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Contents

Executive Summary

Sorghum is one of the cereals which is grown in moisture stress areas of Ethiopia. The community found in this area uses sorghum for foods and beverages. Baked products like injera and bread are a staple food of Ethiopian. *Injera* or *biddena* accounts for approximately 70% of dietary calories of the community. It can be made from quite a lot of cereal grains such as tef, sorghum, millet, maize, barley and wheat depending on the regions and availability. *Injera* made from tef grain is the most preferred by consumers due to is eating quality. However, these days it is getting difficult to afford tef *injera* due to its price. And unfortunately, consumers are looking for options like value added sorghum based injera. Actually, genetic, environmental and processing factors play a major role in determining grain composition and its final product characteristics. Sorghum and tef grains have different inherent characteristics which could affect both dough and its final product properties.

The use of composite flours has a long time history in humankind. Even though sorghum alone or in combination with tef is used for staple food preparation in Ethiopia, the extent of its use is still limited. Particularly, the urban community less or do not consume sorghum based products mainly due to a poor image they have for the grain. This shows as there is a need for awareness creation through developing injera and bread making standards. Besides, the price of tef based injera shows an increase and the productivity of this grain is still not matched with the demand on the ground. This situation has forced the urban community to look for optional grains like sorghum and others. Therefore, protocol development and improvement on the injera and bread making processes, and demonstrating the protocols to organized women group supplying injera to hotels and residents is crucial.

For the success of this milestone, the Food Science and Nutrition research program is working with the Cultivate Africa's Future Fund (CultiAF-II) Project to enhance demand for sorghum by enabling markets and small businesses with its specific objectives developing sorghum-based products and deploying to women-owned small-scale injera baking enterprises, and developing and demonstrating high quality sorghum- and wheat-based bread products to bread-baking enterprises.

Traditional injera and bread making processes has been assessed and documented, and improvement on the protocols has been done. The nutrient profiles and functional properties of

composite flours were conducted. In addition, consumer preference for the products has been done using five point hedonic scale. Injera texture improvement was conducted using mustard seed flour. The pasting profiles of the flours were investigated. A training was given for five organized groups (77 women and 7 men) selected from Adama-Melkassa, Gololcha, Shenenkolu, Harar and Babile towns and the training feedback was collected from the participants.

Research problem

The utilization of sorghum is limited to few food products and beverages, and specific to certain areas. Particularly, the urban community less or do not consume sorghum based products mainly due to a poor image they have for the grain. On the contrary, the price of tef based injera shows an increase and the productivity of this grain is still not matched with the demand on the ground. This situation has forced the urban community to look for optional grains like sorghum and others. Thus, developing protocols for best injera and bread making processes with acceptable sensory characteristics could boost the utilization of sorghum.

Progress towards milestones

3.1. Developing sorghum-based products and deploying to women-owned small-scale injera baking enterprises

3.1.2. Protocol develop for high quality injera using sorghum flour from the new variety, mixed with tef

Assessment of the indigenous knowledge was conducted. Documentation of the traditional injera making methods and processes were done. D-optimal mixture design was used for process and recipe optimization. Optimization and improvement of the processes has been conducted. Proximate compositions such as moisture, protein, ash, total starch and mineral contents also determined. Cost-benefit analysis of the technology was conducted using 15 of the trainees.

3.1.2.1. Sorghum injera retro-gradation reduction

Three sorghum varieties namely Argity, Melkam and Tilahun were collected and decorticated.

Mustard seed flour was used for sorghum injera texture improvement. Pasting profiles of the flour was conducted.

3.1.3. De-hulling sorghum grain as a pilot and demonstrate to users as a business model

During the training, a de-hulled sorghum grain was demonstrated to the trainees. The perception of the trainees towards the de-hulled grain color collected. Discussion has been made with individual injera makers on the local practice of decortication, if any.

