0.03	-0.28	-0.21	-0.3	-0.30	-0.07	1.00

*p< 0.05, **P<0.01, *** p<0.001 PH=plant height (cm), NPB= number of primary branch, NSB= number of secondary branch, DF= day to 50% flowering, DTM=day to 90% maturity, GY= total grain yield, HY= haulm yield, BP=biomass production, HI= harvest index, HSW=hundred seed weight

4.2. Farmer Preferences and Knowledge Related to Food-Feed Traits

4.2.1. Demographic and socioeconomic characteristics of the respondents

Descriptions of respondents' socioeconomic characteristics are summarized in Table 14. The majority of the households in the study area were headed by males. This is similar with the observations of several previous studies (Ararsa Derara *et al.*, 2018; Dirsha Demam *et al.*, 2018; Habte Abaya *et al.*, 2019) which means most of the responses were given by men on behalf of their households.

The average household age in the current study was 42.64±1.10, which indicates that the household heads of the respondents fall in the economically active age group. This is in agreement with other studies (Sisay Belete, 2018; Ararsa Derara *et al.*, 2018). Age can determine how active and productive of the head of the household. The educational levels of the respondents ranged from totally illiterate to those who attend formal education. From the interviewed households, about 42, 13.3, 42.7 and 2% of the respondents were illiterate, could read and write and attended formal and religious education, respectively. A relatively higher proportion of the respondents attended formal education. This result is similar to Yassin Esmael *et al.*(2019) who reported that 75% of the respondent were attended formal education while disagrees with the result of Belay Duguma *et al.*(2012) and Habte Abaya *et al.*(2019) who reported that higher proportion of the respondents were illiterate. The main livelihood of the respondents was agriculture.

Table 14. Demographic and socioeconomic characteristics of the respondents in three kebeles of Gimbichu district

	Kebeles			
Parameter	Lemlem Chefe (n=50)	Adadi Goli (n=50)	Grimi (n=50)	Total (n=150)
Gender (%)				
Male	86	86	92	88
Female	14	14	8	12
Main occupation (%)				
Agriculture	100	45	48	95.3
Agriculture and trade	0.0	5	2	4.7
Educational status (%)				
Illiterate	52	32	42	42
Read and write	12	8	20	13.3
Formal education	32	60	36	42.7
Religious education	24	0.0	12	2
Age (years) (Mean ±SE)	45.68±1.89	42.66±1.82	39.58±1.65	42.64±1.05

The respondents' schooling years, the numbers of persons currently living in the household and farming experience are presented in Table 15. The overall mean of schooling years was 1.84±0.43 years and there was a significant ($p<0.05$) difference among kebeles of the study district. The overall mean number of persons currently living in the household was 5.02±0.15 with no significant (p>0.05) difference among kebeles of the study district. The overall mean person currently living in the household is lower than the findings of Endale Yadessa (2015) (6.08±2.85) in Meta Robi District and Habte Abaya *et al.* (2019) (6.53 ±2.12) in selected districts of West Shewa Zone. The average farming experience of the household was 21.47 years.

Table 15. Means and SE of years of schooling and number of persons currently living in the HH in three kebeles of Gimbichu District

	Kebeles				
Parameter (Mean±SE)	Lemlem Chefe (n=50)	Girimi (n=50)	Adadi Goli (n=50)	Total (n=150)	Sig
Years of schooling	1.84±0.43[a]	1.94±0.39[a]	3.34±0.49[b]	2.37±0.26	*
Number of persons currently living in the HH	5.2±0.25	4.82±0.26	5.04±0.28	5.02±0.15	ns
Years of farming experience	24.18±1.84	21.44±1.83	18.80±1.53	21.47±1.01	ns

n= number of respondents, [a, b] means in a row with different superscripts differ significantly at *P< 0.05 significant levels, ns= not significant, HH= household, SE= standard error of mean, Sig = significant level

4.2.2. Livestock and landholding of the respondents

Livestock holding per household in TLU in the study areas is summarized in the appendix (Appendix 3). Farmers keep different livestock species including cattle, goats, sheep, equines (donkeys and horses) and chicken. Cattle were the dominant livestock species reared in the study area. This is in agreement with the previous reports (Belay Duguma *et al.*, 2012; Ararsa Derara *et al.*, 2018). The average oxen owned per household was higher than the rest cattle herd structure. This is because oxen are very important for crop farming activities in the study area. This is comparable to Derbie Alemu *et al.* (2019) result in Raya Kobo District, North Wollo Zone, Ethiopia.

The overall average milking cows and calves owned per household was higher as compared to heifers owning. This is comparable with the result of Derbie Alemu *et al.* (2019) and the reason could be farmers aimed to produce more milk for their family consumption and income. The overall average number of bulls owned per household was higher as compared to heifers owning.
The reason could be farmers used bulls for the replacement of oxen.

On the other hand, small ruminants were the least reared livestock species due to shortage of feed, the occurrence of diseases and lack of improved sheep breed according to the respondent's response. The mean of trained oxen and mature chicken were significantly ($p<0.001$) different between kebeles of the study districts. Similarly, the mean bull TLU was significantly ($p<0.05$) different between kebeles of the study area. Furthermore, the overall average livestock holding per household was 6.44 TLU and significantly different between kebeles of the study district ($p<0.001$). the overall average livestock holding is higher than the 5.86 reported earlier in Ada'a Sinana Damot-Gale district (Sisay, 2018) while lower than 9.43 and 7.14 reported by Dawit Assefa *et al.* (2013) and Ararsa Derara *et al.*(2018) in selected kebeles of Kombolcha district and Weliso district, respectively.

The mean land size per hectare of sample respondents is described in Table 16. The overall cultivated landholding per household was significantly higher than landholding for uncultivated land. Own cultivated land for crop production and own uncultivated land was significantly ($p<0.05$) different among kebeles of the district. The overall mean own cultivated landholding of the respondents was 1.5 ha per household which is relatively comparable with 1.58 ha reported by Ararsa *et al.* (2018) in Weliso district south west Shoa.

On the other hand, it is lower than 1.82 ha reported by Habte Abaya *et al.* (2019) and higher than 0.95 reported by Derbie Alemu *et al.* (2019). The overall own landholding of the respondents was 1.78 ha per household which is comparable to Getahun Belay and Tegene Negesse (2018) in Burie Zuria district, north-western Ethiopia. Furthermore, the overall average total landholding per household (2.47±0.18ha) observed in this study is higher than 2.10±0.13ha reported by Sisay Belete (2018) in Sinana, Damot-Gale and Ada'a districts. On the other hand, it is lower than 3.8 and 2.85±0.83ha reported by Endale Yadessa (2015) in Meta Robi district and Habte Abaya *et* *al.* (2019) in Selected Districts of west Shewa zone, respectively. The difference might be due to the population density difference in different rural areas of the country.

