Research article

Preference and perception of value chain actors to quality parameters and factors affecting the quality of tef (*Eragrostis tef* (Zucc. Trotter) in Central and Northwestern Ethiopia

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ABSTRACT

Tef grain color is considered as the dominant parameter in the trading and price setting on the local markets. However, there are no comprehensive studies conducted so far on the preference and perception of actors on tef grain quality attributes and factors affecting it. Its implicitly assumed that other quality parameters also play a role in the value chain of tef. Using semi-structured questionnaires, this study researched the parameters and factors affecting the quality of tef, perceived by farmers, traders, and consumers in central and northwestern highlands of Ethiopia. Results from this survey indicated that grain color, size, density, shininess, cleanness, purity, and hulledness were the perceived tef grain quality attributes by all respondent groups'. Grain color followed by grain size, cleanness, and purity were the most perceived and directly or indirectly affected the price setting of tef. Farmer and trader respondents' perception for tef color was mainly dependent on their clients' (consumers). However farmer preferred the brown color tef for their consumption. Trader respondents categorized their client's preference of grain color on the income level as high, medium and low-income consumers. The high-income consumers mostly preferred the whitish color; middle-income for the mixed and brown color; and low-income for the brown color tef. The perception between farmer and trader, farmer and consumer, and trader and consumer as well as the same group of respondents living in different areas showed significantly (p < 0.05 to p < 0.0001) different on most of grain quality attributes. Nevertheless, there was no preference variability on grain color and density between farmer and trader respondents. While there were considerable differences in the color of tef between farmer and consumer and trader and consumer respondents. However, between the central and northwestern highland farmers (grain color, density and cleanness, traders, (color and cleanness), and consumer (color, density, purity, and hulledness) did not show considerable differences. From respondents, 100% of farmers, 97.7% of traders, and 93.3% of consumers perceived that grain quality variability comes from the variability of production area. Soil types, topography, and climatic factors were the main perceived causes for the variability of quality. Ninety eight percent of farmer and 100% of trader respondents perceived that black and brown color soils produced tef had highest quality in terms of whiteness or brightness as compared to tef produced on red soils. All respondent groups were also perceived that the quality of injera affected by tef grain quality. To better connect the value chain actors to the needs and preferences of tef grain and the economy in Ethiopia; the quality attributes like grain size, density, and shininess which affect the price of tef needs consideration in Ethiopian tef breeding program. The effects of soil type, agroecology, and crop variety should also be tested experimentally for a better understanding of factors influencing tef grain physical quality.

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1. Introduction

Tef (*Eragrostis tef*), is a small-seeded cereal crop widely cultivated in the highlands of Ethiopia. Tef leads the total area coverage from all grain crops and second in productivity in the country (CSA, 2016). It can grow in a wide range of environments and agro-ecological conditions (Seyfu Ketema, 1997; Alganesh Tesema, 2010; Kebebew Assefa et al., 2011). Its grain is used to prepare an Ethiopian favorite staple food called injera (a bubbly, slightly sour, large pancake-like, flatbread with many eyes on the top surface) (Senayit Yetneberk et al., 2004, 2005). The high-quality injera with appreciable nutrients at possible quality is only made from tef (Senayit Yetneberk et al., 2004, 2005).

The grain color of tef is usually used as an indicator of its quality and thereby affects the market price. Its grain varies in colors, from pale white to ivory white, light tan to dark brown to reddish-brown purple (Roseberg et al., 2005; Gamboa and Ekris, 2008). The Ethiopian Standard Agency (ESA, 2012) classified tef grain quality in four major color categories: very white (*Magna*) tef, white (*Nech)* tef, brown (*Key*) tef, and mixed (*Sergegna*) tef. The very white, white, mixed, and brown tef fetched around 16,000, 15,500, 14,000 and 12,000 Ethiopian Birr/t(-tone), in the period October–November 2012, respectively from the whole sellers (Minten et al., 2013b). Similarly, in 2014, the price of tef in Addis Ababa (the capital city of Ethiopia) was 18,000 Birr/t for the white variety and 15,000 Birr/t for the brown varieties (Tadessa Daba, 2017). The price of white tef is hence 20–30% higher than for brown tef. However, the color could not be the only factor that affects the price of the grain, but also there might be other quality attributes that affect the price or the color of grain like cleanness and purity. For example, the mixture of white and brown tef is called 'Sergegna' is sold at a low price as compared to white and very white. The very white color tef could also be clean and clear too.

Tef has an appreciable balanced nutritional profile and health benefits. Tef grain contains high minerals (calcium (Ca), iron (Fe), phosphorus (P), magnesium (Mg), and zinc (Zn)) than most other cereal crops (null[; nullQ). It contains about 342–345 kcal $100g^{-1}$, higher fiber content (7.6–8%), and reasonable amount of fat (3.2%) (Tadessa Daba, 2017). Its grain contains high amount (up to 13%) protein and rich source of the essential amino acids that cannot be synthesized by the human body (Belitz et al., 2009); Anteneh et al., 2019). Tef is a gluten-free crop and has the potential to reduce nutritional disorders and diseases like anemia (Hopman et al., 2008; Bergamo et al., 2011).

The research result showed that the mineral content of brown, mixed, and white tef varies in a wide range. The brown color tef has a higher iron, zinc, calcium, and crude fiber while low crud fat content than mixed or white color grain (Geremew Bultosa, 2007; Yewelsew Abebe et al., 2007; Tadessa Daba, 2017). Despite the higher mineral grain content of brown color tef grains, the white-colored grain fetches a higher price (Tadessa Daba, 2017).

Not only the grain color but also the production area had also an important role in determining the price of tef. The most preferred and most expensive very white tef "*Magna*" is believed to be grown only in certain areas of the Ethiopian highlands (central highlands), and it requires the most suitable growing conditions (Mulat Demeke and Di Marcantonio, 2013; Abraha Reda, 2018). Its implicitly assumed that the price of tef is determined by the production area (soil type and agro-ecology) (Minten et al., 2013a). The production area effect on grain quality could be associated with grain color and the visual judgment of grain color could also be affected by other grain factors like cleanness, purity, and others. Yet, except for color, other tef physical quality parameters are not clearly described and its measurement is exposed to the subjectivity of individual differences (Mintenet al., 2013a; Tedessa Daba, 2017).

So far, however, there are no comprehensive studies conducted on the factors affecting the preference and perception of actors on quality attributes of tef grain and injera. There is not a comprehensive study for the variability of tef quality as influenced by different environmental factors such as climate, soil type, crop husbandry practices, and related factors in Ethiopia. Most of the research activities, including the national breeding program, focused mostly on developing high yielding and very white color grain genotypes. Generally, the perception and preference of tef grain physical quality parameters that influenced market price and production were not addressed by research and it is understated. Hence, defining tef physical quality parameters and factors influencing them are important for the producers focusing on the important quality parameters and achieve maximum market prices for their produce.