3.1.5. Demonstration of dehulling, packing and distribution of sorghum grain to organized women groups

Site selection has been performed through extension methods approach. Awareness has been created on the objective and the future plan of the project. Discussion has made with individual injera makers on the local practice of decortication and other pre-treatments and its impact in the grain and injera quality. Based on the discussion sites and users were identified within the selected regions (Oromia and Amhara). From Oromia region: Chiro town women injera making groups and Oda Bultum University) and from Amhara region: Kobo town women injera making groups and Woldia University were considered.

3.1.6. Identification of injera making groups focusing on women and create linkage with sorghum growers and dehullers

Identification of injera maker women has been done and organized. Organized groups containing 84 individuals (77 women & 7 men) were selected from Adama, Melkassa, Gololcha, Shenenkolu, Babile and Harar. Training was given on the injera making processes and consumer preference. Then after, feedback was collected for the trainee’s perception to the technology.

3.2. Developing and demonstrating high quality sorghum- and wheat-based bread products to bread-baking enterprises

3.2.1. Protocol development for making high quality bread using both sorghum and wheat and assessment of consumers quality preference

Information on the traditional technique of bread making processes was collected, evaluated and documented. Based on the identified traditional sorghum bread baking and the best proportion for sorghum bread was identified. Three sorghum grains physical property and chemical composition has been investigated. Different bread making processes were assessed and evaluated. Optimization of processes has been conducted. A standard bread baking processes has been developed. Evaluation of sorghum-wheat mixtures for best bread baking has been performed. Finally, a ratio of 20:80 recommended

Synthesis of research results and development outcomes

Specific objective 3.1. Developing sorghum-based products and deploying to women-owned small-scale injera baking enterprises

3.1.2. Protocol develop for high quality injera using sorghum flour from the new variety, mixed with tef

This activity is mainly focused on the development of protocols for best sorghum based injera quality. Because injera is a staple food of Ethiopian and neighboring countries, the available knowledge and information in the community was collected for our consumption in the protocol development. Based on the indigenous knowledge found in the community, a protocol for high quality injera using sorghum-tef flour mixes were conducted. The traditional injera making processes and recipes was also documented. Information related to injera processing such as variety type, decortication technique if any, mixing of grains, kneading time, absit/slurry proportion and preparation were collected. Depending on the identified injera making process, the proportion of sorghum and teff were determined using sensory quality traits. Recipe optimization was done using D-optimal mixture design containing eight run with different proportions of sorghum and teff.

Three sorghum varieties namely, *Argity, Melkam* and *Tilahun* were considered for this experiment. The grain color properties and nutrient profiles were done using HunterLab and Near-infrared Spectroscopy, respectively (see Table 1 & 2). The mineral contents such as iron, zinc, calcium, sodium and potassium the composite flour were conducted. The result indicated that the optimum formulation for best injera quality in terms of its sensory attributes like color, overall acceptability and L* value was obtained with a formulation of 50:50 ratio with a desirability of 0.909. This formulation had a score of 7.05, 7.78 and 67.21 for its color, over all acceptability and L* values, respectively. As a conclusion, this study showed that there are possibilities to make sorghum based value added injera for commercial use with acceptable product quality and lower production cost.

Table 1. Color properties of the sorghum grains

Variety	L*	a*	b*
Argity	62.65±0.56[b]	5.3±0.17[b]	21.5±0.91[b]
Melkam	66.46±0.47[a]	4.51±0.31[c]	21.15±0.85[b]
Tilahun	63.03±0.46[b]	5.76±0.14[a]	23.17±0.28[a]

Data of duplicate samples

Table 2. Proximate composition of the three sorghum grain varieties

Variety	MC (%)	Protein (%)	TS (%)	Amylose (%)
Argity	14.37±0.12[b]	6.17±0.12[a]	75.93±0.23[ab]	20.18±0.04[a]
Melkam	14.7±0.1[a]	6.36±0.06[a]	75.41±0.06[b]	20.07±0.02[b]
Tilahun	14.93±0.12[a]	6.31±0.07[a]	76.12±0.321[a]	20.01±0.01[b]

MC, moisture content; TS, total starch

The functional properties of composite flours such as solubility, swelling power, water absorption capacity and water absorption index are shown in Table 4. In food processing applications, functional properties determines how flours behave during preparation and cooking, and how it affects the finished food product in terms of appearance, tastes, and feels. A significant difference was observed between the formulations. Sorghum flour varied significantly and had the highest water absorption capacity (142.5%), and the lowest percent solubility (4.53 %), swelling power (3.77 g/g) and water absorption index (2.77 g/g) compared to teff flour which showed the reverse. The increment in sorghum proportion resulted in decrement in all functional properties.

