Advancing improved functionality and protein quality sorghum hybrids for food applications in Ethiopia

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<table>
<thead>
<tr>
<th>No.</th>
<th>Research Problem of SMIL Phase I and II Projects</th>
<th>Key Problem Solutions Achieved</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Commercial underutilization of sorghum resources in Ethiopia - Gaps in Science &amp; Technology for commercial food application of sorghum</td>
<td>Sorghum value chain and food processing technology to scale for commercial application</td>
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<tr>
<td>2</td>
<td>Export ban of teff, while it has huge healthy food market gain - The need to partially substitute with cheaper sorghum &amp; to liberate 1/3 of teff for export market</td>
<td>Partial substitution of teff with sorghum ingredients in injera production are made possible</td>
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<td>3</td>
<td>Import of huge barely malt (about 60%) for brewery industry - the need of partial barley malt &amp; adjunct substitution to barley &amp; sugar in use</td>
<td>Partial substitution of barley malt and adjunct with sorghum are possible to scale in brewery</td>
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<td>4</td>
<td>The then import of wheat for bakery &amp; low nutrition of its white flour - Wheat import substitution using whole sorghum flour as partial ingredient of bread, cookies, snacks, etc. with enhanced nutrients</td>
<td>Partial substitution of wheat with gluten free whole sorghum flour for nutritious cookies, snacks, and bread are possible to scale in bakery, cookies and snack factories. Snacks were in school feeding program.</td>
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<td>5</td>
<td>Qualified manpower capacity building for commercialization of sorghum - Limited qualified human capacity</td>
<td>Qualified and vibrant young scientists are working on utilization of sorghum in Ethiopian foods for commercial application.</td>
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Phase II Background

- Sorghum breeding programs in Ethiopia lacked the end use characterization and segregation of the existing germplasms.

- Research and development endeavors focused only on the high yielding, disease and weed/striga resistance.

- Researches on the nutritional and industrial applications of sorghum as food ingredient was limited.
  - TAMU – HwU collaboration SMIL program was the first addressing this gap.
Phase II goal & objectives

- Goal to improve sorghum competitiveness and value as food ingredient in Ethiopia
  - Advancing opportunities for new HPD sorghums
- Research objectives
  - Commercially viable sorghum processing technologies for local food application: cookies, pancakes, kinche/couscous, popped/boiled sorghum, Brewing malt (injera, & adjunct)
- Improved HPD sorghum hybrid seed production in Ethiopia
- Functional basis of HPD sorghum
Key Project Objectives (Simplified)

✓ Commercially viable sorghum processing technologies for local food applications (staple recipes and commercial product scales)
  - Locally released varieties
  - Material exchange among collaborators

✓ Improved HPD sorghum hybrid seed production in Ethiopia

✓ Functional basis of HPD sorghum
Accomplishments
**Key Activities, challenges & Achievements**

✔ **Obj. 1:** Commercially viable sorghum processing technologies for local food applications

- Injera recipe for waxy and HD normal is documented from previous works (SMIL I) and refinements (sensory) are completed
- Cookies recipe from HD with normal starch are documented
  - adopted to Ethiopian sensory preferences – spices addition
- Pancakes from HD normal sorghum will also be tailored to Ethiopian market
- Sorghum quality analysis and Milling at TAMU is complete – milling trials in Ethiopia – milling for the production of kinche/couscous, others like popping
Key Activities, challenges & Achievements … Obj. 1

✓ Product showcasing organized in July 2022 with engagement of SMEs and large scale industries
  ▪ Products and recipes were presented to stakeholders
  ▪ Media coverage on the potentials of sorghum production and use in Ethiopia

✓ The cost benefit analysis of the production & use of sorghum is underway
  ▪ Production cost in comparison with the other cereals
  ▪ Cost advantage of substituting sorghum for tef, wheat, maize, barley
Table 1. Economic modeling on Ethiopian food/beverage products with partial or full substitution of the customary cereals with sorghum ingredients.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of food and beverage from customary cereal of first choice</th>
<th>Amount of sorghum replaced for matching/similar product quality</th>
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<tbody>
<tr>
<td>1</td>
<td>Injera from tef (red or white)</td>
<td>30%</td>
</tr>
<tr>
<td>2</td>
<td>Bead from wheat</td>
<td>10%</td>
</tr>
<tr>
<td>3</td>
<td>Cookies from wheat</td>
<td>30%</td>
</tr>
<tr>
<td>4</td>
<td>Kinche from wheat (rye)</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>Popped snack from maize/popcorn</td>
<td>100%</td>
</tr>
<tr>
<td>6</td>
<td>Beer from barely adjunct (non-malted)</td>
<td>10%</td>
</tr>
<tr>
<td>7</td>
<td>Beer from barely adjunct (malted)</td>
<td>30%</td>
</tr>
</tbody>
</table>
Trials from SMIL phase I
Key Activities, challenges & Achievements . . . Cont’d

Obj. 1: Commercially viable sorghum processing technologies for local food applications

✓ Grain analysis, small-scale malt and adjunct trial completed

✓ Sorghum-Teff injera formulations identified and being evaluated with trained sensory panel (9 women trained for sensory evaluation)
Key Activities, challenges & Achievements . . . Cont’d

Steep-out

Germinated (72h)
Sorghum malt and Adjunct Cold water Extract, Endosperm Modification, hot water extraction, mashing, filtration and sugar analysis – Sorghum adjunct & malt brewing trials
Whole sorghum-based snacks prepared for showcasing technologies to stakeholders (July, 2022), popes and couscous (left); injera (middle) by SMIL Team; and cookies (right) by private partners (Azi Shallom).
Sorghum substitution (30%) for tef in injera

30% Melkam + tef

50% waxy + tef

30% Marara + tef

30% waxy + tef

100% white tef

100% red tef
Sensory assessment revealed that sorghum-Tef injera at 30:70 regular sorghum: tef produced and 50% for the waxy gave same injera quality as 100% tef.

