Utilization of Orange-Fleshed Sweet Potato in Teff-Based Complementary Foods

Mesfin W. Tenagashaw

Dr. John Kinyuru, Prof. Glaston Kenji, Dr. Eneyew Melaku

Food Science and Nutrition Programme

Jomo Kenyatta University of Agriculture and Technology

Presented at:

4th Annual Meeting

SPHI Marketing, Processing and Utilization Community of Practice (MPU-CoP)

1st–3rd March 2017, Kisumu, Kenya

Presentation Outline

- Background
  - Objectives
- Materials and Methods
  - Raw materials
  - Processing of CF
  - Laboratory analyses
- Results and discussion
- Conclusion

Background

- Being free of malnutrition declared basic human right (UN, 1948)
- **Micronutrient malnutrition/hidden hunger**
- A major nutritional disorder in Sub-Saharan Africa and South-East Asia
  - One-third of world's population affected
  - worse among infants and children- during transition period
  - Major MNDs: **Vitamin A, Iron, Zinc, Folic Acid, Iodine**
  - Globally, 127 million children affected by VAD
- Negative impact on **economic development** of a nation
  - ☞Public health costs
  - ☞Loss of human capital

Background…cont'd

Ethiopia's Scenario:

- MNM contributes to 53% of infant deaths
- The sixth highest country in the world (MoH, 2004)
  - The second highest rate in Africa
    - 61% of children (6-59 months) affected with VAD
      - Estimated 50,000 deaths each year
    - 44% of children (6-59 months) are anaemic
- Limited access to commercial/fortified complementary foods and/or animal origin foods
- Dependence on high bulk, low nutrient- and energy-dense cereal-only or cereal-legume foods
- Inappropriate infant feeding practices:
  - ☞ Only 4% of children (6-23 months) fed appropriately (EDHS 2011)

Background (cont'd)

Current recommendations on infant feeding:

- Starting **complementary foods** from 6 months
- Use of local crops (cereals, legumes, tubers) through blending
- Application of household-level or small-scale processing methods
- Improving energy and nutrient density, digestibility, bioavailablity, porridge consistency

Background (Cont'd)

⇨Thus, there is a need for complementary foods with appropriate formulation and processing in the SSA:

- Readily available/affordable
- Nutritious and safe (rich in micronutrients)
- Desirable consistency/solid content
- Acceptable in a given community

A well-fed infant is healthy, happy and productive!
(WHO, 2000)

Objective

⇨To develop and evaluate vitamin A, selected minerals and their bioavailability in complementary foods (CFs):

- produced from a blend of **teff, soybean and orange-fleshed sweet potato (OFSP)**
- using household-level combined methods and extrusion cooking

Materials and Methods

Raw Materials

- Teff *(Eragrostis tef)*
  - ✓ Rich in iron (especially the red variety)
  - ✓ Excellent essential amino acids balance
- Soybean (*Glycine max*)
  - ✓ Rich in protein (quality + Quantity)
  - ✓ Well-balanced amino acid pattern
  - ✓ Higher fat content (energy)
- Sweet potato (*Ipomoea batatas*)
  - ✓ The orange-fleshed variety (OFSP)_Tula
  - ✓ Rich in β-carotene (Vitamin A precursor
  - ✓ **More than 80%** of total carotenoids in OFSP is β-carotene
  - ✓ Antioxidant activity, sweetness (fructose)

Fig 2. Raw materials (Teff, soybean, sweet potato)