Therefore, this study was conducted to understand the perception of farmers, traders, and consumers on tef grain quality and to analyze their preferences to grain quality as well as their discernment on factors affecting its quality. Such information is critical to evaluate whether the market prices depend on quality parameters agreed upon by actors or not. Therefore, the agreed attributes between actors will be analyzed and recommended to produce on the national quality standards. For those, that are not agreed by actors will be analyzed why the difference of perception existed. Moreover, this research evidence helps to evaluate the quality of tef produced in different areas and to define tangible measures to be taken by producers to improve the quality of tef and what external factors affected the physical quality of tef. It also helps to develop strategies to improve the quality of tef grain for the local market according to different value chain actors' preferences.

2. Materials and methods

2.1. Description of the study area

The study was conducted in eight Kebeles (the lower administrative unit) namely: Hidi, Ude, Arerti Zuria, and Memihir Hager from the central highlands and Awobel, Mossebo, Kore, and Yetnora from northwestern highlands of Ethiopia (Figures 1 and 2). The specific study administrative zones of the highlands of Ethiopia were East Shewa and North Shewa from Oromia and Amhara ragional states of Ethiopia, respectively (Figure 1). The two highlands and specific zones were selected purposively due to their tef production potential and area coverage in the country (FAO, 2015; CSA, 2016). Oromia and Amhara regional states were covering more than 87% of tef production and East Gojam zone from Amhara and East Shewa zone from Oromia covered the highest tef production area in Ethiopia (CSA, 2016). The central highland of Shewa is found around Addis Ababa (the capital city of Ethiopia) at the escarpment of Great Rift Valley. The northwestern highlands of East Gojam and west Gojam zones are found at the source of the upper Blue Nile River (Figure 1).

The Study zones are characterized by a uni-modal rainfall pattern, 70% of the rainfall occurred from June to September. Since the selected rural Kebeles' climatic data are not available in the National Metrological Agency (NMA) of Ethiopia, the nearest meteorological station data have been used to describe the study areas (Figure 1). The climatic conditions of the selected meteorological stations in the northwestern highlands of Ethiopia received a mean total annual rainfall of 1156.9mm and 1308mm, respectively; the mean maximum and minimum temperatures of Adet and Debre Markos are 26.1 °C and 23.6 °C, and 9.7 °C and 11.2 °C, respectively. Similarly, the central highland total ten years (2008–2017) mean annual rainfall of Bishoftu and Arerti were about 779.33 mm and 783.5 mm, respectively. The two areas mean daily minimum 11.1 °C and 13.83 °C, and maximum 27.3 °C and 28.17 °C temperatures, respectively. The northwestern highland and central highland surveyed Kebeles altitudes ranged from 2260 to 2450 and 1780–1920 m above sea level (m.a.s.l.), respectively (Figure 1). Soil properties of the study area.

The soil property of the representative sites of the research locations is described in Table 1. Soil fertility rating of the locations as described by Hazelton and Murphy (2007) was from strongly acidic at Adet Nitisols to moderately alkaline for Minjar Vertisols, respectively (Table 1). Adet Nitisols had lower CEC, Ca, Mg, and P than the soils of Adet Vertisols

except for similar P concentration with Adet Vertisols (Table 1). The color of the soils for Nitisols were red and for the Vertisols black (Anteneh et al., 2019). Vertisolss had relatively highest CEC, Ca, and Mg as compared to the Nitisols. However, there was a considerable soil nutrient/mineral concentration difference within the same color or soil types too. Variability of soil mineral concentration in the same soil type is due to the variability of parent materials, organic matter, topography, temperature, rainfall, and land use together (Tekalign Mamo et al., 2002; Lemma Gizachew and Smit, 2008; Achalu Chimdi et al., 2012).

2.2. Sampling methods and sample size

This study conducted in three major actor groups namely: farmers, traders, and urban consumers who were actively participated in their crop production, marketing, and consumption of tef grain. Farmers were the main actors for this study due to their role in representing the three actors (producer, trader, and consumer) in the value chain (Minten et al., 2018). Traders and urban consumer groups were included to compare the perception and preference of farmers with them and to verify the farmers' view. Since farmers represented 82.2% of the population and 73 % of an employee of Ethiopia (FAO, 2019); the proportion of the interviewed farmers should exceed trader and consumer respondents. Therefore, farmer to a trader and urban consumer proportion was fixed to 68.8: 18.0: 14.2. In order to compare and verify farmers' perceptions and preferences; traders and consumers were included in this study.

Farmer respondents were selected by using a multi-stage and stratified sampling procedures (Figure 2) (Denscombe, 2012). The procedure was (i) two major tef production areas (northwestern and central highlands of Ethiopia), which contributed 86.5% of the tef production area (CSA, 2016) were selected. (ii) From each selected area, two zones with higher tef production potentials (CSA, 2016). (iii) Eight Kebeles, (two Kebeles from each zone) were selected based on their tef area coverage in purposive random sampling techniques. Form the total respondents' farmer respondents were selected randomly with a determined sample size to meet a population size of 174. Besides, forty three trader and 36 urban consumer respondents were included in this survey (Table 2). For

traders, five cities (Bahir Dar, Debre Markos, Bishoftu, Addis Abeba, and Adet) and for consumers four major cities (Bahir Dar, Bishoftu, Debre Markos, and Addis Abeba) were selected purposively due to the proximity to the production area and to accommodate the national central market "Addis Ababa city" due to its diversity in consumption of foods and *Injera* trading and export.

Focus Group Discussions (FGDs) were organized with farm households comprised of different wealth status (from poor to rich), sex, age and education in each Kebele to collect information regarding tef quality parameters and affecting its quality. The group sizes were 8–12 farm households to make it manageable and participants were invited randomly to speak out their ideas and opinions during discussion. One facilitator, one note taker and one observer were assigned during discussion time.