Table 16. Landholding (ha HH^{-1}) of the respondents in the study area of Gimbichu District

	Kebeles				
Parameter (Mean±SE)	Lemlem Chefe (n=50)	Girimi (n=50)	Adadi Goli (n=50)	Total (n=150)	Sig
Own cultivated land(ha)	1.64 ± 0.14^{b}	0.99 ± 0.13^{a}	1.86 ± 0.22^{b}	1.5±0.10	*
Own uncultivated land (ha)	0.33 ± 0.04^{b}	0.02 ± 0.01^{a}	0.32 ± 0.04^{b}	0.28±0.02	*
Rented/shared in land cultivated(ha)	0.45±0.10	0.46±0.12	0.8595±0.18	0.59±0.08	ns
Rented/shared out land uncultivated (ha)	0.04±0.02	0.19±0.02	0.02±0.02	0.02±0.01	ns
Rented/shared in land/ used for forage production (ha)	0.003±0.003	0.99±0.13	0.01±0.01	0.003±0.002	ns
Total	2.47±0.18	1.69±0.16	3.20±0.31	2.50±0.14	

[a, b] Mean values with different superscripts in a row indicate statistically significant differences among kebeles at * ($p<0.05$) significant level, Sig= significant level

4.2.3. Crop production and land use pattern

The dominant cereal crops produced in the study area were wheat and teff in as indicated in Table 17. A comparable result was reported by Tibabu Kochare (2018) in Wolayta zone, southern Ethiopia. Chickpea, grass pea and lentil were the major legume crops found in the study area. This result is comparable with Yitbarek Tegegne (2017) in Bale Zone of Sinana and Ginir district.

The average land (ha) allocated for wheat and faba bean were significantly different ($p<0.001$) among kebeles of the study area, while the average land allocated for barely, chickpea, teff, grass pea, lentil, garlic and field pea were non significantly different among kebeles of the study area. The average yield of faba bean is significantly different (p<0.001) among kebeles of the district (

Table 17. Average land allocated and yield of crops in three kebeles of Gimbichu District

Land allocated and yield of crop	Lemlem Chefe (n=50)	Girimi (n=50)	Adadi Goli (n=50)	Total (n=150)	Sig
Land allocated (ha) (mean $\pm$**SE**)					
Barley	0.01 ± 0.01	$0.02\pm.011$	0.06 ± 0.03	0.03 ± 0.001	ns
Wheat	0.88 ± 0.10^{a}	0.62 ± 0.10^{a}	1.35 ± 0.16^{b}	0.95 ± 0.07	***
Fababean	0.014 ± 0.01^{a}	0.03 ± 0.01^{a}	0.16 ± 0.03^{b}	0.07 ± 0.01	***
Chickpea	0.51 ± 0.04	0.40 ± 0.04	0.40 ± 0.05	0.43 ± 0.03	ns
Teff	0.45 ± 0.04^{ab}	$0.37 \pm .05^{a}$	0.55 ± 0.06^{b}	3.10 ± 1.30	*
Grass pea	0.11 ± 0.02	0.09 ± 0.02	0.16 ± 0.03	0.12 ± 0.01	ns
Lentil	0.06 ± 0.02	0.02 ± 0.01	2.13 ± 1.98	0.74 ± 0.66	ns
Garlic	0.04 ± 0.01	0.03 ± 0.01	0.01 ± 0.00	0.02 ± 0.01	ns
Field bean	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.003 ± 0.00	ns
Yield (q/ha) (mean ±SE)					
Barley	0.14±0.74	0.41±0.74	0.57±0.20	0.37±0.89	ns
Wheat	25.13±2.76	25.13±2.76	28.13±3.24	24.29±1.60	ns
Faba bean	0.25 ± 0.11^{a}	0.55 ± 0.23^{a}	2.36 ± 0.44^{b}	1.05±0.19	***
Field bean	0.00 ±0.00	0.00±0.00	0.1 ±0.11	0.3±0.33	ns
Chickpea	4.63±0.60	4.79±0.83	6.10±0.75	5.16±0.42	ns
Teff	8.35±1.99	5.70±0.58	8.46±0.89	7.50±0.75	ns
Grass pea	1.46±0.39	1.83±0.38	2.81±0.64	2.03±0.28	ns
Lentil	0.55±0.23	0.32±0.17	1.20±0.50	0.68±0.20	ns
Garlic	1.84±0.77	1.22±0.51	0.3±0.30	1.12±0.32	ns

[a, b] Mean values with different superscripts in a row indicate statistically significant differences among kebeles at * (p<0,05) and *** (p<0.001) significant level, SE= standard error, ns= not significant, Sig= significant level

4.2.4. Chickpea production

The dominant legume grain produced in the study area was chickpea. The production of improved chickpea varieties in the study area is illustrated in Figure 6. About 98 and 90% of the respondent farmers planted improved Kabuli type chickpea varieties in Girimi and Lemlem Chefe, respectively, which is the highest proportion while a relatively lower proportion of the respondents (about 72%) planted in Adadi Goli kebele. A higher proportion of the respondents (about 72%) in Adadi Goli kebeles were planted improved Desi type chickpea varieties, while a lower proportion of the respondents were planted improved Desi type chickpea varieties in Lemlem Chefe and Girimi kebeles. In general higher proportion of the respondents in the study area planted Kabuli-type chickpea than improved Desi chickpea varieties. Similarly, higher proportion of the respondent's farmer had been growing improved Kabuli type chickpea continuously since they first planted it.