Processing Approaches for CFs

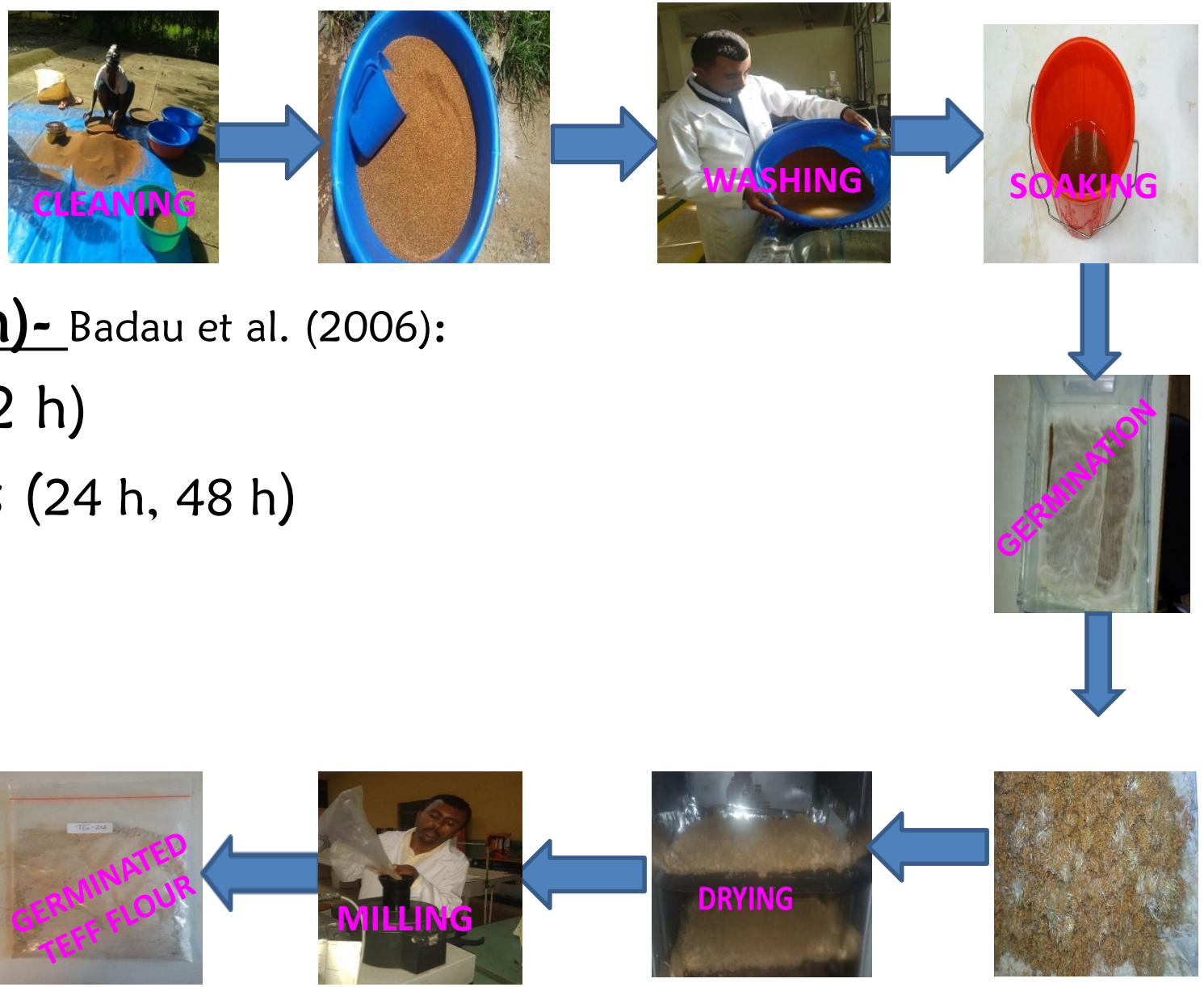
❖Two different processing approaches were employed:

i. Household-level approach
⇨Combined strategies

ii. Industrial-level approach
⇨Extrusion cooking

☺ I can take only 200 ml of food at a time
⇨ Don't fill me with just water!

i. Household-level methods



Teff processing (ARF preparation)- Badau et al. (2006):

- ✓ Cleaning, washing, soaking (12 h)
- ✓ Germinated for two durations (24 h, 48 h)
- ✓ Drying, milling
  - ✓ Germinated teff flour (ARF)
    - Added to the CF at 10% level
    - ⇨60% is ungerminated

Fig 2. Processing of teff grains into ARF

Soybean processing:

- Using two different approaches:
  - Blanching: 100 °C for 10 min (Iombor et al., 2009)
  - Roasting: 170 °C for 15 min (WFP, 2004)

+ Dehulling, Decortication, Milling

a.

SOYBEAN GRAINS

b.

Fig 3. Processing of soybean seeds (a. Roasting b. Blanching)

OFSP Processing:

- According to the method described by Haile et al., (2015)
  - ☞Peeling, slicing, blanching, drying, milling
    - ➔Blanching inactivates enzymes that affect β-carotene

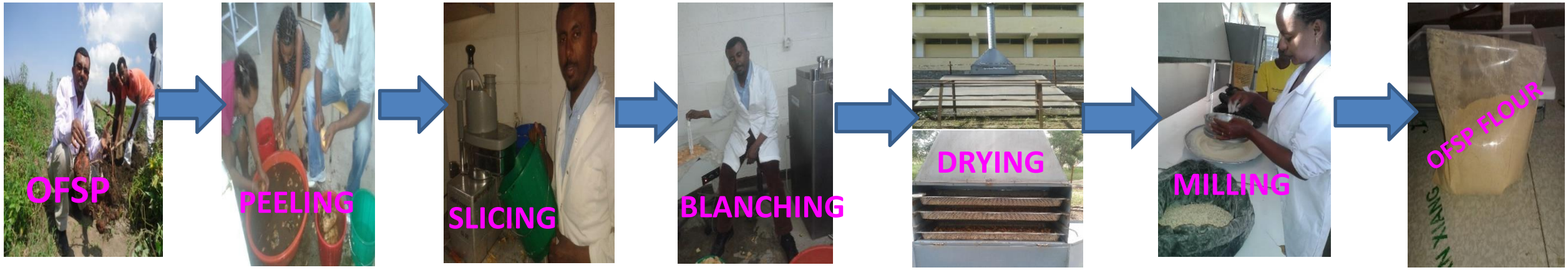


Fig 4. Processing of OFSP

- Finally, the three flours were thoroughly blended (Fig. 6)
- Using a fixed proportion of 70:20:10 for teff, soybean, sweet potato, respectively (Table 1)
  - → Approximation using NutriSurvey software