2.3. Data analysis and interpretation

In this survey, before field-testing, cognitive testing was used to identify potential sources of response error in the survey questionnaires and interpretation. Additionally, to collect narratives from respondents, and to analyze their understanding in limited sample size but with detailed information, we used cognitive pretesting (UN, 2008). The methodology is a qualitative one using a limited sample size but with the detailed information provided by each respondent obtained in semi-structured interviews. Based on the feedbacks obtained from the cognitive pretesting, the necessary improvements were made to the draft questionnaire to ensure the ease, consistency, and validity of each question to the respondents. For each group of the respondent, a semi-structured questionnaire was prepared in their local language. The questioners were grouped into three main parts: a) socio-demographic characteristics b) single option, and c) multiple options. For single option/response/questions, respondents must give only one answer to have a total result to 100%. In the multiple option type questioners, respondents listed multiple answers and the results would be above 100%. The respondent answers were coded in a Microsoft Excel spreadsheet and analyzed using the Statistical Package for Social Sciences (SPSS) version
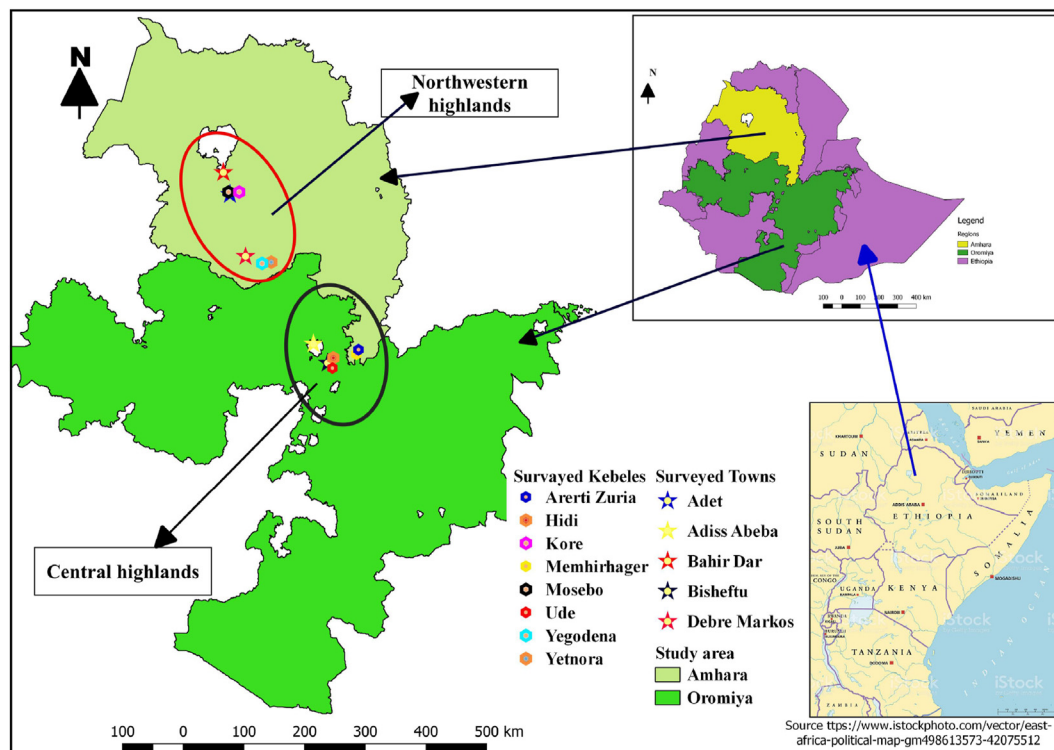

Figure 1. Location map of study areas.

16 software. A Chi-square (Phi and Cramer's V) test was performed to test the level of significance. Results summarized into frequency or percentage, average, minimum and maximum scores, presented in tables and graphs.

3. Results

3.1. Demographic and socioeconomic characteristics of respondents

Male, female, and total average family sizes of farmer respondents were 3.04, 2.57, and 5.6, respectively. The ages of the farmer, trader, and consumer respondents ranged between 22-78, 23–65, and 20–60 years old with the average age of 47, 41, and 39 years, respectively (Table 3). Almost all respondents were married. Fifty-nine percent of respondent farmers and 100% of traders and consumers had mobile phones. Farming, trading, and *Injera* baking experiences of farmers, traders and, consumers ranged between 3-60, 1–25, and 3–58 years with means of 3, 11 and 21 years, respectively (Table 3).

Farmer respondents continually produce tef every year. Farmers' average farm size per household in 2017 was 1.38 ha with a range of zero to 4.5 ha. Farmers who didn't have enough land for farming rented land with money for 1–5 years, or they rented on in-kind (shared the grain yield equally with the landowners). The average size of rented and shared land was 0.52 ha and 0.20 ha, respectively. The size of cultivated land per household of respondent farmers including their own rented and shared land in 2017 ranged from 0.23 ha to 7.00 ha with a mean of 2.08 ha. From the cultivated plots, land allocated for tef cultivation ranged from 9.38% to 100% with an average of 59.35% (Table 4).

3.2. Perception and preferences of different actors on tef grain quality attributes

In the multiple response questioners farmers', traders', and consumers' respondents perceived the presence of different types of tef grain quality attributes. Farmer respondents' listed the main tef grain quality attributes like color, density, grain size, purity (free of the varietal mixture), cleanness (free of foreign materials or dirt), hulledness (covered grain), and shininess. Traders and urban consumers also perceived smoothness and tef grown on black soils together with all the listed tef quality attributes by farmers (Table 5). The mean percent from the total respondent of perception showed that grain color (71.1 %), size (66.4%), cleanness (34.0%), density (26.5%), purity (23.9%), shininess (19.8%), hulledness (9.5%) growing location (6.3%) and smoothness (4.0%) were in the order from high to low perceived quality attributes (Table 5). The top-scored grain quality attributes by farmer respondents were grain size (70.1%), color (64.9%), and purity (50.0%). Tef grain color, size, and

density, respectively were the three top-scored grain quality attributes by traders and consumers (Table 5). The least perceived grain quality attribute was un-hulled grain (10.3%) by farmer and smoothness (16.3%) by the trader and smoothness (8.3%) by consumer respondents (Table 5). The grain color and cleanness of tef grain as the main tef price determinant quality attribute were also specified by Ethiopian Standard Agency (ESA). However, purity indirectly described as percentage of one color from the other in ESA quality description. ESA (2012) mentioned that tef grain color specification in to very white, white, brown, and mixed. The grain purity was also included indirectly as a percent of whiteness, or brownness in the color specifications by ESA (2012). The pure white or a very low mixture of other color seed is named as very white or *'Magna'* together with its shininess (brightness), while dim white with some mixture of brown color considered white. The ESA (2012) stated that the first standard very white grain color tef should have 98%–100% white color, less than 1.5% foreign material, and less than 0.6% sand(stone); while the white class first grade tef should have 95%–98% white color, less than 1.5% foreign material, and less than 0.6% sand(stone). This is also confirmed by the farmer and trader group discussion. In the group discussion, they stated that tef grain size and shininess are attracting the consumers and have an indirect effect on the price, while purity and cleanness are directly affecting the price of tef. The farmers did not include growing location as a grain quality in the list. This could be due to their perception on the variability of grain quality and grain environment effect on grain quality. Actually, the grain produced in some location has high market price as compared to others due to grain quality differences.

The result showed that farmer and trader respondents' preference on tef grain quality attributes were mostly depending on their clients' preference. The interest of the farmer to produce tef grain was depend on the grain quality preference of their clients (trader and consumer), while traders purchased tef grain quality depend on their consumer clients. Grain color is an important attribute by traders' clients (consumers), but they also perceived none color attributes. The preference of farmers for their consumption was brown color, but they produce much very white and white grain color for the market. Similarly, traders have many clients who prefer any type of color. Since traders are the middlemen for farmer and consumer, the preferences of traders depend on the farmers' supply and the demand of consumers.