Table 3. Functional properties of sorghum-teff composite flours

Treatments	WAC, %	Swelling power, g/g	Solubility, %	WAI, g/g
100S	142.5±0.14[a]	3.77±0.03[c]	4.53±0.22[c]	2.77±0.02[d]
100T	117±0.99[e]	5.13±0.04[a]	8.84±0.63[a]	4.07±0.05[a]
75S:25T	136.55±0.49[b]	4.20±0.14[b]	6.93±0.09[b]	3.34±0.04[c]
50S:50T	128.95±1.2[c]	4.43±0.11[b]	7.73±0.28[ab]	3.55±0.08[b]
25S:75T	124.25±0.49[d]	4.97±0.03[a]	8.21±0.29[ab]	3.96±0.02[a]

S, sorghum; T, teff; WAC, water absorption capacity; WAI, water absorption index.

The swelling power (SP) which describes the water holding capacity of flours upon heating in water ranged from 3.77 to 5.13 g/g and the solubility ranged from 4.53 to 8.84 %. A higher SP of flour from *teff* was probably due to its lower content of fat, grain hardness and longer chains in amylopectin structure.

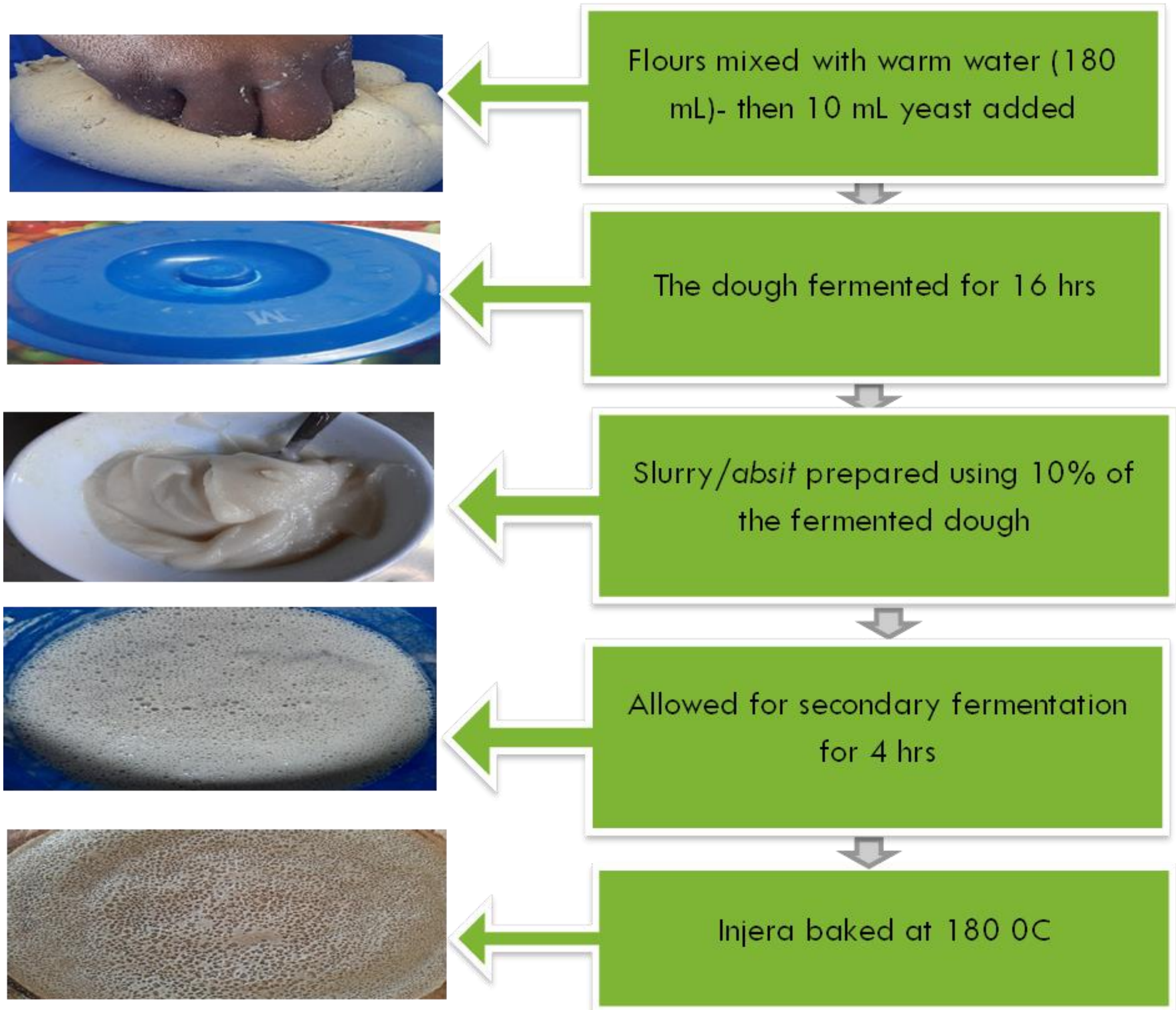


Fig. Sorghum injera processing flow chart

Product preference test

Table 4 depicts sorghum-teff injera consumer preference test. Formulations, 100T, 50S:50T and 25S:75T did not show significant variation in injera appearance, texture, taste and color. Perceptibly *injera* with a characteristics of white color, even eye distribution, less sour and less bitter, rollable and less stick is preferred by consumers. Injera made from 75S:25T and 50S:50T formulation had evenly distributed injera eyes.