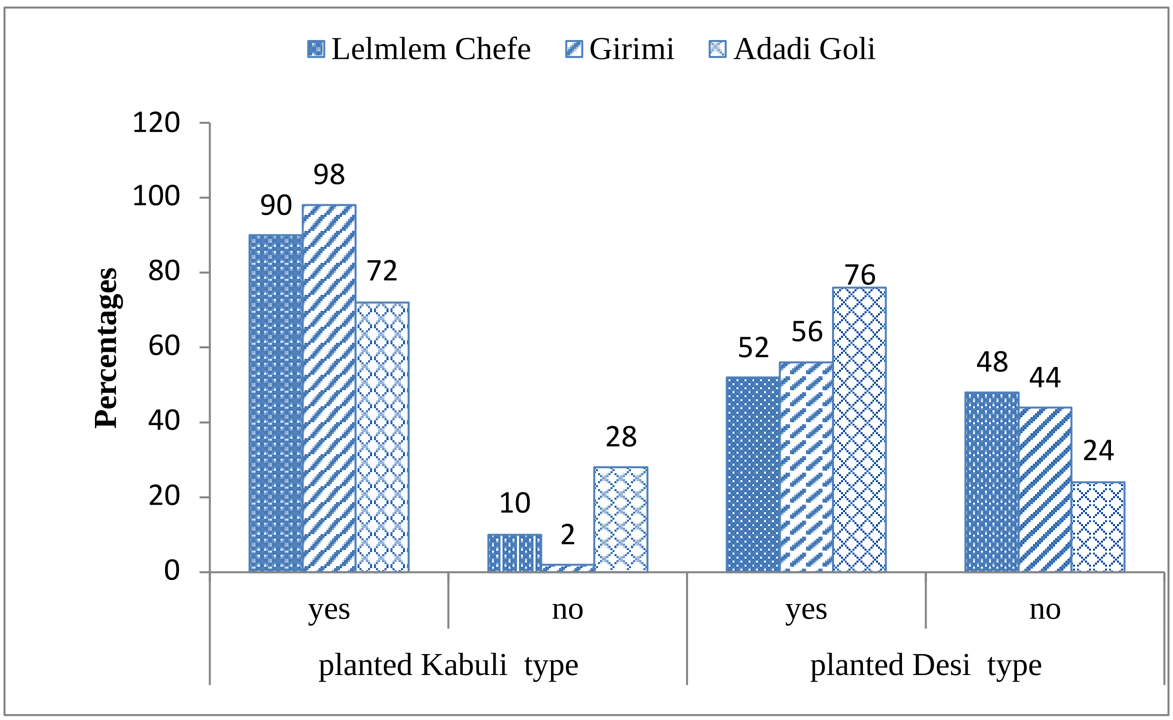

Figure 5. The proportion of improved chickpea production in three kebeles of Gimbichu district

4.2.5. Chickpea varietal selection criteria

The varietal selection criteria for chickpea based on the ranking are illustrated in Table 18. Accordingly, the first thing that draws the attention of respondents to plant chickpea varieties was good price and acceptance in the market. This includes chickpea varieties having large seed sizes especially the Kabuli type. Good productivity and high grain and haulm yield were other selection criteria of the respondent in the study area respectively.

Table 18. Selection criteria of chickpea varieties in Gimbichu district

	Ranks									
Criteria (n=150)	1	2	3	4	5	6	7	Total weight	Index	Rank
Early maturing	22	1	1	1	0	0	0	169	0.06	5
Good price and acceptance in the market	92	33	5	3	0	0	0	876	0.30	1
Resistance to disease	11	12	14	5	1	1	0	239	0.08	5
Accepted by the land conditions and suitable for local environment	5	58	14	5	0	0	0	473	0.164	3
Good productivity	20	36	30	15	1	0	1	570	0.197	2
Multipliable	0	2	2	0	0	0	0	22	0.007	9
Large seed size	0	1	6	14	6	0	0	110	0.038	7
Resistant to drought	0	2	5	5	1	0	0	60	0.02	8
Good straws for livestock	0	0	30	15	8	5	0	244	0.084	4
Other**	0	1	4	18	5	7	1	128	0.044	6

**List of other (Easy to work, consumption), Index mean = (7× number of responses for 1st rank + 6× number of responses for 2nd rank + 5× number of responses for 3rd rank + 4 × number of responses for 4th + 3 x number of responses for 5th +2×number of responses for 6th + 1×number of responses for 7th) divided by (7 × total responses for 1st rank + 6 × total responses for 2nd rank + 5× total responses for 3rd rank + 4× total responses for 4th rank +3x number of responses for 5th + 3 ×total responses for 6th rank +1 × number of responses for 7th rank

4.2.6. Major Feed Resources

There were different feed resources available in the study areas with different levels of contribution as shown in Table 19. Accordingly, crop residue was the main feed resource used in the study district, which is consistent with previous reports (Tolera Adugna *et al.,* 2012; Solomon Gizaw *et al.,* 2017; Getahun Belay and Tegene Negesse, 2019). This high contribution of crop residues to livestock feeding reflects the level of integration between crop and livestock farming (Solomon Gizaw *et al.,* 2017). Wheat and teff residues were by far the most dominant source from cereal crops, this is comparable with previous reports of Yayneshet Tesfay *et al.* (2016) in central and eastern Tigray, Northern Ethiopia and Solomon Gizaw *et al.*(2017) in Tigray region and Lume district in Oromia region. The largest pulse residue was obtained from chickpea and this also comparable with previous reports by Solomon Gizaw *et al.*(2017) in Lume district. On the other hand, it contradicts with Kassahun Gurmessa *et al.*(2016) that report faba beans and field pea is the dominant residue source from pulse crop. This variation might be due to the type of legume grain grown across the area is varied.

About 92% of the respondents of the sample farmers had a year-round supply of crop residues and about 89.3% of the respondent's farmers stored surplus crop residues for later use. From those respondents, who stored surplus crop residues 94.8% stacked outside in the form of a heap around the homestead and it was commonly fenced with locally available materials especially with thorny branches of trees and shrubs for protection from free-roaming animals, while 5.2% stacked under-shed. About 68.7, 29.3 and 2.0% of sample respondents started feeding crop residues at the beginning of the dry season, at the middle of the dry season and the beginning of the rainy season, respectively (Figure 7). This indicated that crop residues are the major dry season feed resource in the area.

Next to crop residue, the main feed resource in the study district was industrial by-products (Furishika and Fagulo). These results contradict with Solomon Gizaw *et al.* (2017) and Tolera Adugna *et al.*(2012) report. This might be due to the shortage of grazing land in the area in turn farmers use this agricultural by-product as an important supplement to the poor-quality crop residues during the dry season.

Table 19. Rank of feed resources in the study district

	Ranks						
Feed resource	1	2	3	4	Total weight	Index	Rank
Crop residue	145	5	0	0	595	0.43	1
Natural pasture and stubble grazing	5	40	30	14	214	0.15	3
Industrial by-product	0	55	54	8	281	0.20	2
Local brewery by-product	0	13	28	25	120	0.09	5
Hay	0	31	15	17	140	0.10	4
Other feeds**	0	5	8	5	36	0.03	6

** Lists of other feeds include vetch and salt, weeds # weighted values for each variable for major feed resource based on rank, Index mean= sum of (4 × number of responses for 1st rank + 3× number of responses for 2nd rank + 2 × number of responses for 3rd rank + 1× number of responses for 4th) divided by (4 × total responses for 1st rank + 3 × total responses for 2nd rank + 2× total responses for 3rd rank + 1 × total responses for 4th rank)