Farmer and trader respondents' classified grain color in to very white, white, mixed, and brown. Farmers perceived that 59%, 11.9%, and 29.3%, of their clients (consumers) preferred white, very white, and other none color quality attributes (production area) of tef grain, respectively (Table 6). Similarly, farmer respondents' perceived that 6.9%, 28.2%, 17.82%, 9.2%, and 37.9 % of their client traders preferred very white, white, mixed, brown color, and other non-grain color (production area) attributes, respectively (Table 6). The perceptions of
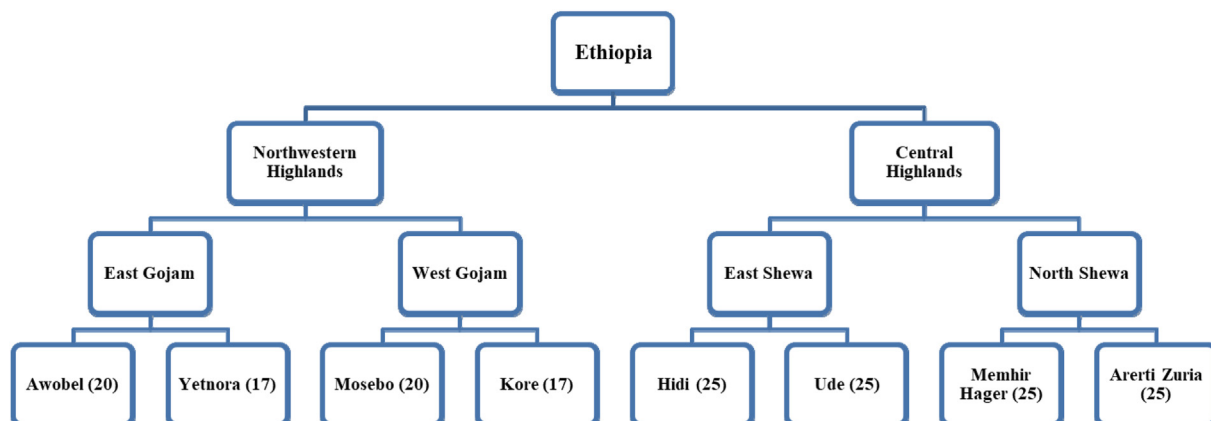

Figure 2. Schematic representation of multistage stratified sampling for farmer's respondents (numbers in parenthesis are the number of respondents in each Kebele).

traders were also assessed based on the preference of their consumer clients. They categorized their consumer clients as high, middle, and low-income consumers. According to this category, traders perceived that their high-income consumers preferred 88.4% and 11.6% of whitish color (very white and white) and both white and brown color tef grain, respectively; while middle-income consumers preference for whitish color tef grain limited to 14%; and none of the low-income consumers preferred whitish color grain of tef (Table 6). Trader perception on middle-income consumers' preference was 60.5% and 25.5% for mixed and both white and mixed colored tef grain, respectively. The low-income customers' preference as perceived by the traders was 2.4%, 67.4%, and 30.2% for mixed, brown, and both mixed and brown color grain, respectively (Table 6).

The highest rank preference for the whitish color tef grain by high-income, only 14% by middle income and none of the low-income consumers are in confirmation of the work of Minten et al. (2013a). They reported that 58% and 31% of high-income consumers purchased very white and white color tef grain, while 62% and 23% of the low-income consumers purchased mixed and brown as compared to, and 3% white color tef grains.

There have been different arguments and reasons for the preference of brown color grain tef. The reason for the preference brown color tef for high-income urban consumers could be due to the advocacy of the high iron and calcium content of brown tef grain as compared to whitish colors. Research results confirmed that brown color grain tef had better iron and calcium content than the white color grain (Yewelsew Abebe et al., 2007; Tadessa Daba, 2017). Now a day, in restaurants and in ceremonies serving the brown color *Injera* together with the white color became a fashion (personal observation). The preference of brown color grain tef by low-income urban consumers would be a matter of unaffordable price for the white color and low price for brown color grain. In confirmation of this assumption Minten et al. (2013a), reported that the preference of brown color tef by low-income consumers was due to its low price. The premium price for very white and white color and low price for brown color tef grain is due to the high demand for the white color grain of tef (Mulat Demeke and Di Marcantonio, 2013). Farmers' preference for brown color grain for their consumption is due to the lowest price in market and better aroma than the white color. Since white colors have highest market value, they consume the brown color sale the white and very white color tef grain. In agreement with the present result, Minten et al. (2013b) reported that from the total tef grain produced by Ethiopian farmers, 58% very white and 13% brown tef was used for sale. From the total tef grain sold in 2012 in Addis Ababa market, very white, white, mixed, and brown color accounted for 22.4 %, 60.3%, 7.2%, and 10.2%, respectively (Minten et al., 2013b). The preference of traders for the white color tef was the high demand for it by consumers. Not only Ethiopian consumers prefer the white color grain, but also the Ghanaian consumer's preference was on the white color rice grain than the brown color. Atsante et al. (2013) reported that Ghanaian consumer's preferred white color rice grain as compared to the brown color.

The Chi-square test result on the perception percent between all farmers and traders respondents (living on both localities) on tef grain quality showed highly significantly different ($P \leq 0.001$) on purity,

Table 2. Number of respondents in the central and northwestern highlands of Ethiopia.

Respondents	Central highlands	Northwestern highlands	Total number of respondents
Farmer	100	74	174
Trader	17	26	43
Consumer	18	18	36
Total	135	118	253

cleanness, growing locations, and smoothness; ($P \leq 0.05$) on grain size and hulledness; but not significantly ($P > 0.05$) different on grain color, density, and shininess (Table 7). The Chi-square test result between farmer and consumer respondents also showed that there were significantly ($P \leq 0.001$) different on most of the grain quality parameters except on grain size, cleanness, and hulledness ($P > 0.05$). Nevertheless, the Chi-square test results between traders and consumers did not show significant differences ($P > 0.05$) on most of the quality parameters except significantly ($P \leq 0.01$) different observed on grain color, cleanness, and hulledness (Table 7).

Even though different respondent groups had different degree of perception on grain quality attributes of tef, farmers living in the central and northwestern highlands of Ethiopia showed highly significantly different ($p < 0.01$) on grain size, purity, and hulledness; while there were not significantly different ($p > 0.05$) on grain color, density, cleanness, shininess, smoothness, and grown locations (Table 8). The two area trader respondents Chi-square test result showed significantly different ($p < 0.01$) on grain density and purity, ($p < 0.05$) grain size, and smoothness; while there were not significantly different ($p > 0.05$) on grain color, cleanness, shininess, and growing locations (Table 8). The central and northwestern highland consumer respondents' perceptions also showed significantly different ($p < 0.01$) only on cleanness and ($p < 0.05$) tef growing locations (Table 8).

