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REVIEW ARTICLE

Teff, A Rising Global Crop: Current Status of Teff Production and Value Chain

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Abstract:

Introduction:

The global dominance of the three crops, maize, wheat, and rice in the current food system has raised an alarm. Heavy dependence on these crops can limit our capacity to deal with food shortage and dietary imbalance.

Explanation:

Teff (*Eragrostis tef*), a warm-season annual cereal, is one of the underutilized crops that can contribute to food security and crop diversification. Teff contains high and unique nutritional values, which will meet the need of health-conscious consumers. It is also a low risk crop, which resists many biotic and abiotic stresses. Currently, Ethiopia is the largest teff producing country, and the only country to have adopted teff as a staple crop. However, the teff production and value chain in Ethiopia largely rely on traditional practices, and the teff market is limited by the government's export ban. Instead, other countries such as USA are increasingly participating in the teff market.

Conclusion:

This study investigates the current status of teff production and value chain mainly in Ethiopia. The results suggest what areas Ethiopia should improve to take the lead in the rising teff market, and in what way others may participate.

Keywords: Agriculture, Crop diversification, Ethiopia, Food security, Teff, Value chain.

1. INTRODUCTION

There are over 50,000 known edible plants in the world [1]. However, two-thirds of plant-derived food at a global level comes from three major cereals, maize (*Zea mays*), wheat (*Triticum aestivum*) and rice (*Oryza sativa*). Their increasing dominance has contributed to a declining number of crop species as potential food sources [1]. Dependence on a few crops limits our capability to deal with adverse effects from food shortage and dietary imbalance. One solution to reduce this heavy dependence is to diversify food sources by tapping underutilized crops. Examples of such crops are amaranth (*Amaranthus* spp.), buckwheat (*Fagopyrum esculentum*), quinoa (*Chenopodium quinoa*), and teff [*Eragrostis tef (Zucc.) Trotter*] [1].

Of them, teff is a warm-season annual cereal and the only cultivated species in the genus *Eragrostis*. Ethiopia, located in eastern Africa, is considered the center of origin of teff [2]. Nutritionally, 100 g of teff grains have 357 kcal, similar to that of wheat and rice [1]. Yet, its grains are comparably rich in iron, calcium, and fiber [3]. Teff with 11% of protein is an excellent source of essential amino acids, especially lysine: the amino acid that is most often deficient in grains [4]. Teff grains are low on the glycemic index, which makes them suitable for people with Type 2 diabetes. The grains are also gluten-free [3]. This, in particular, attracts individuals who suffer from gluten intolerance or celiac

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disease [5]; a study of 1,800 people with celiac disease reports that regular consumption of teff significantly reduced their symptoms [6]. With an increasing number of health-conscious consumers across the world, teff has started generating a similar phenomenon with quinoa, the nutritious grains native to South America for global prominence [1].

In Ethiopia, teff is a major staple. It is the most important crop in terms of cultivation area and production value [7]. In 2017, teff accounted for about 24% of the nationwide grain-cultivated area, and nearly half of the smallholder farmers grew it between 2004 and 2014 [8, 9]. For dietary requirements, the country relies on teff for two-thirds of the daily protein intake and 11% of the per capita caloric intake [10, 11].

The most common utilization of teff in Ethiopia is the fermented flatbread called injera [12]. Crymes (2015) described this traditional flatbread as a soft, thin pancake with a sour taste. The most preferred form of the injera is one made from pure teff flour [10]. Injera mixed with other flour such as wheat or sorghum is considered inferior. Other utilizations of teff include local alcoholic beverages called *tela* and *katikala*, and porridge [13]. Additionally, teff plant residues could be used as fodder for livestock, and often incorporated as construction materials [1].

Teff is an economically superior commodity in Ethiopia. It often commands a market price two to three times higher than maize, the commodity with the largest production volume in the country [3], thus making teff an important cash crop for producers [13]. Due to the high price, the urban affluent consumers consume relatively more teff than the rural poor [12]. Studies estimate that annual urban consumption of teff was 61 kg per capita on average whereas 20 kg for rural [10]. Outside Ethiopia, global consumers following the super-food wave are willing to pay premiums for teff [12]. Various teff-based products are developed to capture the premium market in the form of bread, porridge, muffin, biscuit, cake, casserole and pudding. The crops' potential is also explored as a thickener for soup, stew, gravy and baby food [15].