The formulations are promising for commercially viable productions, industrial applications and marketing of injera products (flour mix and injera products).
Key Activities, challenges & Achievements . . . Cont’d

✓ Obj. 1: . . .

✓ Identified Milling types for trial processing of sorghum

✓ Milling facilities specified and identified (mill, oven, tools, consumables, etc.)

✓ Local sorghum varieties with potential for adjunct in brewery and injera making are identified
Figure 1: Endosperm texture of the local sorghum varieties

- A Argity,
- B Debir,
- C ESH-1,
- D ESH-4,
- E Macia,
- F Gambella-110,
- G Meko,
- H Melkam,
- I Red-Swazi,
- J Teshale and
- K Tilahun,

G = Germ,
FE = Floury Endosperm &
CE = Corneous endosperm.
Adjunct Brewing Quality of sorghums

- Debir, Macia, ESH4 and ESH-1 - have excellent brewing quality in terms unmalted adjunct
Malt Brewing Quality of sorghums

- Melkam (45.53) and ESH-1 (47.37) have excellent brewing quality in terms adjunct & malt
Brewing with Sorghum

Sensory attribute generation for screening of sorghum-Barley malt Beers.

Figure 1b Wordcloud for beer quality and regular beers of different quality used to generate the sensory attributes

✓ The large font and centered words are sensory attributes that could change with adding sorghum into beer formulations.
Key Activities, challenges & Achievements . . . Cont’d

Obj. 1: Sorghum-Teff Injera formulation – technology refining

- Training - Discriminative and Descriptive Sensory Test of Sorghum-Teff injera formulations
- Nine women are trained to screen injera formulation – before release of the technology
Key Activities, challenges & Achievements . . . Cont’d

- Obj. 2: Improved HPD sorghum hybrid seed production in Ethiopia

(EIAR) Melkassa is working on getting the TAMU HPD lines into the Ethiopian seeds systems, although conflict affected many of the centers where trial were underway

- Dr. A. Tirfesa may give details of the progress (discussion, presentation)
Key Activities, challenges & Achievements . . . Cont’d

Spider Plot – Analysis of sensory properties of sorghum-fef injera formulations: (A) Texture related attributes, (B) Aroma, appearance & taste properties
Higher level of cysteine residues in regular sorghum proteins suggests higher ability to cross-link during cooking vs the HD proteins.
Free thiol groups in HD vs wild type sorghum as affected by cooking and oxidation

Cooking increased free thiol groups in HD sorghum (contrary to LD), suggesting less cross-linking tendency, likely due to unfolding to expose previously hidden cysteine residues.

Less protein X-linking means starch being more free to swell, plus protein-starch interactions are more likely during processing – better functionality as food ingredient.
Effect of HD trait on gel hardness over time (starch retrogradation)

Maize starch + sorghum protein

Sorghum endosperm

HD trait reduces rate of cooked gel hardening in both endosperm and pure starch model – reduced staling, better shelf stability of products.
Effect of Thermal Processing (Annealing) on sorghum functionality in injera

- Annealing resulted in better fermentation performance in terms of microbial load regardless of grain type (tef, sorghum) – revealing the potential of physical (thermal) modification of sorghum in injera making.
Effect of Thermal Processing (Annealing) on sorghum functionality in injera

- After annealing, sorghum behaved like tef in terms of microbial load dynamics over 72 hrs fermentation time.
- This indicates that sorghum can be annealed before making into batter for injera making.
Obj. 2: ... Ethiopian varieties also being characterized

Marara sorghum variety (red) from Bako research center showed a promising functionality in injera making and special phytochemical profile
Lessons

- Macia and Melkam are suitable for adjuncts with higher HWE.
- ESH-1 and Melkam could be considered for malting with comparable desirability to that of waxy and HD lines.
- Cooking increased free thiol groups in HD sorghum (contrary to the case in normal), suggesting less cross-linking tendency – HD – Better functionality.
- HD reduces rate of cooked gel hardening in both endosperm and pure starch model. Indicating slower staling, which may be due to lower cross-linking tendency of HD proteins, enabling better protein-starch network formation.
- Melkam, Merera, Waxy have potentials for industrial applications of injera products (mix flour and injeras) - based on their advantage to specific groups of consumers.
Future Aspects of the research achievements (SMIL I & II)

- Establishing national grain quality standard for sorghum to facilitate commercial food market development
- Establish standardized sorghum processing technology guidelines for industry
- Develop product quality assurance & testing standards and protocols
- Technical support to sorghum milling and food manufacturing sector
- Economic impact analysis and policy advocacy to facilitate value chain
Thank you!

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Thank you for the Attention