Traders and consumers considered grain size as a second quality attribute. The larger grain size is the most preferred as compared to the smaller grain size. Since tef grain is smaller than other cultivated crop species in the world, its size may have an impact on the consumers' and traders' attraction. One hundred and fifty grains of tef weight is equal to one kernel of wheat (Gamboa and Van Ekris, 2008). The grain size and density of tef could have an advantage on flour yield. The preference of the big grain size grain has its scientific background. Research results showed that kernel size and density had an advantage on milling and baking properties of wheat (Dziki and Laskowski, 2005). Even though the two area respondents gave high emphasis to grain size, the northwestern highland consumer preference was highest from the others (Table 8). They also preferred grain size than color. This could be the advantage of grain yield and flour yield due to the grain size.

Grain purity was one of the grain quality attributes. Its perception was the least from the overall mean, but the third by the farmer respondents'. There was a significant difference between the central and northwestern highland area farmers' and trader's perception of grain purity, but not on consumers. The northwestern highland farmers did not give high

Table 1. Soil mineral concentration of some tef growing locations in selected areas of central and northwestern highlands of Ethiopia.

Location	Soil type	pH	TN	OC	CEC	Ca	Mg	K	P	Fe	Mn	Cu	Zn	Mo
			%		Cmol (+) kg^{-1}	mg kg^{-1}								
Adet 1	Nitisols	5.40	0.10	1.07	31.20	2302	519	226	7.9	124.0	150.0	4.8	1.4	0.29
Adet 2	Vitisols	6.60	0.07	1.34	58.80	6032	1303	293	7.8	154.0	106.0	4.1	1.4	0.29
Bichena	Vitisols	6.40	0.09	1.21	66.00	6966	1362	349	11.5	168.0	96.0	5.1	1.1	0.30
Debre Zeit	Vitisols	6.80	0.08	0.88	41.90	5495	1135	540	43.0	158.0	246.0	3.7	2.0	0.32
Minjar	Vitisols	7.70	0.08	1.46	46.10	8620	933	713	22.2	72.0	256.0	4.2	1.6	0.30

Source: Anteneh et al., 2019

Table 3. Age, work experience and sex category of respondents.

Respondents	Age			Work Experience			Sex		
	Min	Max	Mean	Min	Max	Mean	Female	Male	Total
Farmers	22.00	78.00	47.38	3.00	60.0	28.05	13	161	174
Traders	23.00	65.00	40.88	1.00	25.0	10.63	4	39	43
Consumers	20.00	60.00	38.58	3.00	58.0	21.06	31	5	36

Table 4. Farmer respondents' landholding size by ownership and share of tef cultivation in 2017 cropping season.

Ownership and landholding size (ha)*	Minimum	Maximum	Mean
Family/own land	0.00	4.25	1.38
Rented land	0.00	6.00	0.52
Shared land	0.00	2.75	0.20
Total cultivated land	0.23	7.00	2.08
Area covered by tef	0.13	6.00	1.11
Percentile of land covered by tef	9.38	100.00	59.35

  * Per household basis.

Table 5. Percent of the perception of the value chain actors on tef grain quality attributes.

Parameters	Farmers	Traders	Consumers	Mean of the group	Mean % from the total number of respondent
Color	64.9	77.4	97.2	79.8	71.1
Density	21.8	27.9	47.2	32.3	26.5
Grain Size	70.1	53.5	63.9	62.5	66.4
Purity	50	20.9	13.9	28.3	23.9
Cleanness	36.8	9.3	50	32.0	34.0
Hulledness	10.3	NL	16.7	9.0	9.5
Shininess	14.9	23.3	38.9	25.7	19.8
Growing location	NL	25.6	13.9	13.2	6.3
Smoothness	NL	16.3	8.3	8.2	4.0

NL = not listed by respondents.

Table 6. Perception of farmers and traders on the preference of consumers for tef grain quality attributes (single option).

Tef grain quality attributes	Farmer's perception(%) on the preferences of		Trader's perception on the preference of consumers by income (%)		
	Consumers	Traders (%)	High-income	Medium_income	Low income
Very white	11.49	6.90	27.90	14.00	NS
White	59.20	28.16	4.70	NS	NS
Mixed	NS	17.82	NS	60.50	2.40
Brown/red	NS	9.20	NS	NS	67.40
Very white and white	NS	NS	55.80	NS	NS
Very white and red	NS	NS	11.60	NS	NS
White and mixed	NS	NS	NS	25.50	NS
Mixed and red	NS	NS	NS	NS	30.20
Other qualities*	29.31	37.92	NS	NS	NS
Total	100	100	100	100	100

  * Grown on black and brown soils and NS = not selected by respondents.

emphasis to purity; rather they gave more emphasis to grain size. The reason for central highland farmers gave high emphasis for purity than northwestern highlands could be the fact that their proximity to the countries central market (Addis Ababa). The price setting of the central market for very white tef grain forced them to produce purely white varieties. The very white tef grain called *Magna* fetches the higher price due to its purity and has no mixture from other genotypes or color. Mulat Demeke and Di Marcantonio (2013) reported that very white tef has higher demand and superior prices in the Ethiopian central market. Therefore, the central highland area produced tef premium price could be the purity of the grain. The very low perception of grain purity by traders and consumers could be the knowledge gap between purity and cleanness.

This result showed that cleanness was the fourth grain quality attribute criteria by the three respondent groups mean and third by the consumer respondents and fourth by farmer and trader respondents' (Table 8). Cleanness, as a tef grain quality attributes did not show a considerable difference between the central and northwestern high land farmer and trader respondents, while there was a significant difference ($p < 0.001$) on the perception of cleanness between the two area consumers. Clean grain for consumers would have no extra expense for winnowing and sifting. The consumption preference and the market price are attractive for pure, clean, and very white tef grain. Tadessa Daba (2017) stated that the quick and usual method of judging the quality of tef is based on its grain color and purity.

The central highland area farmer preference of tef grain quality parameters was in the order of purity, color, size (larger grain size), and cleanness; while the northwestern highland farmer respondents, preference was grain size, color (whiteness), cleanness, density, shininess and hulledness from high to low preference (Table 8). The main reason for the high emphasis given for grain color and purity by the central highland could be the very white tef preference on the central market. White color with no mixture of other varieties could give a very white color. That is why breeders renew their breeder's seed every year to get pure varieties/genotypes.

There are considerable differences between the central northwestern highland area farmers' perception of tef grain quality attributes. The central highland farmers gave equal emphasis for grain color and purity followed by size and cleanness; while the northwestern highland farmer respondents, preference was grain size, color (whiteness), cleanness, density, shininess, and hulledness from high to low preference (Table 8). The main reason for the high emphasis given for grain color and purity by the central highland could be the very white tef preference on the central market. White color with no mixture of other varieties could give a very white color. That is why breeders renew their breeder's seed every year to get pure varieties/genotypes.