Nevertheless, teff has shortcomings to become an income-generating global commodity for Ethiopian producers. Some of the shortcomings are low yields compared to other major cereals, high labor-input requirement, lack of infrastructure, and limited or inefficient market [1, 14].

Concurrently, interests in teff cultivation are spreading to other parts of the world. Those countries include Australia, Cameroon, Canada, China, India, Netherlands, South Africa, the UK, Uganda and the USA [13]. However, comprehensive statistics on the teff production, utilization and trade are little available in those countries.

Teff was first introduced to the USA in the 1980s [10]. At least, 25 states including Idaho, Kansas and Nebraska are known to grow the crop. Their main purpose of production is forage for horses, cattle and other livestock. Another purpose is for the large Ethiopian diaspora communities in the USA. Anecdotally, their increasing demand drives the expansion in teff acreage [15, 16]. Teff is relatively a new crop to Australia. In 2014, experimental quantities of teff were cultivated in northern New South Wales, and cultural and marketing practices suitable to Australian conditions are being explored.

This study investigates the current status of teff, the rising new crop. The findings and updates will offer an insight on issues and opportunities for teff to capture its global momentum and increase its market share. Additionally, they can provide updated information to farmers and traders in other parts of the world, who are looking for new opportunities.

2. CURRENT STATUS OF TEFF PRODUCTION AND VALUE CHAIN

2.1. Teff Production

Ethiopia is the largest teff producer in the world. In 2017, Teff accounts for 24% of the grain area, followed by maize 17% and sorghum 15% (Table **1**). Amhara and Oromia are the two major regions, and collectively, the two regions account for 85.5% of the teff area and 87.8% of the teff production.

Table 1. Production of teff in Ethiopia in 2017.

Crop	Area in ha	Yield in ton / ha	
Grain crops	12,574,107 * (100%)	-	
Maize	2,135,571 (17%)	3.675	
Sorghum	1,881,970 (15%)	2.525	
Teff	3,017,914 (24%)	1.664	
Teff production region	Area in ha (% total area)	Production in ton (% of TP [#])	Yield [‡] (ton / ha)
Tigray	167,584 (5.5%)	2,410,116 (4.8%)	1.438

(Table 1) contd.....

Crop	Area in ha	Yield in ton / ha	
Amhara	1,137,844 (37.7%)	19,328,573 (38.5%)	1.699
Oromia	1,441,030 (47.8%)	24,737,963 (49.3%)	1.717
SNNPR	246,099 (8.2%)	3,412,547 (6.8%)	1.387
Benishangul-Gumuz	24,433 (0.8%)	303,184 (0.6%)	1.241
Others	924 (0.03%)	12,014 (0.02%)	-
Total	3,017,914 (100%)	50,204,400 (100%)	

Source: Ethiopia Statistics (2017), *: all numbers rounded, # TP: total production, ‡: averaged yield.

Teff is popular because it is a low risk crop [7]. Of the 12 million smallholder farmers in Ethiopia, 6.2 million grew the crop between 2004 and 2014 [8]. It can be harvested two to five months after sowing [10]. It is relatively resistant to many biotic and abiotic stresses [3]. Thus, it adapts to a range of growing conditions where major crops may fail [12]. However, the overall teff production in Ethiopia is at a rudimentary stage. Adoption of improved teff seeds is low, farm plots are fragmented, mechanization is almost absent, harvest loss is substantial, and public investment in research is lacking [3, 17]. To estimate inefficiency in teff production, Bachewe *et al*. (2015) use the average Relative Total Factor Productivity (RTFP). Their calculated RTFP value is 0.361, indicating the RTFP could be improved by 177% [8].

In fact, Ethiopia initiated teff research programs as early as late 1950s. The research programs focused on breeding teff varieties to enhance production [1, 17, 18]. With such efforts, 35% of teff producers adopted improved teff seeds in 2012, compared to 7% in 2002. Although increased over the decade, the limited access to and unaffordable price of the improved seeds still prevent smallholder farmers from widely adopting the seeds [17].