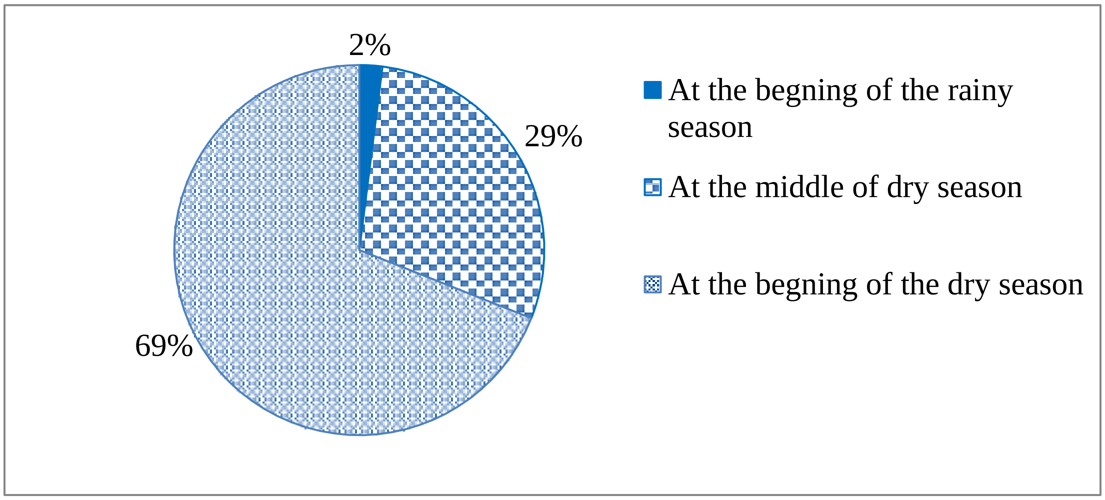

Figure 6. Season of feeding crop residues

4.2.7. Uses of chickpea and other legumes haulms as livestock feed

Crop residues were the main feed source for livestock and given the predominance of teff and wheat straw in the study area. Next to cereal straw grain legume haulm also a source of feed resource in the study area. The main grain legume haulm prioritized and ranked is illustrated in Table 20. Accordingly, the major legume haulm used by the sample respondent farmers was chickpea, grass pea, faba bean and lentil, respectively.

Table 20. The rank of legume haulms used for livestock feed

variables	1	2	3	Total weight	Index	Rank
Grass pea	18	32	7	125	0.2	2
Chickpea	121	23	4	413	0.65	1
Faba bean	4	16	5	49	0.1	3
Lentil	6	9	10	46	0.07	4

Index mean= sum of (3× number of responses for 1st rank + 2× number of responses for 2nd rank + 1× number of responses for 3rd rank) divided by (3× total responses for 1st rank + 2× total responses for 2nd rank + 1× total responses for 3rd rank)

4.2.8. Chickpea cultivar residue preference and feeding system

Utilization of chickpea haulm as feed resources, cultivar haulm preferences as a livestock feed and storage months are summarized in Table 21. Chickpea haulm was the major feed resource from legume haulms in the study district. This result contradicts with previous result Yayneshet Tasfay et al. (2016) who showed that Faba bean was the most dominant crop across the study districts. About 99.3% of the sample respondents have used chickpea haulm as livestock feed (Table 21). About 76% of the respondents of farmers were fed just as soon as threshing directly on the threshing field rather than after storage (Figure 9).

This may be due to the small quantity of chickpea production as compared to cereal crops (wheat and teff) and the straw from these crops is sensitive to moisture to develop moulds. This is comparable to Mekuanint Gashaw and Girma Defar (2017)., report while 24.2 % of the respondents were feed after store some time as they mixed with cereal straw. The majority of the respondents preferred both Desi and Kabuli-type chickpea haulm as a source of livestock feed

(Table 19). Higher proportion of the respondents fed their animals chickpea haulm mixed with other cereal straws mainly with wheat and teff straw (Figure 8). The average mean months of storing chickpea haulm were 3.7 ±0.26.

Table 21.The proportion of chickpea haulm usage, cultivar haulm preferences as a livestock feed and storage months

Parameters	Percentage (%)
Uses of chickpea haulm as livestock feed	99.3
Feeding Kabuli type chickpea haulm	30
Feeding Desi type chickpea haulm	6
Feeding Desi and Kabuli type chickpea haulms	64
Months of storing chickpea haulm (Mean ±SE)	3.40±0.24