From tef quality attributes, grain color was the only parameter that did not show a significant difference ($p > 0.05$) between the perception of each of the central and northwestern highland farmer, trader, and consumer respondents. This result accentuated that the perception of actors across locations does not make differences in grain color. Farmers' preference is mainly brown color for their consumption and white color for the market due to the premium price for the white color. Trader's preference for whitish color is also due to the preference of the consumers for the white color all over the country. Therefore, color preference was not a location-specific preference by each group of respondents, but the variability existed between the value chain actors' preference.

Table 7. Comparison of the perception percentage of tef grain quality attributes between farmer and trader, farmer and consumer, and trader and consumer respondents.

Grain quality attributes	Respondents		Chi-square		Respondents		Chi-square		Respondents		Chi-square	
	Farmers	Traders	Value	P value	Farmers	Consumer	Value	P value	Traders	Consumers	Value	P value
Color	64.9	77.4	1.396	ns	64.9	97.2	14.927	***	77.4	97.2	7.910	**
Density	21.8	27.9	0.716	ns	21.8	47.2	9.942	***	27.9	47.2	3.147	ns
Grain Size	70.1	53.5	4.299	*	70.1	63.9	0.541	ns	53.5	63.9	0.871	ns
Purity	50.0	20.9	11.811	***	50.0	13.9	15.081	***	20.9	13.9	0.092	ns
Cleanness	36.8	9.3	12.100	***	36.8	50.0	2.190	ns	9.3	50.0	16.152	***
Hulledness	10.3	NL	4.851	*	10.3	16.7	1.178	ns	NL	16.7	7.756	**
Shininess	14.9	23.3	1.722	ns	14.9	38.9	11.093	***	23.3	38.9	2.264	ns
Growing location	NL	25.6	44.888	***	NL	13.9	24.750	***	25.6	13.9	1.659	ns
Smoothness	NL	16.3	29.270	***	NL	8.3	14.710	***	16.3	8.3	1.119	ns

*, **, ***and ns are significant at the $p < 0.05$, $p < 0.01$, $p < 0.001$ levels and ns not significantly different at $p > 0.05$; and NL = not listed by respondents.

Table 8. Percent of perception between the central and northwestern highlands of Ethiopian tef value chain actors on tef grain quality attributes (multiple option answers).

Quality attributes	Farmer				Trader				Consumer			
	Central	N/Western	Chi^2 value	P value	Central	N/Western	Chi^2 value	P value	Central	N/Western	Chi^2 value	P value
Color	64.00	66.20	0.09	Ns	82.40	69.20	0.93	ns	87.50	70.00	0.82	ns
Density	20.00	24.30	0.47	Ns	52.90	11.50	8.76	***	50.00	45.00	0.09	Ns
Grain size	58.00	86.50	16.47	***	76.50	38.50	5.97	*	81.20	50.00	3.76	*
Purity	65.00	29.70	21.62	***	5.90	7.70	6.96	**	6.20	20.00	1.41	Ns
Cleanness	39.00	33.80	0.50	Ns	41.20	11.50	0.39	ns	87.50	20.00	16.20	***
Hulledness	5.00	17.60	7.42	*	NL	NL	NL	NL	6.20	25.00	1.25	Ns
Shininess	15.00	14.90	0.00	Ns	29.40	19.20	0.60	ns	56.20	25.00	3.65	Ns
Growing location	NL	NL	NL	NL	11.80	34.60	2.82	ns	0.00	25.00	4.65	*
Smoothness	NL	NL	NL	NL	0.00	26.90	5.47	0.02	0.00	15.00	2.62	ns

*, **, ***and ns are significant at the $p < 0.05$, $p < 0.01$, $p < 0.001$ levels and not significantly different at $p > 0.05$, respectively; and NL = not listed by respondents.

Even though the low-income consumers and farmers preferred the brown color tef for their consumption, farmers used white color grain for injera baking where the respected guest is coming. Low-income consumers' preference for white grain color tef is only due to the low price it has. Our result is in confirmation of Minten et al. (2013a), Taddesa Daba (2017). They reported that white tef grain is the most preferred and prestigious in the consumers as well as farmers.

3.3. Perception of the farmer, traders, and consumers on the effect of soil, and agronomic factors on tef grain quality and yield

Since the growing location was an important factor for tef grain quality, it was better to understand the value chain actors' perception of the effect of the environmental factors on those attributes. The results of the three surveys showed the presence of variable tef grain quality due to differences in production areas. Farmer, trader, and urban consumer respondents' perception showed that the same tef variety grown in different localities showed differences in grain quality variability. From the respondents, 100% of farmers, 97.7% of traders, and 93.3% of consumers perceived the existence of grain quality variability of tef due to production area variability. They stated that the production area affected the physical quality specifically the white color tef brightness (Very white, white, dim white) of tef and consequently the market price. Farmer respondents perceived and listed the cause of variability of tef grain quality associated with production area as climatic factors, soil types, topography, and other pre-harvest and post-harvest practices.

Farmer and trader respondents perceived the variability of tef grain quality by production environment specifically by soil type. Tef traders perceived that the central highland area tef fetches the higher price than the northwestern highlands tef. The perception of traders in the group discussion noted that low prices for the northwestern highland tef grain

are due to color inconsistency and responses of clients on poor quality on the staleness of *Injera* as compared to the central highland tef. This could be the reason for the low price of tef for northwestern highlands and the highest price for the central highlands of Ethiopia produced tef. FAO (2015) reported that very white-colored grain tef (*Magna*) is produced in the central highlands of Shewa areas and fetches the highest premium price than other types of tef.

In multiple response criteria, perceptions of trader respondents, for the quality variability in tef production environments were due to variability in soil type (95.3%), farmers' production experience (25.6%), farmer input use (93%) and variety grown in the area (7%). Consumer respondent perception was not consistent and most of them did not know why tef physical quality variability existed. Nevertheless, most of them expected that the variability of the quality of tef is due to the soil type differences across production areas. From farmer respondents, 98% perceived the existence of grain quality and yield variability in different years/seasons. Farmer respondents perceived that the better year for grain yield was also the best year for grain quality. In multiple response criteria fertilizer application, proper weeding, plowing, and use of improved varieties was perceived by 78%, 69%, 68%, and 46% of farmer respondents, respectively, as the main agronomic practices attributing to better tef grain yield. Similarly, weeding, using pure seed, clean threshing ground, and harvesting on time was perceived by 68%, 63%, 54% and 39% of farmers as the main reason for better tef grain quality (Figure 3).