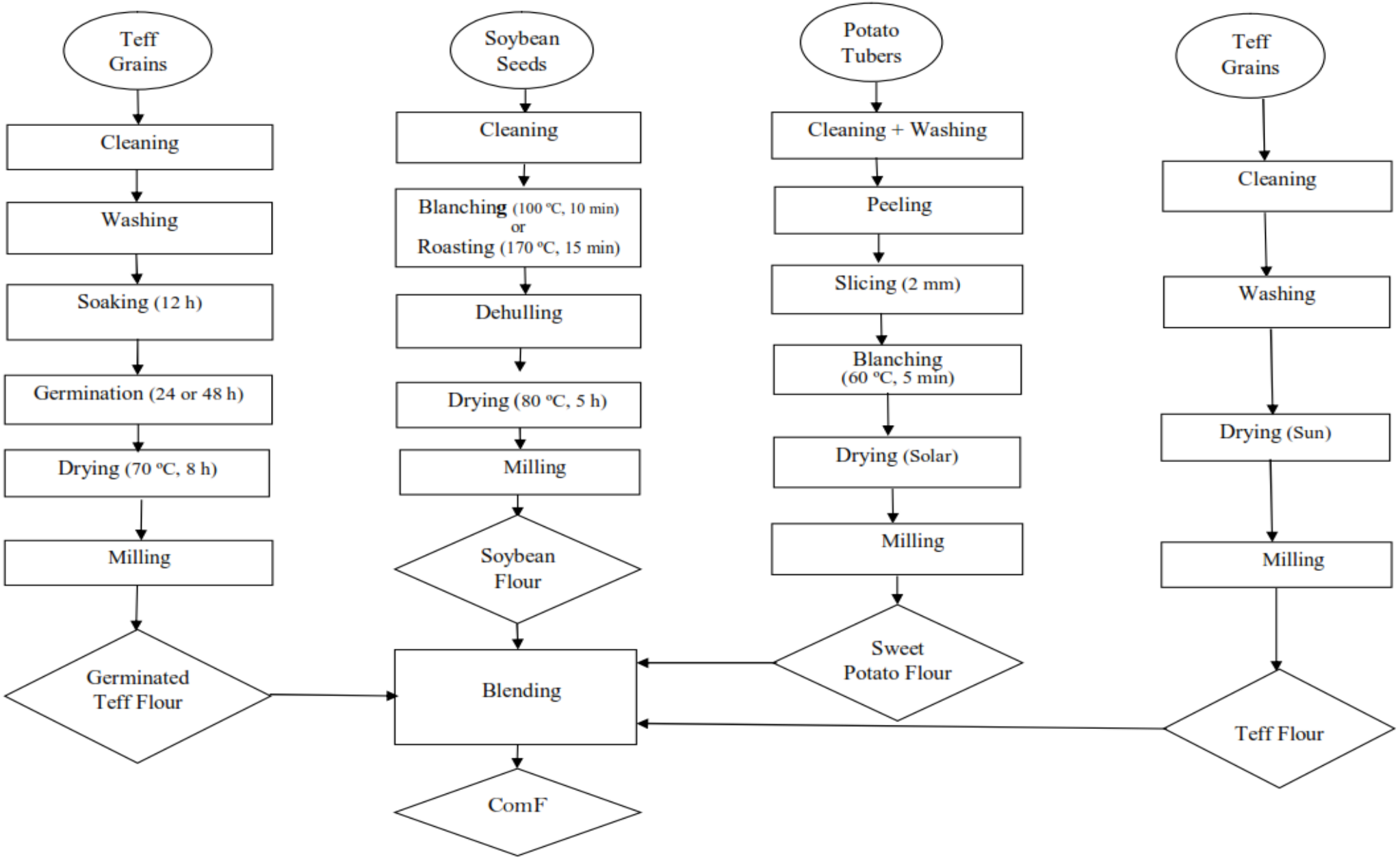


Fig 5. Flowsheet for household-level methods of CF processing

2. Industrial-level Approach

Extrusion cooking

- A high-temperature short-time thermal and mechanical process that precooks a food ingredient through a number of different integrated unit operations using an extruder

****

- Processing of the raw materials into flours separately (Fig. 7)
- The flours blended into a composite flour at a ratio: of 70:20:10 for teff, soybean and OFSP, respectively
- Composite flour extruded into a complementary food
  - ✓ Pilot scale twin-screw extruder
- Selected operating conditions (Literature, trial tests):
  - Feed moisture (22%), Barrel temperature (120 °C), Screw speed (225 rpm)
- Drying and milling of extrudates, packaging and storage of the flour (CF)