Table 4. Results for sensory evaluation of injera made of sorghum-tef composite flours

Proportion	Texture	Appearance	Taste	Colour	Aroma	Overall acceptability
100:0	5.43+0.21[cd]	4.8+0.35[d]	5.17+0.15[c]	6.97+0.67[a]	4.9+0.78[d]	5.8+0.35[c]
87.5:12.5	5.63+0.06[cd]	5.33+0.15cd	5.6+0.1[cb]	6.5+0.2[a]	5.33+0.06[cd]	6.03+0.06[c]
75:25	6.0+1.59[bc]	5.93+1.03[c]	5.6+1.59[cb]	6.57+1.1[a]	5.93+1.81[cd]	6.73+1.14[bc]
62.5:37.5	6.4+1.71[b]	5.91+1.06[c]	5.80+1.56[b]	6.56+4.87[a]	5.89+1.45[b]	6.87+1.15[b]
50:50	7.33+1.27[a]	7. 47+0.76[ab]	6.99+1.82[a]	7.05+0.2[a]	6.8+1.25[ab]	7.8+0.6[a]
Control (tef)	7.98+0.06[a]	8.02+0.0[a]	7.87+0.0[a]	6.87+0.15[a]	7.5+0.0[a]	8.33+0.31[a]
Mean	6.16	5.89	5.83	6.84	5.77	6.65
CV	3.87	3.80	2.15	4.24	4.10	3.25
significant	***	***	***	ns	***	***

Carbon dioxide gas production during fermentation plays a fundamental role in *injera* eyes formation which could be contributed from the inherent characteristics of the grain. Geleta, Labuschagne, Osthoff, Hugo, & Bothma, (2005) revealed that *injera* quality was positively correlated with protein content.