Farmers and traders perceived that soil types had an effect on tef grain quality. The Chi-square test result showed that there were highly significantly different ($p < 0.05$) between the farmer and trader respondents, ($p < 0.001$) between farmer and consumer, and ($p < 0.05$) between trader and consumer respondents on the perception of the effect of soil type on tef quality. Not only between the respondent actors but also there was a variability of perception on the same actors living in
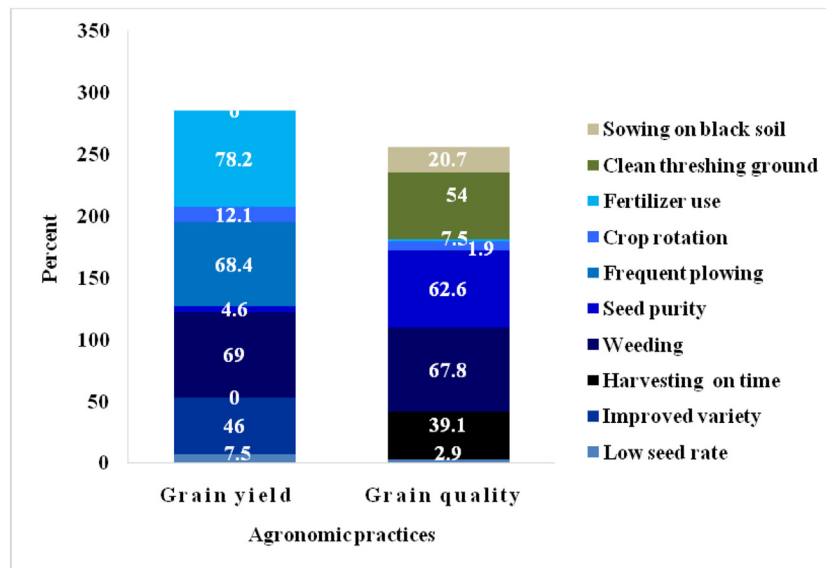
Figure 3. Perception of farmers on grain quality and yield of tef as affected by agronomic practices.

different areas on the soil type effect on grain quality. The Chi-square test result showed significantly different $p < 0.05$) between the central and northwestern consumers, while there were no significant differences ($p > 0.05$) between the two area farmers and traders on the effect of soil type on grain quality variability (data not shown).

The Chi-square test result on the questions, in which soil type produced the best quality of tef showed a highly significantly different ($p < 0.001$) between farmers and traders (Table 9). The same group of respondents living in different locations showed a significant difference ($p < 0.001$) on which soil type produced the best quality tef (Table 9). Both black and brown soils (Vertisols) ranked highest by farmer (98%) and trader (100%) for the production of very white and white-colored tef (Table 9). From the red (Nitisols) and black and brown soils (Most probably both are Vertisols) black and brown color soils ranked highest by farmer and trader respondents, respectively as better quality tef production. Whereas tef produced on red color soil types ranked lowest for the production of best quality tef (Table 9). Since farmers are not aware of the scientific classification of the soil, they responded as color type. Therefore, most of the red soils like Adet are Nitisols (EIAR, 2006). The black and brown colors are linked to Vertisols. Wilding et al. (1984) and Moussadek et al. (2017) stated that as Vertisols varies from the proper black to light gray, light black and dark brown.

Except for four percent of the northwestern highland farmer respondents', other respondents did not perceive red soil as best soil for quality tef production (Table 10). Most of (94.1%) the central highland traders perceived brown soil and the rest 5.9% whitish black soil (black soil with white concretions) as the main soil color for quality tef production (Table 10). Whitish black soil type (black soil with white

Table 9. Perception between the tef value chain actors on the effect of soil color for better tef grain quality (in %).

Soil type	Farmer	Trader
Red	1.7	0
Whitish black	6.9	2.3
Brown	19.5	97.7
Black	70.7	0
Both black and brown	1.1	-
Chi² value	93.08	
P value	***	

*** is significant at p < 0.001 level.

Table 10. Perception of the central and northwestern highland Ethiopian tef value chain actors on the effect of soil color for better tef grain quality.

Soil type	Farmer		Trader	
	Central	N/Western	Central	N/Western
Red	0.0	4.0	0	0.0
Whitish black	0.0	16.2	5.9	0.0
Brown	29.0	6.8	94.1	100.0
Black	69.0	73.0	0.0	0.0
Both black and brown	2.0	0.0	0.0	0.0
Chi ² value	32.614		1.566	
P value	***		Ns	

*** and ns are significant at the p < 0.001 level and not significantly different at p > 0.05, respectively.

concretion) as best soil for quality tef production was also perceived by one percent and 16.2% of central and northwestern highland farmers, respectively (Table 10).

To our understanding and experience, the northwestern highland tef production soil types are mainly red color soils (Nitisols) and black color soils (Vertisols). Tef produced from reddish color soils is not accepted as quality tef grain as compared to tef grown on the black and brown color soils. Forty-two percent of consumers thought that the cheapest tef produced on red soil.

Respondents 'responses to questions on soil type and its effect on price variability were not indeed consistent. From consumer respondents who did not have an idea on the best soil type for best quality tef production, 12.5%, and 25% were from the central and northwestern highland areas, respectively (Table 10).

This perception of soil type effect on grain yield and quality of tef is in harmony with Alicja et al. (2011), who reported that farmers perceived the yield and quality of winter wheat as affected by soil type. Researchers reported that Vertisols of the same area with different slope and land use had different soil fertility status (Tekalign Mamo et al., 2002; Zingore et al., 2007; Sanginga and Woomer, 2009; Achalu Chimdi et al., 2012) and this may attribute to quality differences of the specific crop grown. Farmer and trader respondents perceived that tef grown on black and brown soil type has a better grain quality, while tef produced on red soils has poor quality. Farmers perceived that tef grown on Vertisols has a shiny appearance and bright/white color as compared to grown on red color soils. Respondents did not have a comprehensive idea of how the red soils
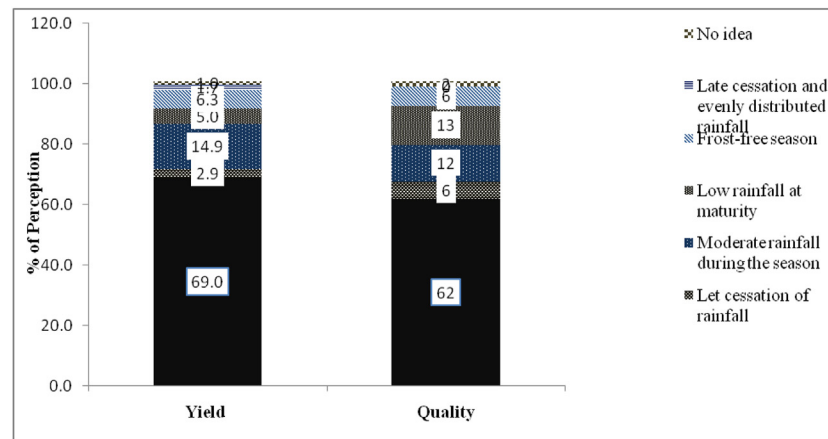
Figure 4. Perception of farmer respondents on the effect of climatic factors for grain yield (left) and quality (right).