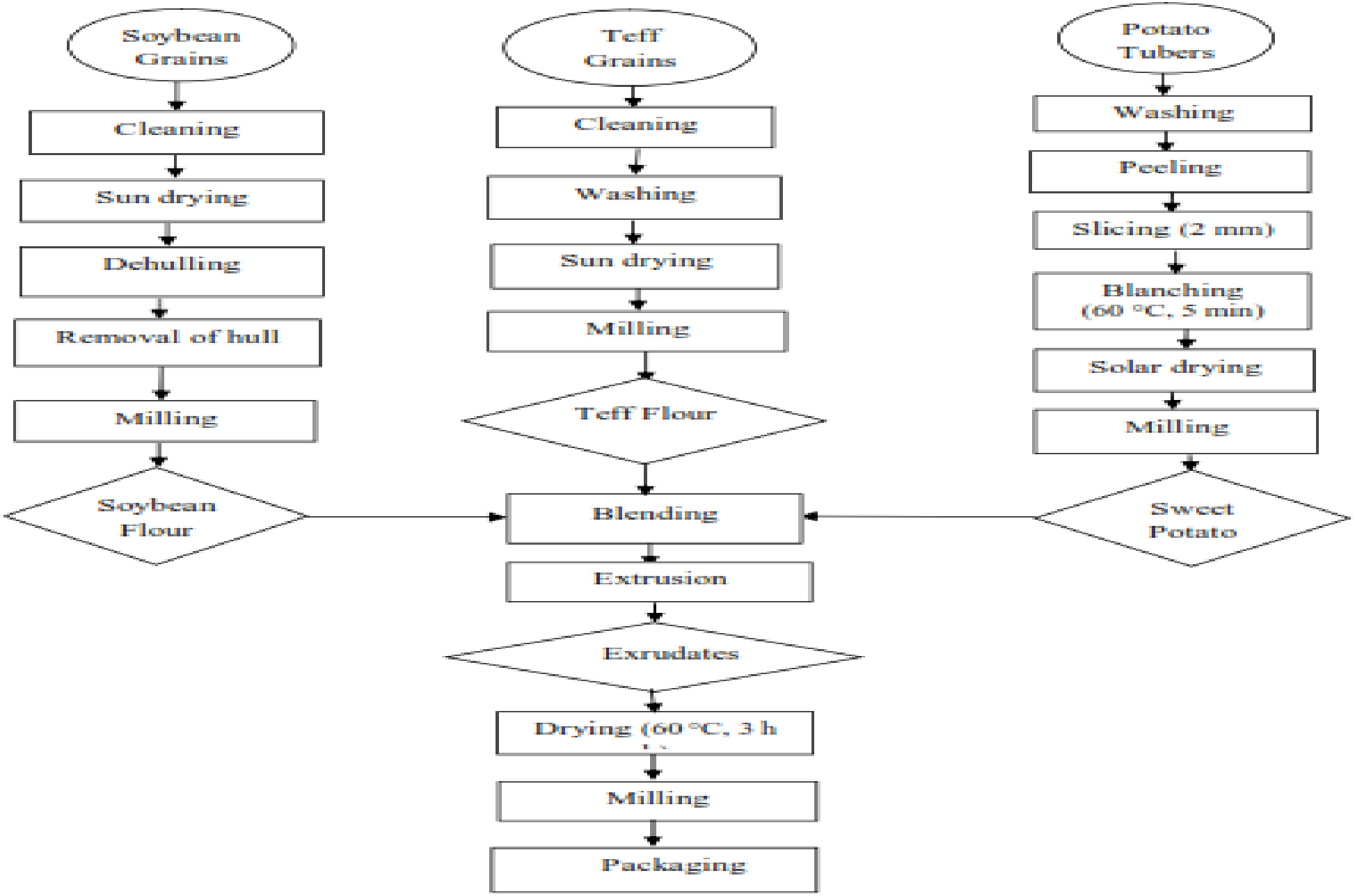


Fig 6. Flowsheet for extrusion cooking of the composite flour into CF

Table 1. Developed complementary foods and their ingredients with proportions (%)

ComF Formulation	Processing method	Ingredients	Proportion (%)
ComF1	Extrusion cooking	Ungerminated teff	70
		Unprocessed soybean	20
		Processed sweet potato	10
ComF2	Household-level methods	Ungerminated teff	60
		Germinated teff - 24 h	10
		Blanched soybean	20
		Processed sweet potato	10
ComF3	Household-level methods	Ungerminated teff	60
		Germinated teff - 24 h	10
		Roasted soybean	20
		Processed sweet potato	10
ComF4	Household-level methods	Ungerminated teff	60
		Germinated teff - 48 h	10
		Blanched soybean	20
		Processed sweet potato	10
ComF5	Household-level methods	Ungerminated teff	60
		Germinated teff - 48 h	10
		Roasted soybean	20
		Processed sweet potato	10