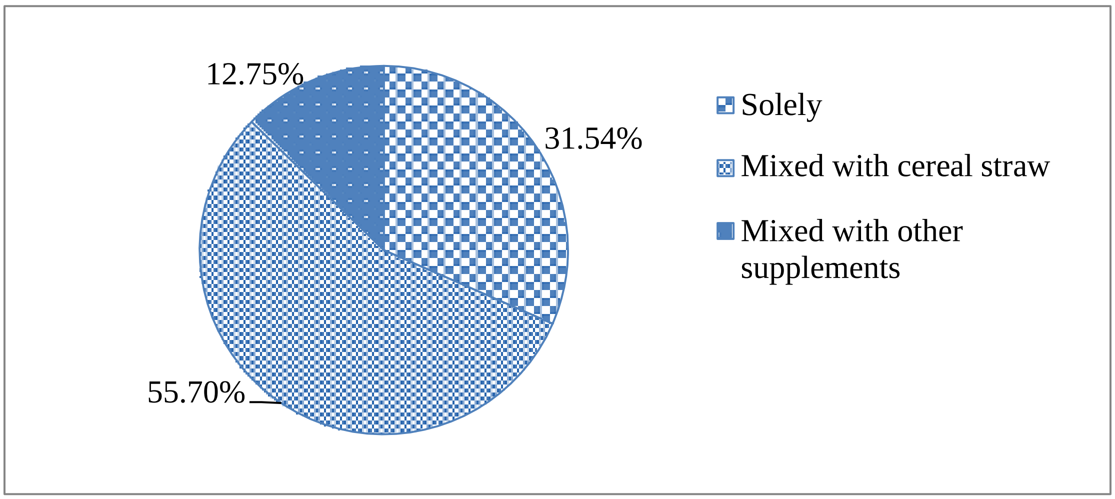

Figure 7. Feeding system of chickpea haulms

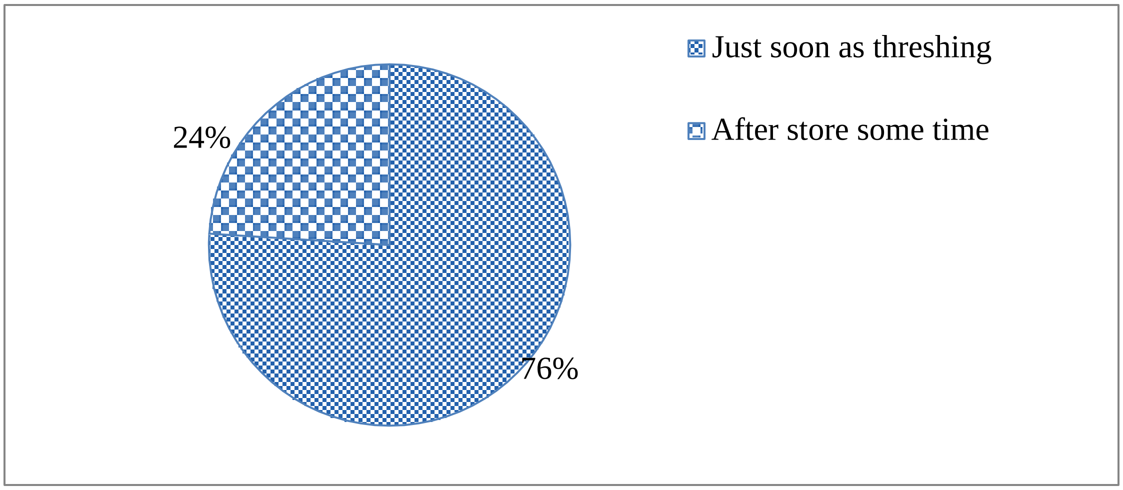

Figure 8. Time of feeding chickpea haulms

4.3. Participatory Varieties Selection

Farmer's field day was held on the experimental plot to evaluate and select chickpea varieties for food feed traits. The selection criteria were plant height, branching, plant density, palatability of straw, straw yield, grain yield and disease resistance. The participant farmers were explained how the selected criteria determine grain and haulm yield - a variety with many branches and good plant density will have better grain and straw yield which is associated with more side branches, seed pod and haulm. A variety of low disease resistance will have less plant density resulted in poor yield (grain and straw). Then the participant farmers had compared the criteria and rank them in order of importance. According to the ranking matrix, grain yield followed by disease resistance, haulm yield, branching, plant height and palatability of haulm were ranked first, second, third, fourth, fifth and sixth, respectively. Grain yield, disease resistance and haulm yield were the most prioritized and preferred traits by the farmers for selecting the better chickpea variety (Table 20).

The result from participatory variety selection showed that Teketay, Dalota, local, Minijar, Ararti and Ejerie were the most preferred varieties by farmers, respectively (Table 21). This result is comparable with Yasin Goa and Genene Gezahegn (2018) who showed that the participant farmers were selected and accepted Teketay and Dalota as the best varieties based on the number of branches, diseases and pest resistance, straw and yield grain yield. On the other hand, the elite line DZ-0058 was the last preferred varieties by farmers due to low plant density as a result of poor emergence (seed dormancy, long storage).

Table 22. Pair-wise ranking of selection criteria for chickpea variety by farmers

Criteria	PH	Bra	PD	Pala	GY	HY	DR	Total	Rank
Plant height (PH)	*	Bra	PH	PH	GY	HY	DR	2	5
Branching (Bra)		*	Bra	Bra	GY	HY	DR	3	4
Plant density (PD)			*	PD	GY	HY	DR	1	6
Grain yield (GY)					*	GY	DR	6	1
Haulm yield (HY)						*	GY	4	3
Disease resistance (DR)							*	5	2

Table 23. Participatory variety selection of chickpea varieties in the experimental site

Varieties	Selection criteria (Rank 1-5)							
	PH	Branching	Plant density	Grain yield	Straw yield	Disease resistance	Mean	Rank
Local	3	3	4	4	4	5	3.9	3
Ararti	3	4	2	3	2	3	3	5
Hora	4	3	2	2	2	3	2.6	7
Ejjerie	4	3	2	2	3	2	2.9	6
Teketay	5	5	5	5	5	4	4.7	1
Minjar	3	5	4	2	4	2	3.4	4
Dalota	3	5	4	4	4	4	4	2
DZ-0058	3	4	1	1	1	3	2.4	8

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

Although the present study was based on a single year and a single location, cultivar dependent variation in some yield and nutritional value parameters had been observed among the present tested varieties. Teketay, local and Dalota varieties were found to be the most promising ones in terms of grain and straw yield and similarly, those varieties were preferred and selected by the farmers during PVS.

While higher CP, ME, IVOMD and lower contents of cell wall contents are considered as important nutritional quality traits, the range of CP in the present study was below the critical value for normal rumen microbial action. On the other hand, the range of ME was above the lower limit. The grain yield was significantly and positively associated with plant height, biomass production, harvest index and haulm yield, which indicates that there is a possibility of selecting varieties of chickpea that combining both food-feed traits. On the other hand, even though Dz0058 had lower grain and haulm yield, it was the best variety to be selected compared to the other varieties in terms of higher ash, IVOMD, ME, potentially degradable fraction, the insoluble but fermentable fraction (b) and EDMD and lower cell wall contents. In general, the present study revealed that the presence of variation in food feed traits of chickpea varieties is essential for the improvement of the whole crop.

According to the survey result, chickpea was the dominant legume grain produced and its haulm was the main feed resource from legume residue. The main chickpea varietal selection criteria of the respondents were a good price and acceptance in the market, good productivity and accepted by the land conditions and suitable for the local environment, respectively.

5.2. Recommendations

Based on the above conclusion the following recommendations are forwarded

- Grain legumes can function as a key integrating factor in intensifying crop-livestock farming systems through the provision of food in the human diet and feed for livestock. Therefore, the selection and evaluation of varieties by involving farmers by the PVS approach can be used to enhance productivity and popularize varieties of these grain legumes in smallholder farmers.

- Teketay, local and Dalota varieties found to be good in terms of grain and straw yield and those varieties were preferred and selected by the farmers during PVS hence they could be recommended as suitable candidates for crop rotation with cereals in the study area because of their potential for providing better grain and straws that can help in enhancing livestock production in addition to grain yield for human consumption.
- The elite chickpea i.e. Dz0058 should be further evaluated for its grain yield and other agronomic parameters since in the present study it had lower grain and haulm yield this might be due to the long storage of the seed.
- Further researches should be conducted on the evaluation and selection of varieties of chickpea in different environments since, in addition to the genetic make-up of the crop, the grain yield, quality and quantity of crop residues are affected by the environment and interaction of genetic and the environment.