tef have poor quality *Injera.* However, soil contamination would be one reason for the dimness of white tef. Seyfu Ketema (1997) and Kebebew Assefa et al. (2011) reported that tef lodging affects grain color brightness. This means that there is a contamination of tef grain by direct attachment to the soil or indirectly by higher humidity and spoilage. On the other side, the environment as described by soil property (nutrient composition and water holding/retaining capacity) variability of the soil may contribute to the darkness and lightness of the grain. The research finding in Canada reported that environmental factors affected the anthocyanin (color pigmentation) of the purple wheat (Hosseinian et al., 2008). Soil mineral content could have a contribution for pigmentation of the seed coat and grain color. It should be aware that the color variability is not a complete change of color from brown color to white or vice versa, rather it is a color change from white to dim white or ivory white.

Scientifically, it is not possible generalize the brown and black color soils as a Vertisols. However, the color of Vertisols varies from the proper black to light gray, light black, and dark brown (Wilding et al., 1984; Moussadek et al., 2017). In confirmation with our result, the black color soil perception for a better quality of grain by farmers was in confirmation with the southwest Sulwasi farmers. Eighty-two percent of the southwest Sulwasi farmers preferred black to brown soil as compared to 3% red colored soil as best soil for cocoa production (Wartenberg et al., 2018). This could be associated with the soil chemical property differences between the soil types. The red color soils (Nitisols) are acidic, low in basic cations, phosphorus, and high in soil organic matter as compared to the black color soils (Vertisols) (Table 1).

During group discussion, farmers perceived that tef produced on red soils (Nitisols and/or Luvisols) in high rainfall season had high grain and straw yields and on black soils gave lower yields. On the other hand, during low rainfall seasons, tef grown on Vertisols gave a better yield on red soils. The low yield of tef on Vertisols during high rainfall seasons could be due to the waterlogging problem effect on growth and physiological function of the plant. This is confirmed by Seyfu Ketema (1997), tef growing on Vertisols in heavy wet seasons may face a problem of poor stand establishment which leads to a lower yield, unless and otherwise supported by the good drainage system. Better tef yields on Vertisols during moderate rainfall seasons could be associated with its peculiar characteristics in retaining water for a long time (Dalibor et al., 2012). Vertisols are also categorized as problematic soils, while they have the property of shrinking and swelling during dry and wet seasons that lead to terminal moisture stress and water logging, respectively (Jutzy, 1988).

3.4. Perception of the farmer, traders, and consumers on the effect of climatic factors on tef grain quality and yield

Farmers, who had ample knowledge of farming, perceived rainfall distribution and pattern, particularly its distribution in the season,

amount, onset and cessation of rainfall and frost as the main climatic factors affecting tef quality and productivity. Farmers ranked evenly distributed rainfall (69%) low rainfall at maturity (13%), moderate rainfall (12%) … etc in order as having the major effect on producing the best quality tef (Figure 4).

In a single response criterion in the Addis Ababa market, trader respondents preferred Embur, Ada' and Abote areas tef by 50 %, 25%, and 25%, respectively. In multiple response criteria, their preference was accounted 28.57% for Ada', 14.29% each for Embur, Abote and Dukem, and 7.14% for each of Becho, Wolenkomi, Minjar, and Dima Giorgi's tef. In this selection criteria, almost 93% of traders preferred tef of the central highland area. Only 7% of the respondents preferred Dima area tef in the northwestern highlands as an alternative.

Respondent traders in the northwestern highlands particularly at Bahir Dar and D/Markos preferred the Bichena area produced tef. Nevertheless, central Ethiopia (Addis Ababa and Bishoftu) traders preferred Ada'a area tef. The Ada'a area tef is not available and not well known in the northwestern highlands. Addis Ababa's traders gave a low premium price to Gojam and a high premium price to Shewa tef. Ninety percent of Addis Ababa respondents' were preferred Ada', Abote, Embur, Becho, Wolenkomi, and Minjar [the central highlands (Shewa)] tef. This result is in line with Mulat and Di Marcantonio (2013), tef grew in East Shewa is very white, and it is sold at a maximum price in the central market. The Addis Ababa and Ada' respondents also indicated that the *Injera* of prepared form Gojam (northwestern highland) area produced tef is non-staling and showed darkening after a day of baking (lacking consistency in color) as compared to that of Shewa (central highlands) tef. This could be the reason for their preference for Shewa tef.

4. Conclusion and recommendations

This study revealed that tef grain quality is not only grain color, but also there are other quality attributes like grain size, grain density, purity, shininess, cleanness, hulledness, and smoothness. Growing locations also considered as grain quality attributes by trader and consumer respondents due to its effect on grain quality. Even though there are many tef grain quality attributes perceived by farmer, trader, and consumer respondents; the grain market is dominantly affected mainly by grain color followed by cleanness and purity. Whereas other quality attributes including the grain size, which had high perception rank do not have a direct effect on grain market price setting. The preference of farmer and trader on tef grain quality was affected by their consumer clients' preference. This also affects the production marketing and price setting of tef. Whitish color tef is preferred by the high income consumers, while brown color tef grain by low income consumers due to its lowest price. Farmer respondents' preference for the brown color tef grain for their consumption is due to low demand on market and its pleasant aroma. In the

central market of Ethiopia, some of high-income consumers preferred the brown color tef grain could be due to the advocacy of nutritional profile it has. The black and brown soils most probably (Vertisols) are the most preferred soils for the production good quality tef grain. Grain nutritional quality was of minor or no importance for all groups of respondents except the Addis Abeba Consumers who gave emphasis for nutritional importance. Even though, lesser awareness was obtained from the respondents in the nutritional profile, due to high malnutrition problem in the country, focus should be given to tef nutritional profile. Since tef grain quality attributes like grain color, size, density, and shininess have direct and indirect effect on tef grain market, research strategies should focus to improve these qualities to achieve the interest of the end users. The other quality attributes like cleanness, purity, and hulledness are the effect of farmer's management and can be improved by awareness creation. Grain color, size and density are a major trait and complex, research is needed to identify the relationship of these grain quality attributes with the perceived factors like production area, soil type, weather condition, and agronomic practices. Since, prevalence of stunting and acute malnutrition is high in Ethiopia (USAID, 2008) (USAID, 2014), Scientists should also identify the best production method and soil amendments for the better nutritional quality of tef grain.

Declarations

Author contribution statement

Abewa Anteneh: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Adgo Anteneh: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Alemayehu Anteneh; Yitaferu Birru: Conceived and designed the experiments; Performed the experiments.

Assefa Birru: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

Jan Cools: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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