Table 7. Consumer preference test of sorghum-teff composite flours injera

Treatments	Texture	Appearance	Taste	Colour	Aroma	OA
100S	5.43±0.21[c]	4.8±0.35[d]	5.17±0.15[c]	6.97±0.67[a]	4.9±0.78[d]	5.8±0.35[c]
100T	7.98±0.06[a]	8.02±0.0[a]	7.87±0.0[a]	6.87±0.15[a]	7.5±0.0[a]	8.33±0.31[a]
75S:25T	6.0±1.59[b]	5.93±1.03[c]	5.6±1.59[bc]	6.57±1.1[a]	5.93±1.81[cd]	6.73±1.14[bc]
25S:75T	7.4±1.71[a]	7.91±1.06[a]	7.1±1.56[a]	6.56±4.87[a]	5.89±1.45[b]	6.87±1.15[b]
50S:50T	7.33±1.27[a]	7. 47±0.76[ab]	6.99±1.82[a]	7.05±0.2[a]	6.8±1.25[ab]	7.8±0.6[a]
Mean	6.16	5.89	5.83	6.84	5.77	6.65
CV	3.87	3.80	2.15	4.24	4.10	3.25
Significance	***	***	***	ns	***	***

OA, overall acceptability.

Ash and protein contents of flour and injera

The protein and ash contents of the formulations formed from decorticated sorghum grain and whole teff flours are shown in Table 5.

Table 5. Protein and ash contents of composite flours and injera

Formulation	Flour		Injera	
	Protein, %	Ash, %	Protein, %	Ash, %
100S	6.9±0.18^{c}	2.99±0.15^{a}	7.26±0.51^{c}	2.68±0.15^{a}
100T	9.8±0.21^{a}	1.39±0.0^{d}	9.59±0.05^{a}	1.31±0.0^{d}
75S:25T	6.8±0.14^{c}	2.37±0.06^{b}	7.06±0.08^{c}	2.31±0.06^{b}
50S:50T	7.6±0.14^{b}	1.61±0.16^{cd}	7.89±0.03^{bc}	1.62±0.16^{cd}
25S:75T	8.21±0.16^{b}	1.89±0.09^{c}	8.46±0.19^{b}	1.84±0.09^{c}

S, sorghum; T, teff

Teff flour showed a significant variation and had the highest (9.8%) protein and the lowest ash (1.39%) contents.

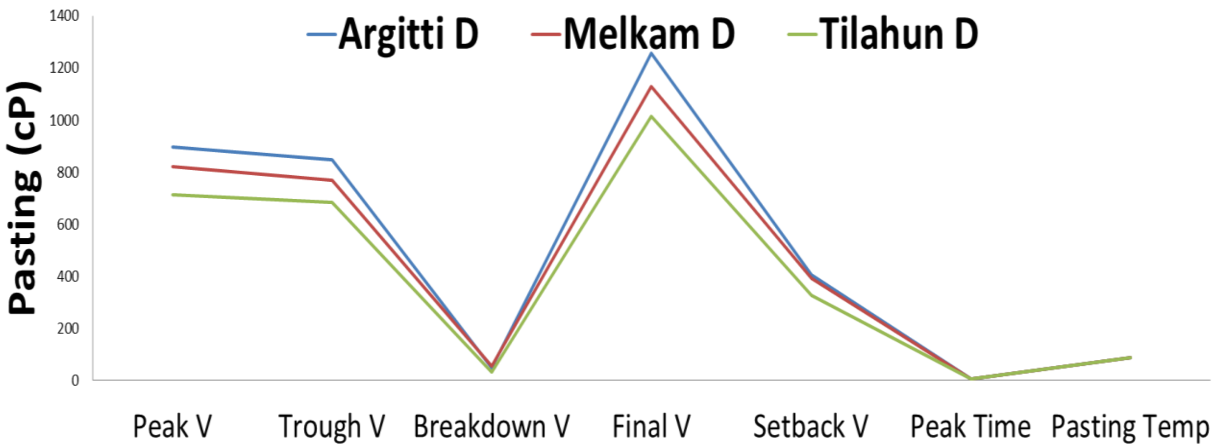
Cost-benefit analysis of sorghum-teff injera