Changes in the types of cultivated teff are observed over time. A noticeable change is the increase in white-colored teff at the expense of red and mixed-colored teff. The white teff made up 69.6% of the teff grown in 2012, compared to 48.2% in 2002. On the other hand, the share of red teff declined from 36% to 19.7% during the same period [17]. The color of teff grains, white, mixed and red, mostly decides its grade for quality and price. The white commands the highest price and red the lowest. The very-white magna, a sub-type of the white, commands even a higher premium price [3]. The premiums for the white and magna teff partly come from the social preference for the white color, and Slaklkneckt (1997) described the white teff as follows [10]:

White teff is the preferred type but only grows in the highlands of Ethiopia. It requires the most rigorous growing conditions, has the mildest flavor, and is the most expensive form of teff. Just like white bread has been a status symbol in the United States, white teff is usually reserved for the wealthiest and most prestigious families in Ethiopia.

In line with the description above, more of the white teff tends to be cultivated and traded around Addis Ababa [17]. Addis Ababa is the capital city where many of the affluent reside, and the largest teff market of the country [7]. Besides the social preference for the white color, the popularity of the white comes from the introduction of the improved variety Quncho [17]. Quncho meaning the top in the local language is the major achievement of the teff breeding program in Ethiopia. The variety was derived from the combination of two traits, high yield and white seed. With its release in 2006, Quncho became the first improved variety broadly adopted by the Ethiopian farmers and contributed to 10% increase in teff productivity [1, 7].

The agronomic practices to cultivate teff have little changed, slowing improvement in teff productivity. One such practice is broadcasting for sowing. Broadcasting is a traditional method commonly used for teff sowing in Ethiopia due to its small grain size [17]. A teff grain measures 0.9-1.7 mm long and 0.7-1.0 mm wide, and 150 teff grains weigh equal to one wheat grain [15]. The current averaged seed rate in broadcasting is around 40-50 kg per ha [17]. This rate compares to 3-4 kg per ha, a suggested teff sowing rate in Australia [15]. Broadcasting scatters seeds unevenly in the field, and establishes irregular stands. It in turn makes a proper farming a challenge [13]. Instead, row planting is recommended as a good alternative to the broadcasting.

The grounds to support the row planting are that it reduces the amount of seeds per unit area, and competition between seedlings for water and nutrients while increasing efficiency in weeding [19]. Some studies show promising yield advantages and reductions in input costs with the row sowing method [13]. However, Vandercasteelen *et al*. (2016) argue otherwise [19]. The adoption of the row planting, in fact can be costlier than the broadcasting. It may require 30% more labor than the broadcasting due to lack of the mechanized row planter. This research further identifies there were no statistical differences between the two planting methods for the farmer profits and land productivity. Such different results imply a careful assessment with a choice of suitable teff sowing schemes [19].

Teff growers till soil 4.4 times on average per production cycle. The rationale behind the frequent tillage is that

unbroken soil prevents proper germination of small teff seeds [17]. On the contrary to this common perception, Gebretsadik *et al*. (2009) show plowing frequency did not affect teff yields in their field experiment [20].

Application of agro-chemicals has risen in teff production. The share of teff producers using herbicide grew from 31% to 62.9% in 2012, and the most frequently applied herbicide was 2-4-D to control broadleaf weeds in a surveyed area. This increase in herbicide use may well be expected as weeding is highly labor-intensive, yet critical for teff productivity [17].

For fertilizer, teff accounts for 54% of the total fertilizer applied in the grain production of Ethiopia, and for the largest fertilized area among cereals. In 2011, 981,000 ha of teff was fertilized whereas maize and wheat were 565,000 ha and 556,000 ha, respectively [3, 21]. In terms of production costs, chemical fertilizer made up 20.2% of the total cost, only behind the land rent 21.4% [22]. It may seem counterintuitive that teff producers would use more fertilizer in this low-yielding cereal (Table **1**). However, the increasing teff market price could justify fertilizer application. In addition, due to its long shelf life, Ethiopian farmers attach an intrinsic value to teff [21].