ComF– Complementary Food

Laboratory Analyses

- **Ingredients and CFs analyzed for:**
  - β-Carotene (vitamin-A)
    - According to the method of Rodriguez-Amaya & Kimura (2004)
  - Minerals: Calcium, Iron, Zinc
    - AOAC International (2000)
  - Phytate
    - Using the method of Camire & Clydesdale (1982)
  - Bioavailability
    - Norhaizan and Nor Faizadatul Ain (2009)
    - Phytate:mineral molar ratio

Fig 8. Determination of β-carotene

Results and Discussion

Table 2. β-Carotene (µg/g), minerals and phytate (mg/100 g) contents of ingredients (dmb)

ComF	Ingredient	β-Carotene	Calcium	Iron	Zinc	Phytate
Teff	Ungerminated	2.59 ± 0.21^{a}	203.78 ± 40.51^{a}	15.93 ± 2.12^{b}	5.83 ± 0.87^{b}	336.34 ± 37.54^{c}
	Germinated – 24 h	4.18 ± 0.27^{a}	182.47 ± 0.78^{a}	42.19 ± 7.97^{d}	5.79 ± 0.15^{b}	20.77 ± 13.33^{a}
	Germinated – 48 h	6.54 ± 0.26^{b}	190.12 ± 0.88^{a}	32.61 ± 1.28^{c}	5.93 ± 0.08^{b}	33.51 ± 3.79^{a}
Soybean	Unprocessed	10.60 ± 0.45^{c}	195.59 ± 40.44^{a}	8.47 ± 1.11^{ab}	5.72 ± 3.20^{b}	221.86 ± 33.28^{b}
	Blanched	14.62 ± 0.57^{d}	392.48 ± 1.74^{c}	7.02 ± 0.15^{a}	5.94 ± 0.09^{b}	25.14 ± 6.12^{a}
	Roasted	12.09 ± 1.87^{c}	289.52 ± 2.42^{b}	7.17 ± 0.12^{ab}	5.28 ± 0.28^{ab}	30.50 ± 2.09^{a}
Sweet potato	Processed	45.08 ± 0.43^{e}	219.18 ± 4.60^{a}	4.23 ± 0.37^{a}	2.13 ± 0.24^{a}	28.53 ± 3.26^{a}
P-value		< 0.001	< 0.001	< 0.001	0.023	< 0.001

Table 3. Vitamin A (µg RE/100 g), calcium, iron, zinc and phytate (mg/100 g) contents of CFs (dmb)

Formulation		Vitamin A	Calcium	Iron	Zinc	Phytate
Control		141.70 ± 1.42^{b}	203.61 ± 36.19^{a}	13.24 ± 1.43^{bc}	5.12 ± 1.03^{a}	300.23 ± 33.29^{b}
ComF1		91.89 ± 1.80^{a}	229.86 ± 28.11^{a}	19.42 ± 0.17^{c}	5.25 ± 0.35^{a}	36.70 ± 7.87^{a}
ComF2		157.03 ± 2.01^{b}	240.93 ± 24.78^{a}	15.60 ± 1.84^{b}	5.48 ± 0.50^{a}	238.93 ± 26.40^{b}
ComF3		148.55 ± 8.03^{b}	220.34 ± 25.30^{a}	10.75 ± 1.72^{a}	5.34 ± 0.49^{a}	240.00 ± 26.23^{b}
ComF4		160.97 ± 2.84^{b}	241.69 ± 24.78^{a}	14.65 ± 1.32^{b}	5.49 ± 0.51^{a}	240.21 ± 26.21^{b}
ComF5		152.48 ± 8.90^{b}	221.10 ± 25.29^{a}	8.83 ± 0.34^{a}	5.36 ± 0.51^{a}	241.28 ± 25.99^{b}
P-value		< 0.001	0.748	< 0.001	0.967	< 0.001
Reference value (/ 100g)		831$^{\alpha}$	340$^{\alpha}$	9.4$^{\alpha}$	4.1$^{\epsilon}$	NA
Reference value (Intake per day)	BM + CF	400$^{\pi}$	400$^{\epsilon}$	9.3$^{\pi,\beta}$	3.0$^{\pi,\mu}$	NA
	From CF	63$^{\pi}$	209	9.1$^{\pi,\beta}$	2.4$^{\pi,\mu}$	NA

$^{\alpha}$ World Food Programme, 2014); $^{\epsilon}$ FAO/WHO, 2004); $^{\pi}$ Dewey (2005)

$^{\beta}$ Medium bioavailability (10%), $^{\mu}$Moderate bioavailability (30%)