Table 8. Cost-benefit analysis of sorghum-teff injera

	Price in ETB (Ethiopian birr)			
Cost items	Sorghum-Teff (50:50)	Sorghum-Teff (75:25)	Sorghum-Teff (25:75)	Teff only (100)
Operation cost				
Grain cleaning and sorting	75	87.5	62.5	50
Decortication	50	75	25	-
Grain price/Qt	3200	2500	3900	4800
Output and output price				
Number of injera/Qt	620-640	650-660	645-655	640-645
Price per injera	8	8	8	10

3.1.2.1. Sorghum injera retro-gradation reduction

Mustard seed flour was used to improve the staling characteristics of sorghum injera. Adding mustard seed flour on the secondary fermentation resulted in better sorghum injera texture improvement. One gram of mustard seed flour resulted



Pasting profile of decorticated sorghum flour

Activity 2. Identification of injera making groups focusing on women and create linkage with sorghum growers and dehullers

To date, a total of five injera making groups with a total of 84 individuals have been established at six sites of the CultiAF-II project intervention areas namely Adama, Melkassa, Gololcha, Shenekolu, Harar and Babile. Theoretical training on potential sorghum grain contaminants, sorghum nutrition and health benefits, the importance of sorghum grain decortication, sorghum injera making recipes and procedure, and consumer preference of sorghum based valued added injera was given to the trainee at both locations. In addition, practical training was also given.

Once we delivered the technology (recipe preparation and processing technique) both orally and practical ways, we have made a random selection and asked to know the opinion and perception for the technology they have. Even though the trainee are living in the potential growing areas of sorghum, most of them do not use but few trainees include up to 5-15% sorghum in their injera preparation. The trainee also told us their experience of injera processing technique. In addition, the interviewee were asked for terminologies like nutrition and healthy diet after the training and they responds as they got a good understanding of sorghum nutrition, purpose of de-hulling sorghum grain, major contaminants of sorghum grain and which attributes of injera could influence the preference of their customers. According to the trainee, flavor, white color and texture are the most important characteristics of injera consumer's need.

In addition, supervision of the established women group also undertaken at Babile, Harar, Gololcha and Shenenkolu. From the supervision we have observed that some of the trainees are familiar with the protocol and started to use sorghum injera in their business. However, the big challenge is the way find the de-hulled sorghum grain.

Dehulling sorghum grain as a pilot and demonstrate to users as a business model

During the training, de-hulled sorghum grains was demonstrated to the trainees. The perception of the trainees towards the de-hulled grain color and appearance collected. Discussion was made with individual injera makers on the local practice of sorghum grain decortication. The research team has asked the trainee the difference between injera made from decorticated and whole sorghum grain and noticed a difference in sensorial attributes particularly bitterness aftertaste and texture.

Figure 2. De-hulled sorghum grain demonstrated to the organized women group

Synthesis of results towards AFS themes

Improving access to markets and income

Sorghum based food products are not common in the urban area. This is partly due to lack of awareness, poor product quality and accessibility. However, sorghum grain de-hulling and injera making protocol development resulted in best sorghum based injera sensory quality. Hence, the organized women groups are in benefit of the technology which able them access to markets and generate income.

Improving nutrition (utilization)

Sorghum is nutritionally important sources of energy, dietary protein, iron, vitamin B complex, vitamin E, niacin, riboflavin, thiamine, fibre and traces of minerals important for humans. Sorghum is used as staple foods particularly in food insecure populations and are most affected by micronutrient deficiencies and aneamia. Even though the grain is rich in nutrients the tannins and other polyphenols found in the grain can hinder the bioavailability of the nutrients *viz.* protein digestion and mineral absorption. Therefore, the removal of the bran through de-hulling enhances the bioavailability of sorghum based foods.

Problems and challenges

There are problems and challenges we faced during the project period. Here are few of the challenges.

- Covid-19 pandemic
- Internal conflict
- Un-availability of alpha-amylase chemical

Annex

Photos from the training