As in the white teff production, more fertilizer is applied around Addis Ababa, the largest teff market. The proximity to this market incentivizes teff growers to maximize yields by increasing fertilizer application [17]. Although the cost of chemical fertilizers can be three times higher around the capital city than other remote areas, the yields and output values per ha are high enough to offset the cost [7, 22]. Nonetheless, anecdotal claims report that distribution, access and affordability are still serious issues with fertilizer. An underlying reason for these issues is the dominance of the government in the agricultural input supplies; the government agencies are the sole fertilizer importer and distributor. Its dominance limits private sector's participation and competition for an efficient fertilizer supply chain [22].

Household characteristics influence teff production [18]. Those characteristics include the gender of household head, number of dependents in the household, level of labor supply, age structure, and involvement in the extension service. Female-headed households are negatively associated with teff production due to relative shortage in labor and capital resources, compared to the male-headed households. Households with a large number of family members are positively associated with teff production due to high labor availability. A U-shaped relationship between a producer's age and probability of producing teff implies learning would be required for a full engagement in teff production. A household's involvement in the extension service seems to increase the likelihood of producing teff by acquiring necessary knowledge and skills [18].

2.2. Loss of Teff

The word 'teff' comes from the Ethiopian word 'teffa', which means 'lost' because of its minute grain size [15]. Teff grains are manually harvested by sickles and threshed with ox tramping on them [3]. Crymes (2015) estimates 25-30% of teff would be lost before and after harvest, and lodging may contribute to the yield loss up to 30%. The high losses along the production processes can reduce the available quantity of teff by up to 50% [10].

To better estimate the loss, Amentae *et al*. (2016) conducted a survey in one of the largest teff production areas in central Ethiopia [14]. The results show the farm-level loss was the highest or 8.18% of teff produced, followed by 3.58% at a consumer level, 2.85% at a retailer level, and 1.67% at a wholesale level. When the farm-level loss was dissected, threshing accounted for 2.91%, transporting from farm to home 2.62%, harvesting 1.87%, transporting from home to market 0.28%, and storage 0.5% [14].

Ineffective tools and little mechanization appear a main contributing factor to the large loss; mechanical tools are developed for maize in Ethiopia, but not for other cereal crops including teff. Poor road conditions and a traditional transporting means such as donkeys are also identified a cause for loss. Inappropriate storage conditions might be a source of loss, yet do not appear to be a major concern [13, 14].

Amentae *et al*. (2016) further relate teff losses to other characteristics: gender of household head, household size, output level, and distance to the nearest market [14]. Female-headed households were more prone to higher loss due to the labor-intensive activities required. Larger family sizes reduced loss with more labor available. Higher levels of output were associated with higher loss because of the handling difficulties. As the nearest market was farther, more loss was expected from spillage and poor handling [14].

However, depending on the study areas and contexts, results of the loss vary. For instance, teff loss along the teff value chain to Addis Ababa appears negligible [23]. The estimated loss during harvest was 1.8%, followed by 0.2% at a

retail level and 0.1% while transporting it. This study concludes the overall loss could range from 2.2% to 3.3% along the teff value chain to Addis Ababa. It challenges the conventional perception that staple supply chains in developing countries are susceptible to high loss. These different findings with the teff loss may indicate that some necessary investment has been put in place to minimize teff loss around the largest teff market, Addis Ababa. Or, post-harvest handling is more conservative in Ethiopia than in developed countries where cosmetic qualities are often of critical importance [23].

Efficient farming practices, favorable household characteristics and loss management are essential to improve teff production, but not an end by itself [22]. A functional value chain, market and supportive policy should coexist to enhance the teff industry.

2.3. Value Chain, Price and Trade of Teff

Ethiopia has yet to develop an efficient teff value chain and marketing scheme. Its value chain is often described as unsophisticated or untraceable [7, 14]. Currently, little evidence exists for modernized teff trading and retailing practices. For instance, the role of credit is minor, most of the transactions are on the cash basis, and standardization of teff grading is virtually absent [7].