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7. APPENDIX

Part I. Questionnaires

General Information

No.	**Question**	**Response**	**Code**
Q1	Name of enumerator		To be coded ,after the data collected
Q2	Date of interview (DD/MM/YYYY)		No need code
Q4	District/Woreda		To be coded ,after the data collected
Q5	PA/Kebele		To be coded ,after the data collected
Q6	Village		No need code

Demographic and Socio-economic Information about the Household Head and the Household

No.	Question (Instructions)	Response	Code
1	What is your name? (write the name of respondent)	Respondent name……………………	Need to ID
2	What is your Marital status ?	Single	1
		Marriage	2
		Divorced	3
		Widow	4
3	What is your main occupation?	Agriculture	1
		Trade	2
		Public service	3
		Agriculture and trade	4
		Other, specify….	5
4	Educational status of the respondent and if applicable in years of education	Illiterate	1
		Read and write	2
		Formal education(…………..)	3
		Religious education	4

5	What is your relationship to the household head? (Circle the appropriate code)		1
			2
			3
6	What is the name of the household head?		
7	What is the gender of the household head? (Don't ask this question, just circle appropriate code)	Female	0
		Male	1
8	What is the household head's age in years?	Years	
9	How many schooling years did the household head complete?	Years	
10	What is the household head's experience in farming practices?	Years	
11	What is the total number of persons currently living in the household?	_________ Male _________ Female	
12	In the last agricultural year (2011 EC), how many household members were engaged in agricultural activities?	_________ Male _________ Female	

Livestock and landholding

	Livestock type	How many do you currently own?
1	Milking cows	
2	Non milking cows (mature)	
3	Trained oxen for plowing	
4	Bulls	
5	Heifers	
6	Calves	

7	Mature goats	
8	Young goats	
9	Mature sheep	
10	Young sheep	
11	Donkeys	
12	Horses	
13	Mules	
14	Mature chicken	
15	Traditional bee hives	
16	Modern bee hives	

Land Holding

Land category	Cultivated land size (cereals, legumes, vegetables etc; in ha)	Uncultivated land size (e.g. grazing, homestead etc; in ha)	Forage production in ha
Own land used			
Rented/shared in land			
Rented/shared out land			

Crop production and yield

Crop type	Land allocated in ha	Yield (q/ha)
Wheat		
Barely		
Chickpea		
Faba bean		
Field bean		
Lentil		

Linseed		

Chickpea production

1. Have you ever planted any improved Kabuli chickpea variety during the last five years?
   1 = Yes 0 = No
2. Do you remember when you planted improved Kabuli chickpea variety varieties for the first time 1 = Yes, when? 0 = No
3. Have you been growing improved Kabuli chickpea continuously since you first planted it?
   1 = Yes 0 = No
4. Have you ever planted any improved Desi chickpea variety during the last five years?
   1 = Yes 0 = No
5. Where did you get the seed of the first improved Desi chickpea varieties? (if you get more than one source pleas select all sources)1. Neighbor farmer(s) 2. Local market 3. Office of agriculture 4. NGO in the area 5. Seed trader(s) 6. Farmers' cooperative 7. Research centers 8. Local grocery shop 9. Relatives and friends 10. University 11.Other5 (specify)_____
6. Do you remember when you planted improved Desi chickpea variety for the first time?
   1 = Yes, when? 0 = No
7. What is the most important factor (criteria) you consider in your varietal selection?
8. Chickpea variety selection criteria (select the selection criteria and separate in comma)
   a. Early maturing
   b. Good price and acceptance in the market
   c. Resistance to disease
   d. Accepted by the land (soil) conditions and suitable for local environment
   e. Good productivity
   f. Multipliable Large
   g. seed size Resistant
   h. to drought
   i. Good straws for livestock
   j. Other factors

Feed resources and feeding strategies

1. List most commonly used feed resources for your livestock in ranking order from topmost
   i . ___________________________________
   ii . _________________________________
   iii . ___________________________________
   iv . ___________________________________
2. If you used crop residues, please respond the following question.
3. How many cropping seasons do you have per annum? __________________
4. Do you get enough year-round supply of crop residues? 1. Yes 0. No
5. If no, what is the reason? ____
6. Do you store surplus crop residues? 1. Yes 0. No
7. If yes, how? A. stacked outside B. stacked under shed C. baled outside D. baled under shed E. others (specify) _____________________
8. 8. When do you start feeding of stored crop residue for your animals?

A. at the beginning of the dry season B. at the middle of the dry season C. at the end of the dry season D. at the beginning of the rainy season

9. What type of crop residues are mostly used for livestock feeding?

____

10. Do you feed legume crop residues for your livestock? 1. Yes 0. No

11. If yes, what is the major legume haulms commonly used for your livestock in a ranking order from top most

i . ___________________________________

ii . ___________________________________

iii . ___________________________________

9. If no, what are the reasons? __________________________________
10. Do you use chickpea haulm as livestock feed resources? 1. Yes 0. No
11. If yes, when you used? A. just as soon as threshing B. after store some time C. other (specify)_________________________
12. For how long you store chickpea straw

Preference of chickpea Cultivar straw and Feeding systems chickpea straw

1. Which chickpea varieties do you prefer to feed your livestock? A. Dese type B. kabuli type
2. Which livestock do you feed chickpea straw? A. Large ruminants B. Small ruminants C. Equines
3. How do you feed chickpea straws for your livestock?

   A. solely B. mixed with cereal straws C. mixed with other supplements D. others (specify)

   ____
4. How/when/ do you feed chickpea straws?

   Fresh………………… Dry…………………. Why...
5. For which type of animal, you offered chickpea haulms mostly? A. Small ruminants …………B. Large ruminants…………………. C. Equines ………D. Other (specify)_________________________
6. How often do you feed chickpea straws? ________________________
7. Which chickpea varieties are preferred by.

   Small ruminants____

   Large ruminants____

   Equines____

   Other (specify)_________________________

End

Thank you very much for your cooperation and time!!

Part II. Conversion factors and other tables

Appendix Table 1. Conversion factors used to calculate Tropical Livestock Units (TLU)

Livestock category	Conversion factor
Calf	0.25
Heifer and Bull	0.75
Cow and ox	1.00
Mature sheep and mature goat	0.13
Young sheep and young goat	0.06
Donkey	0.7
Horse	1.1
Chicken	0.013

Source. Storck *et al.*, 1991

Appendix Table 2. Livestock holding and species composition per HH per TLU

Livestock category	Kebeles					
	Herd structure	Lemlem Chefe	Girimi	Adadi Goli	Overall	
		Mean±SE	Mean±SE	Mean±SE		
Cattle	Milking cows	0.24±0.07	0.22±0.07	0.24±0.07	0.23±0.04	ns
	Non milking cows	0.24±0.07	0.22±0.07	0.24±0.07	0.23±0.04	ns
	Trained oxen	2.88±0.18[a]	1.74±0.16[b]	2.36±0.21[a]	2.33±0.11	***
	Bulls	0.63±0.10[a]	0.35±0.08[b]	0.73±0.13[a]	0.57±0.06	*
	Heifers	0.435±0.075	0.285±0.060	0.405±0.061	0.375±0.038	ns
	Calves	0.23±0.04	0.20±0.03	0.21±0.02	0.21±0.02	ns
Goats	Mature	0.05±0.02	0.01±0.00	0.01±0.01	0.04±0.01	ns
	Young	0.03±0.01	0.01±0.01	0.01±0.01	0.01±0.01	ns