NA - Not Applicable; BM - Breast Milk; CF - Complementary Food

Table 4. Phytate:mineral molar ratios for calcium, iron and zinc of the CFs

ComF Formulation	Phytate:Calcium	Phytate:Iron	Phytate:Zinc
ComF1	0.01 ± 0.00^{a}	0.20 ± 0.02^{a}	0.87 ± 0.07^{a}
ComF2	0.06 ± 0.01^{b}	1.31 ± 0.14^{b}	4.32 ± 0.67^{b}
ComF3	0.07 ± 0.01^{b}	1.90 ± 0.14^{c}	4.45 ± 0.71^{b}
ComF4	0.06 ± 0.01^{b}	1.39 ± 0.15^{b}	4.33 ± 0.68^{b}
ComF5	0.07 ± 0.01^{b}	2.31 ± 0.16^{d}	4.47 ± 0.71^{b}
P-value	0.004	< 0.001	< 0.001
¥Reference value	0.24	1.0	15.0

¥Maximum limits for phytate:mineral molar ratios in plant-based CFs (Norhaizan and Nor Faizadatul Ain, 2009)

Conclusion

- ⇨ Complementary foods produced from teff-soybean-OFSP mixture can meet the requirements of V-A, Ca, Fe and Zn for 6 to 8 month-old infants

- ⇨ It can also support the various initiatives being carried out in low-income countries to reduce MNM problems including VAD

- ⇨ The bioavailability of the minerals should be checked in vivo for checking true absorption

Acknowledgement

“Accelerating OFSP Value Chain Development for Nutrition and Livelihoods”!

Thank you!

Why Teff, Soybean, OFSP?

Teff

- Staple crop for Ethiopia----**highly valued**
- Excellent nutrient profile: essential amino acids, fiber, iron, calcium, potassium **+ more**
- Red teff has the highest iron content
- Becoming a functional food nowadays!

Soybean

- High protein content, well-balanced amino acid pattern, high fat content
- Complements the protein of cereals - quantity + quality
  - Rich in lysine and tryptophan
- Promoted for improving food security problems

Sweet potato (OFSP)

- Produced in large quantity but the white variety
- OFSP is highly promoted to prevent VAD
  - **Excellent source of beta carotene**

Extrusion cooking

- High temperature short time process
- Multi-step, multifunctional, thermal process
- Recommended for infant foods processing
- **Benefits include:**
  - Destruction of antinutritional factors,
  - Gelatinization of starch thereby reducing viscosity
  - Increased soluble dietary fibre
  - Reduction of lipid oxidation
  - Significant nutrient retention
  - Improved protein digestibility
  - Improved sensory properties
  - Instant/ready-to-eat CF (short preparation time)

Combined household Methods

- Blanching:
  - For destroying lipoxygenase and peroxidase enzymes that causes beany flavor in soybean and other antinutritional factors
  - This prevents browning, lipid oxidation and other degenerative reactions which can affect the β-carotene
- Roasting:
  - Removal of volatile substances including hexanal (grassy smelling substances)
  - Onset of Maillard reaction
    - Gives attractive flavor
  - Inactivates trypsin inhibitors
- Germination:
  - Activates or produces endogenous enzymes including phytases
  - Reduces viscosity and dietary bulk (liquefaction effect)
  - Increased availability of amino acids including lysine, tryptophan and methionine
  - Degradation of antinutritional factors
  - Increased availability of minerals and vitamins

Why Teff, Soybean, OFSP

- Teff
  - A significant crop in only one country in the world- Ethiopia
  - Probably the tiniest grain on the planet
  - Excellent source of essential amino acids, especially lysine
  - an excellent source of fiber and iron, and has many times the amount of calcium, potassium and other essential minerals found in an equal amount of other grains
  - gluten-free, and is gaining popularity in the whole food and Health food industry
  - Red teff has the highest iron content
    - Iron content = 11.5 – 150mg/100g

Teff compared to other cereals

	Teff	Maize	Sorghum	Wheat	Rice
Energy (kcal)	357	375	370	359	357
Starch (%)	73	72	63	71	64
Crude protein (%)	11	8-11	8.3	11.7	7.3
Amino acid (g / 16 g N)					
Lysine	3.7		0.3	2.1	3.7
Isoleucine	4.1		0.7	3.7	4.5
Leucine	8.5		2.1	7.0	8.2
Valine	5.5		0.8	4.1	6.0
Phenylalanine	5.7		0.9	4.9	5.5
Tyrosine	3.8		0.7	2.3	5.2
Tryptophan	1.3		0.2	1.1	1.2
Threonine	4.3		0.5	2.7	3.7
Histidine	3.2		0.4	2.1	2.3
Arginine	5.2		0.6	3.5	8.5
Methionine	4.1		0.3	1.5	2.7
Cystine	2.5		0.3	2.4	1.8
Asparagine	6.4			5.1	9.0
Serine	4.1		0.8	5.0	5.0
Glutamine + Glutamic Acid	21.8			29.5	17.0
Proline	8.2		1.3	10.2	5.0
Glycine	3.1		0.5	4.0	4.5
Alanine	10.1		1.6	3.6	5.5