Channels through which teff passes need to be identified to understand the value chain. For instance, Gebremedhin *et al*. (2007) show the most important channel for teff producers appeared to be a producer-wholesaler in their surveyed area [18]. On average, 65% of teff producers sold teff to wholesalers, 31% to retailers, and 4% to rural assemblers or directly to consumers [18].

Urgessa (2011) identifies eight different channels for teff marketing, based on the teff flow in volume (Table **2**). Of the channels, Channel 3 carried the largest volume followed by Channel 4. Urgessa (2011) further characterizes this teff market as oligopoly; the four largest teff traders controled 65% of the total teff volume, expressed as CR4 or market concentration ratio [22].

Table 2. Teff marketing channels identified from two studies.

Channel [#]	Details [22]	No. of Node [#]	Details [7]	Share as %
1	producer-consumer	0	producer-UR*	9.8
2	**producer**-RT-**consumer**	1	**producer**-FT or RT or UT-**UR**	22.4
3	**producer**-wholesaler-UR-**consumer**	2	**producer**-FT-RT, or FT-UT, or RT-UT, or RT-RT, or UT-UT-**UR**	52.8
4	**producer**-UA-wholesaler-UR-**consumer**			
5	**producer**-UA-UR-**consumer**	3	**producer**-FT-RT-RT, or FT- RT-UT, or FT-UT-UT, or RT-RT-UT, or RT-UT-UT-**UR**	13.9
6	**producer**-FT-wholesaler-UR-**consumer**			
7	**producer**-UA-RR-**consumer**	4 and over	Combinations of FT, RT, RT	1.0
8	**producer**-cooperatives-NGO-**consumer**	Total		100%

#: channel between producer and consumer, number of nodes between producer and urban retailer.
* FT: farmer trader, RR: regional retailer, RT: regional retailer, UA: urban assembler, UR: urban retailer, UT: regional trader.

Minten *et al*. (2016 a) conclude the major teff value chain in Ethiopia was relatively short. The study area represents 42% of the national commercial surplus of teff, and supplies over 90% of teff to Addis Ababa. Along the value chain, there are three critical players between teff producer and Urban Retailer (UR): Farmer Traders (FT) operating at a village level, Rural Traders (RT) at a regional level, and Urban Traders (UT) at an urban level. This value chain ranges from zero node where URs purchase directly from teff growers, one node passing through one of the FT, RT or UT, to five nodes FT-FT-RT-RT-UT. The study shows the value chain with two trade nodes or fewer is dominant with 85% of the cases, thus concludes the value chain to the largest teff market is fairly short [7].

Since 2008, the price of teff has increased, widening the price gap between teff and other crops such as wheat and maize [3]. From 2015 through 2017, the average year-on-year price of teff increased 9% or 145 Birr (Ethiopian currency equivalent to USD 5.3) per 100 kg in the surplus market. In January 2017, the price of 100 kg teff was 1750 Birr or USD 64.1, which was twice than that of wheat. The price of teff tends to be individually negotiated and likely varies from one transaction to another. But, the traders in Addis Ababa play a key role in determining a teff price for the major production areas. Referring to the brokers in Addis Ababa, traders in the regional markets set their prices [3].

Minten *et al*. (2016 a) investigated a teff price structure in detail [7]. One notable result is that teff growers obtained 79.4% of the final retail price on average, ranging from 78% up to 84%. Another study by Urgessa (2011) reveals a

similar result; the teff producers took 78.7% of the consumer price while the assemblers, wholesalers and retailers shared the rest of the price. Further, the teff producers collected the highest net profit followed by the urban retailers, farmer traders, regional retailers, urban assemblers, and regional wholesalers in the descending order [22].

The high profit share of the producers appears contradictory to the common observation about producers in developing countries, who may not take a substantial share of the price [7]. Nonetheless, teff producers might not benefit from the price structure when profit per unit of time to produce teff is considered. As the crop is highly labor-intensive with little mechanization, approximately 141 person-days are needed per ha per production cycle. Taken this into account, an average reward per person-day amounts to USD 2.25 per day [7]. It is slightly above the World Bank's extreme poverty threshold, or USD 1.90 per day for low income countries. The high labor requirement to produce teff also imposes negative impacts on Return On Investment (ROI). Elias *et al*. (2017) estimate the ROI of teff as 3.88%, which is very low compared to ROI of wheat or 31.6% [24]. In addition, traders often cheat farmers in weighing. The case is particularly intense at a harvesting season when farmers have to sell in bulk. Such practices can prevent farmers from being rightly paid [22].