Sheep	Mature	0.30±0.05	0.30±0.10	0.40±0.10	0.31±0.03	ns
	Young	0.10±0.01	0.05±0.01	0.08±0.01	0.06±0.01	ns
Equines	Donkeys	1.47±0.11	1.13±0.08	1.3±0.11	1.31±0.10	ns
	Horses	0.10±0.04	0.00±0.00	0.10±0.04	0.05±0.02	ns
Chickens	Mature	0.05±0.01	0.04±0.00	0.10±0.01	0.06±0.01	***
Beehives	Traditional	0.06±0.04	0.00±0.00	0.10±0.05	0.05±0.02	ns
	Modern	0.18±0.07	0.06±0.06	0.04±0.03	0.09±0.03	ns
Livestock ownership in TLU		7.34 ± 0.44^{a}	5.13 ± 0.30^{b}	6.90 ± 0.42^{a}	6.44±0.24	

[a, b] Mean values with different superscripts in a row indicate statistically significant differences among kebeles at * (p<0.05), *** (p<0.001), probability level. SE= standard error, TLU=Tropical livestock unit, HH= Household

Appendix Table 3. Analysis of variance for the yield and yield related traits of chickpea varieties

Dependent Variable: **GY**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	2.95287500	0.29528750	18.92	<.0001
Error	21	0.32772500	0.01560595		
Corrected Total	31	3.28060000			

R-Square	Coeff Var	Root MSE	GY Mean
0.900102	12.18769	0.124924	1.025000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Var	7	2.74150000	0.39164286	25.10	<.0001
Block	3	0.21137500	0.07045833	4.51	0.0136

Dependent Variable: **HY _**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	3.62997500	0.36299750	4.33	0.0023
Error	21	1.76122500	0.08386786		

Corrected Total	31	5.39120000			

R-Square	Coeff Var	Root MSE	SY_ Mean
0.673315	13.48542	0.289599	2.147500

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Var	7	2.28200000	0.32600000	3.89	0.0072
Block	3	1.34797500	0.44932500	5.36	0.0067

Dependent Variable: **HI**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.10214481	0.01021448	6.67	0.0001
Error	21	0.03214209	0.00153058		
Corrected Total	31	0.13428690			

R-Square	Coeff Var	Root MSE	HI Mean
0.760646	12.17042	0.039123	0.321456

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Var	7	0.09102333	0.01300333	8.50	<.0001
Block	3	0.01112148	0.00370716	2.42	0.0944

Dependent Variable: **HDMY**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	2.00177675	0.20017768	1.77	0.1304
Error	21	2.37790925	0.11323377		
Corrected Total	31	4.37968600			

R-Square	Coeff Var	Root MSE	HDMY Mean
0.457059	17.30089	0.336502	1.945000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Var	7	0.88737150	0.12676736	1.12	0.3879
Block	3	1.11440525	0.37146842	3.28	0.0411

Dependent Variable: **PUI**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.07333025	0.00733302	1.66	0.1582
Error	21	0.09292963	0.00442522		
Corrected Total	31	0.16625988			

R-Square	Coeff Var	Root MSE	PUI Mean
0.441058	13.78910	0.066522	0.482427

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Var	7	0.02294102	0.00327729	0.74	0.6408
Block	3	0.05038923	0.01679641	3.80	0.0255

Appendix Table 4. Analysis of variance for the chemical composition of chickpea varieties haulms

Dependent Variable: **DM___**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1.81565625	0.18156563	6.20	0.0002
Error	21	0.61479062	0.02927574		
Corrected Total	31	2.43044688			

R-Square	Coeff Var	Root MSE	DM___ Mean
0.747046	0.189152	0.171102	90.45719

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	1.45673438	0.48557813	16.59	<.0001
Var	7	0.35892188	0.05127455	1.75	0.1511

Dependent Variable: **Ash___**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	26.13218125	2.61321813	6.77	0.0001

Source	DF	Sum of Squares	Mean Square
Error	21	8.10524062	0.38596384
Corrected Total	31	34.23742188	

R-Square	Coeff Var	Root MSE	Ash___ Mean
0.763264	7.596315	0.621260	8.178438

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	18.25358438	6.08452813	15.76	<.0001
Var	7	7.87859688	1.12551384	2.92	0.0269

Dependent Variable: **CP___**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	39.56670625	3.95667062	9.37	<.0001
Error	21	8.87181563	0.42246741		
Corrected Total	31	48.43852188			

R-Square	Coeff Var	Root MSE	CP___ Mean
0.816844	15.95642	0.649975	4.073438

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	33.09870937	11.03290312	26.12	<.0001
Var	7	6.46799688	0.92399955	2.19	0.0781

Dependent Variable: **NDF___**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	321.9581313	32.1958131	4.46	0.0019
Error	21	151.4938406	7.2139924		
Corrected Total	31	473.4519719			

R-Square	Coeff Var	Root MSE	NDF___ Mean
0.680023	4.846778	2.685888	55.41594

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	190.5797844	63.5265948	8.81	0.0006

Var	7	131.3783469	18.7683353	2.60	0.0423

Dependent Variable: **ADF___**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	315.0928250	31.5092825	6.07	0.0003
Error	21	108.9881750	5.1899131		
Corrected Total	31	424.0810000			

R-Square	Coeff Var	Root MSE	ADF___ Mean
0.743002	5.121425	2.278138	44.48250

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	224.2398250	74.7466083	14.40	<.0001
Var	7	90.8530000	12.9790000	2.50	0.0490

Dependent Variable: **ADL___**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	16.37227500	1.63722750	8.88	<.0001
Error	21	3.87352500	0.18445357		
Corrected Total	31	20.24580000			

R-Square	Coeff Var	Root MSE	ADL___ Mean
0.808675	4.182913	0.429481	10.26750

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	12.48247500	4.16082500	22.56	<.0001
Var	7	3.88980000	0.55568571	3.01	0.0235

Dependent Variable: **ME_**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	2.93685000	0.29368500	5.17	0.0008
Error	21	1.19315000	0.05681667		
Corrected Total	31	4.13000000			

R-Square Coeff Var Root MSE ME_MJ_Kg_ Mean

0.711102	3.330248	0.238362	7.157500

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	1.32705000	0.44235000	7.79	0.0011
Var	7	1.60980000	0.22997143	4.05	0.0059

Dependent Variable:**IVOMD___**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	133.8051813	13.3805181	6.50	0.0002
Error	21	43.2254406	2.0583543		
Corrected Total	31	177.0306219			

R-Square	Coeff Var	Root MSE	IVOMD___ Mean
0.755831	2.939256	1.434697	48.81156

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	70.60338437	23.53446146	11.43	0.0001
Var	7	63.20179688	9.02882813	4.39	0.0039

Dependent Variable: **RFV**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	3661.456956	366.145696	6.43	0.0002
Error	21	1194.993477	56.904451		
Corrected Total	31	4856.450433			