- Teff's amino acid composition is well-balanced
- A relatively **high concentration of lysine**, a major limiting amino acid in cereals, is found in teff.
- Similarly, compared to other cereals, higher contents of isoleucine, leucine, valine, tyrosine, threonine, methionine, phenylalanine, arginine, alanine, and histidine are found in teff

Table 3.2—Mineral content of teff grain compared to other cereals, mg/100g

Minerals	White teff	Red teff	Mixed teff	Maize	Sorghum	Wheat	Rice
Iron	9.5-37.7	11.6- >150	11.5- >150	3.6-4.8	3.5-4.1	3.7	1.5
Zinc	2.4-6.8	2.3-6.7	3.8-3.9	2.6-4.6	1.4-1.7	1.7	2.2
Calcium	17-124	18-178	78.8-147	16	5.0-5.8	15.2-39.5	23
Copper	2.5-5.3	1.1-3.6	1.6	1.3	0.41	0.23	0.16

Sources: Abebe et al. 2007; Baye et al. 2014; Gebremariam et al. 2012; Kebede 2009; USDA/ARS 2014.

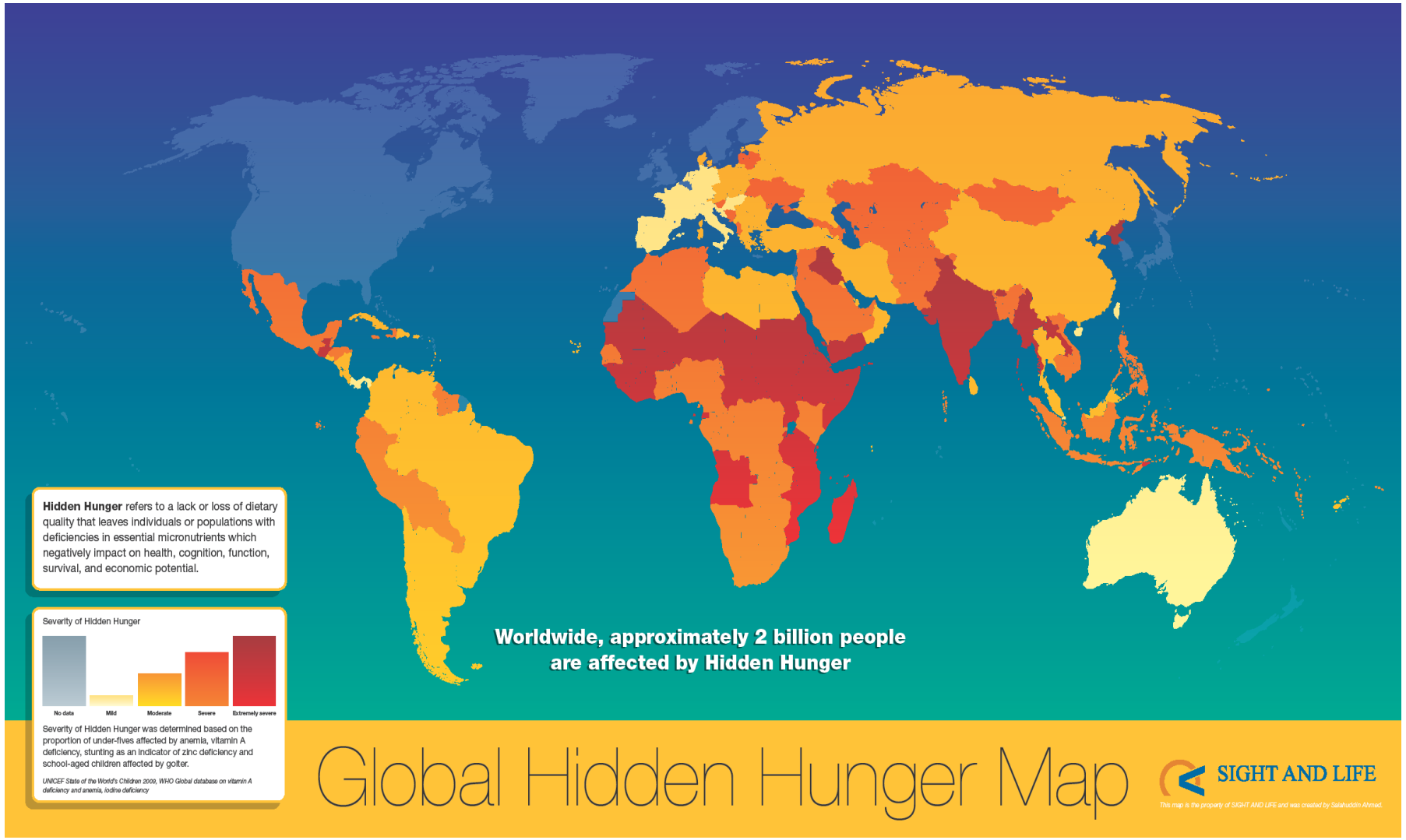
Soybean

- high protein content and well-balanced amino acid pattern
- a valuable protein source in the human diet
- Protein content is approximately 40% and fat 20% with considerable variations depending on the cultivars.
- Protease inhibitors have a harmful effect on the digestion of soy protein