On the consumer side, market uncertainty entails additional costs to verify quality of teff they purchase. Ethiopian consumers purchase teff at a cereal shop or a market, clean it at home, and get it milled at a mill [17]. Therefore, the final price consumers pay is likely higher than the retail price, given their additional time and costs [3]. However, mills around the capital city started making changes. The mills are becoming a one-stop shop; they began selling, cleaning and milling in a stream line for consumers [17]. Urban better-off consumers may prefer and be willing to pay premiums for the one-stop service for reduced search costs, guaranteed quality and increased convenience [3]. Working women highly demand the convenience because their opportunity costs are high from the multiple steps involved from purchasing teff to preparing injera at home [17].

2.4. Export Ban and Trade of Teff

Ethiopia grows more than 90% of the teff in the world [11]. Despite its largest production volume, the country is not capitalizing its own crop in the international market [3]. Instead, other countries are actively participating in teff production and marketing to capture the rising market [15].

Eritrea was once a major importer of Ethiopian teff. But, from 1998 to 2000, the war between the two countries severed their formal trading relations. Critically in 2006, the Ethiopian government imposed a ban on exporting unprocessed teff grain and flour. Since the imposition of the ban, the export volume of teff has declined [3].

The rationale behind the ban is to bring the domestic price of teff to an affordable level, and improve food security. A low domestic price of teff benefits consumers, especially the rural and urban poor. Removing the export ban would likely increase the local price of teff to a higher international level. It would hurt domestic consumers [13]. For teff producers, the export ban limits their exposure to price volatility in the international market, and discourages multinational companies to take over the local teff industry. Otherwise, their takeover would likely drive smallholder farmers out of teff business, and raise land conflicts, a similar phenomenon with quinoa in Bolivia. Additionally, exporting teff might weaken the nutritional status of Ethiopia. With teff less available and costlier, poorer Ethiopians could be forced to switch to cheaper yet less nutritious substitutes such as sorghum, barley or wheat as their staple [10].

Despite the standing export ban, the domestic price of teff remains high. The high price is attributable to the rapid increase in domestic demand from the growing population, income, and urbanization. A study shows income growth of 20, 30, or 40% would increase the urban teff demand 22, 33, or 44%, respectively [17]. Minten *et al*. (2016 b) also show the income elasticity in teff is higher in urban areas than rural, 1.2 for urban and 1.1 for rural.

Other factors holding the teff price high include alleged smuggling to neighboring countries and increasing injera export [3, 10]. Following the export ban of teff grain and flour, export volumes of injera increased to 2.5 million kg in 2012, or 270% increase from the 2008 level [3]. The United Arab Emirates (UAE) was the top destination of the injera exports, absorbing over 65% of the volumes. The UAE was followed by the USA, Bahrain and Sweden, each of which made up about 10% of the injera exports [3]. Over the last several years, many local companies entered the injera business to benefit from the growing market. The Mama Fresh, for instance is one of the largest local companies. According to a survey, the local companies export over 30,000 pieces of injera daily to Washington and New York in the USA where large Ethiopian communities exist [11].

Teff is the only cereal crop that Ethiopia has a comparative trade advantage. It can be grown in a large part of the country. The current lack of opportunities for international markets discourages teff producers and traders to improve

yields, reduce post-harvest losses, add more values, and develop standardized teff grading systems [3]. The food security issue hardly justifies the present export ban; teff is not a staple for the most food insecure due to its relatively high price [13]. Thus, Ethiopia needs to reconsider the export ban in order to lead Ethiopian farmers to engage in the rise of teff popularity. Otherwise, the country would miss a good opportunity to enhance farmer income, livelihood as well as GDP. And once the global teff market is mature, Ethiopia would have to grapple with countries with advanced farming technologies, a large-scale production system, and efficient value chain so as to capture the share of the teff market [13].