R-Square	Coeff Var	Root MSE	RFV Mean
0.753937	8.157474	7.543504	92.47353

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	3118.982869	1039.660956	18.27	<.0001
Var	7	542.474088	77.496298	1.36	0.2721

Dependent Variable: **Cellulose**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	195.0846000	19.5084600	5.14	0.0008
Error	21	79.7086000	3.7956476		
Corrected Total	31	274.7932000			

R-Square	Coeff Var	Root MSE	cellulose Mean
0.709932	5.694117	1.948242	34.21500

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	135.2743000	45.0914333	11.88	<.0001
Var	7	59.8103000	8.5443286	2.25	0.0710

Dependent Variable: **Hemicellulose**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	12.67595625	1.26759562	1.08	0.4179
Error	21	24.61356563	1.17207455		
Corrected Total	31	37.28952188			

R-Square	Coeff Var	Root MSE	hemicellulose Mean
0.339933	9.901954	1.082624	10.93344

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	6.92660938	2.30886979	1.97	0.1494
Var	7	5.74934688	0.82133527	0.70	0.6713

Appendix Table 5. Summary on analysis of variance for in sacco dry matter degradability of chickpea varieties haulms

Incubation time (hr)	DF	Sum Squares	Mean Square	F Value	Pr > F	Root MSE	CV	R Square
0	7	68.7738	9.8248	78.60	<.0001	0.3536	1.8275	0.9717
6	7	659.0068	94.1438	13.17	<.0001	2.6739	9.1745	0.8521
12	7	629.8948	89.9850	22.02	<.0001	2.0217	5.8217	0.9059
24	7	574.0689	82.0099	112.99	<.0001	0.8520	1.9446	0.9802
48	7	404.6831	57.8119	34.14	<.0001	1.3012	2.5418	0.9373
72	7	513.3001	73.3286	42.93	<.0001	1.3069	2.4337	0.9495
96	7	818.6695	116.9528	67.36	<.0001	1.3177	2.3542	0.9672

Appendix Table 6.Summary on analysis of variance for in sacco dry matter degradability characteristics of chickpea varieties haulm

Parameters	DF	Sum Squares	Mean Square	F Value	Pr > F	Root MSE	CV	R Square
a	7	112.3616	16.0517	13.45	<.0001	1.0925	5.5707	0.8726
b c	7	261.3867	37.3410	8.57	0.0004	2.0877	5.7815	0.8113
PD	7	0.0018	0.0003	11.49	<.0001	0.0047	10.0197	0.8556
ED	7	482.2221	68.88888	32.50	<.0001	1.4560	2.6129	0.9423
	7	443.37596	63.33942	115.72	<.0001	0.7399	1.7841	0.9831

a = soluble fraction, b = slowly degradable fraction, c = rate of degradation, PD = potential degradability, ED = effective degradability, SE= standard error of mean

Appendix Table 7. Name of varieties and assigned entry number

Local #1 , Ararti#2, Hora#3, Ejerie#4, Teketay#5 Minijar#6 Dalota#7

DZ-0058#8

Farmer I (Layout and Randomization)

variety #	7	5	8	4	6	3	1	2

Farmer II (Layout and Randomization)

variety #	1	7	4	2	8	5	6	3

Farmer III (Layout and Randomization)

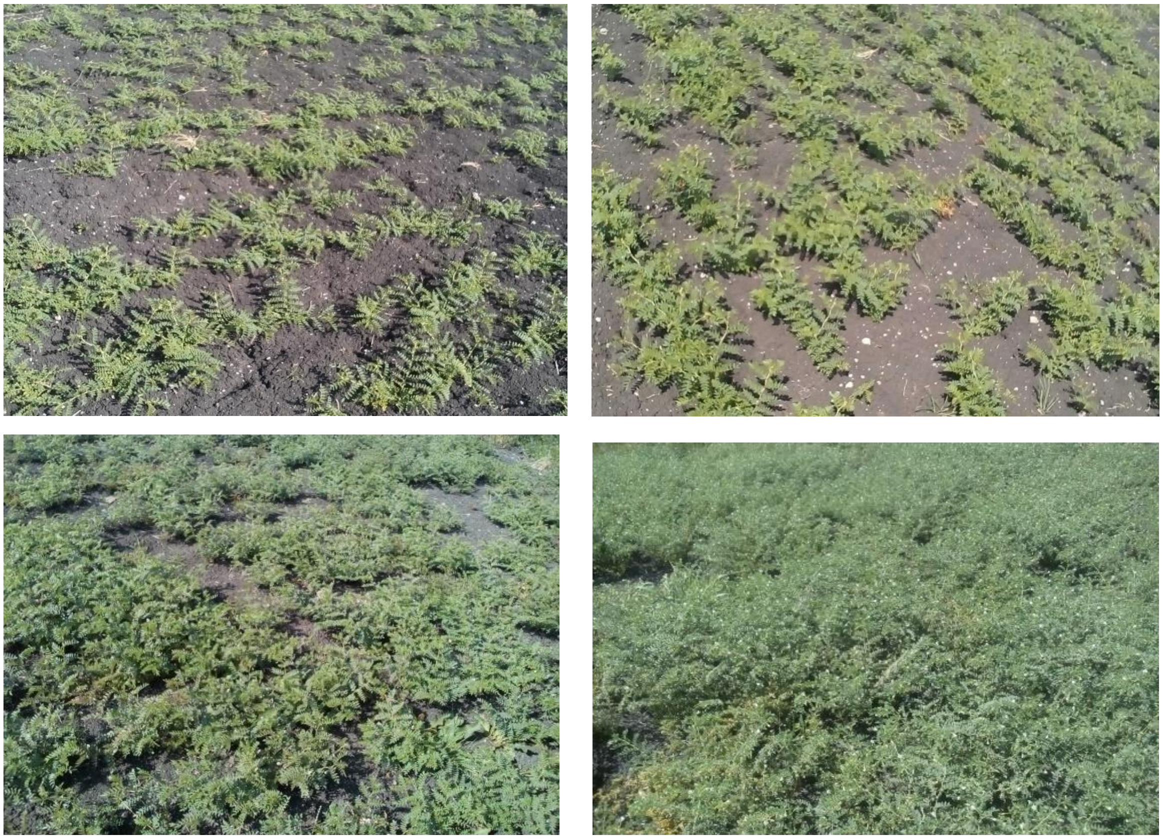
variety #	5	10	1	6	7	4	2	3

Farmer IV (Layout and Randomization)

variety#	6	1	7	3	2	5	8	4

Part III. List of Figures

Appendix Figure 1. Row planting of the experimental material



Appendix Figure 2. Pictures of some experiment material plot

Appendix Figure 3. Farmer’s participation during varieties selection

Consent Statement: “Personal information including Name, Business title, Email, Phones, Images and GPS points included in this report have been authorized in writing or verbally by the data subject” *E. Bzuneh*