Orange-Fleshed Sweet Potato

- β-carotene-rich
- **More than 80%** of total carotenoids is β-carotene.
- Bechoff (2010) reported that blanching inactivates enzymes that degrade provitamin A such as lipoxygenases and peroxidases and thereby prevent browning, lipid oxidation and other degenerative reactions which can affect β-carotene

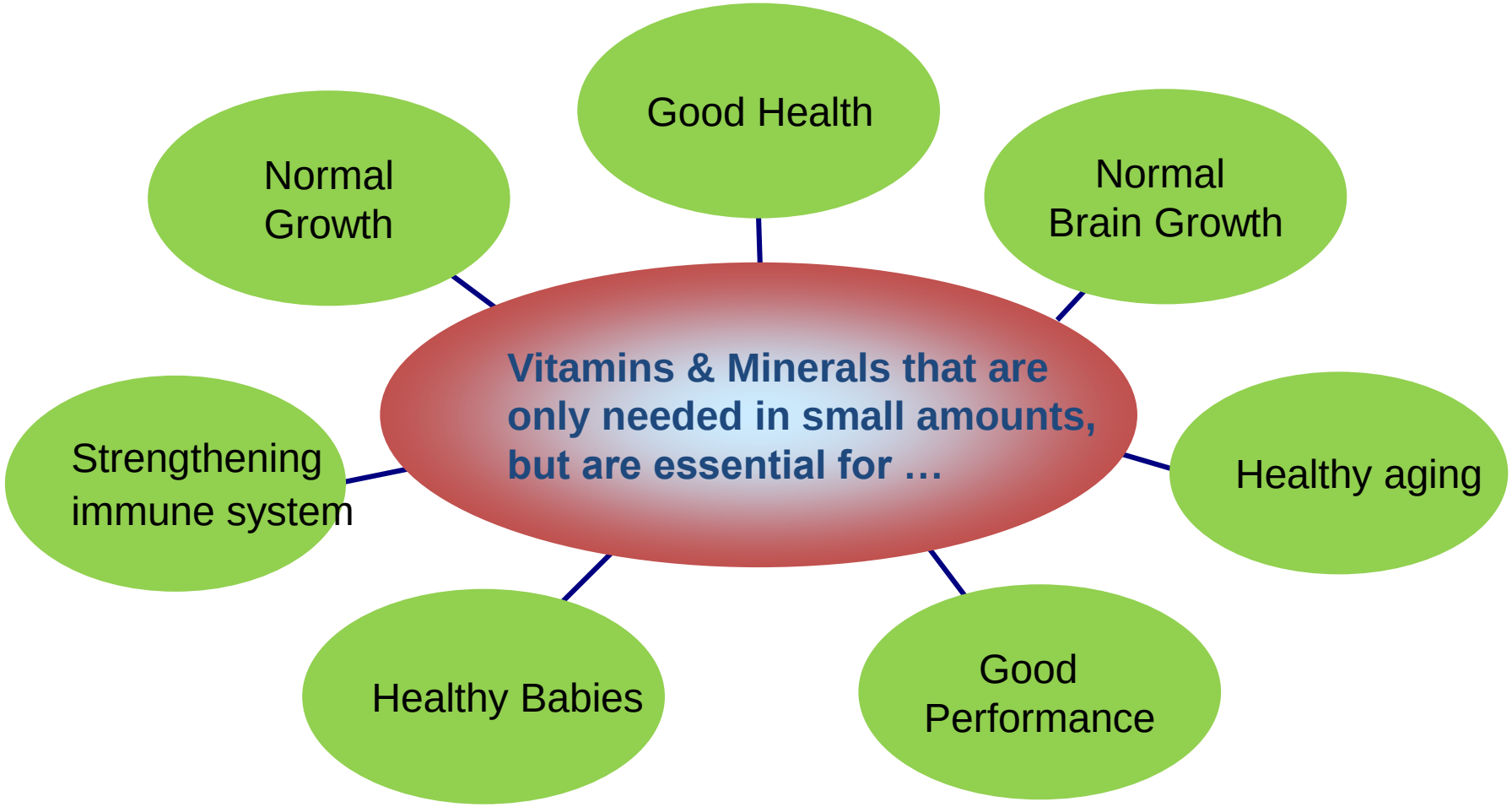
- Development of complementary foods is guided by:
  - high nutritional value to supplement breastfeeding,
  - acceptability,
  - low price,
  - use of local food items



Global hidden hunger map:

Micronutrients (vitamins and minerals)

are essential for many functions and health



They cannot be produced by the body and have to come from the diet