DISCUSSION AND CONCLUSIONS

This study provides the updated information of the rising new crop. However, limitations exist for a comprehensive review. The available statistics are incomplete, and some of the reviewed articles cover the selected areas and segments of the teff industry. Therefore, part of the value chain is missed out due to the lack of empirical evidence. Still, this review offers a valuable insight on the world's largest teff producer and its value chain.

Overall, the teff production in Ethiopia largely relies on the traditional methods, efficiency of the value chain varies depending on the areas, and the market lacks large-scale processing and purchasing to capture economies of scale. Little value is added to teff, and a lack of grade standardization causes uncertainty and additional costs at transactions. The existing export policy does not support teff producers to profit the overseas market. Therefore, incentives rarely exist to invest in modernizing teff production and its value chain. The current situation draws some suggestions for teff to become a more of a global commodity.

The Ethiopian government needs to ensure sustained public investment in teff research for better agronomic performances. Internationally, teff does not meet the agricultural research priorities because such priorities focus on crops covering a majority of food insecure countries. In the 1970s and 1980s, the domestic policy of Ethiopia paid little attention to teff research due to its political situations [13]. Yet, given the current consumption patterns and popularity, heavy investment in research would pay off for the public. Presently, the white variety Quncho is the only improved variety that is widely adopted. However, more varieties should be developed with improved traits such as lodging resistance.

Research on technical improvement needs to be facilitated. Mechanization along the production process is almost absent. But, it is required to increase efficiency by decreasing loss and labor input. For instance, mechanized harvesters may reduce 70-80% of the number of days for labor per ha [13]. Technological improvement is essential for the injera industry as well, considering the flatbread is a source of livelihood to many in Ethiopia. At present, a traditional clay pan is the broadly used tool for baking injera [3]. Technical improvement in making injera would increase productivity, commercialization, and export opportunities while decreasing its domestic price. Private sector involvement should be strongly promoted as substantial financing is necessary for technical advancement. International companies can explore this niche market to export their technology. Collaboration of local and international food companies would add more value to teff by developing new and improved teff-based products for both domestic and international consumers.

The Ethiopian government has heavily invested in the agricultural extension service. Ethiopia now has one of the lowest ratios for number of farmer to extension in the world [17]. Yet, the role of extension service is limited to delivering a package with an improved variety and fertilizer [13]. The service should pay more attention to appropriate field management practices, which include a suitable planting method, weed management, crop rotation, and soil and water management. Moreover, given the increasing input prices, an improved crop management can minimize the production cost by efficient input uses [13].

Lifting the export ban and liberalizing teff industry need to be considered. This would likely commoditize teff. The commoditization could create large-scale activities necessary to increase productivity and support export volumes. In doing so, teff needs to be added to the Ethiopian Commodity Exchange (ECX) for more transparent and efficient trading [10, 25]. The establishment of ECX in 2008 was to support its commodity market and transform agricultural trade in order to better serve Ethiopian farmers, traders, processors, consumers and other actors [3]. The ECX is currently operating with the major commodities such as coffee, haricot bean, maize, sesame and wheat, but not teff.

Critically, the country must protect teff genetic resources before implementing national strategies to make teff a global crop. In 2005, the Ethiopian government agreed to support a Dutch company, HPFI to develop teff-based products for the European and American markets. The government provided the company with access to 12 teff varieties and genetic resources. However, HPFI went bankrupt, and Ethiopia virtually gained no profit although the

same owner of HPFI later set up different companies to continue exploiting Ethiopian genetic resources without sharing any financial returns [10]. Awareness of the importance in genetic resources and relevant actions would assist Ethiopia to better manage invaluable genetic resources. International donors may share their knowledge through training programs.

Ethiopia owns this unique crop, which has started gaining worldwide popularity. The country's specialization in teff and value-added products will likely contribute to generate incomes, reduce poverty, and improve food security. Equally importantly, teff can offer one more feasible solution to a global food and nutrition crisis.

CONSENT FOR PUBLICATION

Not applicable

CONFLICTS OF INTEREST

The author declares no conflict of interest, financial or otherwise.

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