BREEDING SORGHUM CULTIVARS FOR PROCESSING

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WHAT IS NEEDED TO IMPROVE A CROP?

- Knowledge of the crop
- Genetic diversity
- Variability for the trait of interest
- Evaluation and screening tools
- Economic benefit for improving the crop

WHAT TRAITS HAVE BEEN IMPROVED?

- Yield – grain or forage
- Resistance – disease, insects, drought
- Adaptation – environmental, acid soils, salt
- Forage quality – many components
- Grain quality – area with great potential

PRIMARY SELECTION EMPHASIS IS FOR YIELD, STRESS RESISTANCE, ADAPTATION

IMPORTANT TRAITS IN U.S. FORAGE PROGRAM

Wet chemistry analysis conducted on all hybrids

- %ADF acid detergent fiber
- %NDF neutral detergent fiber
- %CP crude protein
- %ADIP acid detergent insoluble protein
- % Soluble protein
- %NDIP neutral detergent insoluble protein
- %Ash
- %Fat
- %Starch
- %Lignin
- %IVDMD invitro dry matter disappearance
- %IVTD-30 invitro total disappearance 30 hours
- %NDFD-30 neutral detergent fiber disappearance 30 hour
- %Calcium
- %Phosphorous
- %Magnesium
- %Potassium
- %Sodium
- %Sulfur
- %chloride
- ppm Iron
- ppm Copper
- ppm Zinc
- ppm Manganese
- %NFC non functional carbohydrates
- %Hemicellulose
- %Lactic acid
- %Butyric acid
- pH
- ppm Nitrate
- %Fructose
- %Glucose
- %Sucrose
- %Manitol

MANAGEMENT SYSTEMS ARE IMPORTANT TO PRODUCING QUALITY FORAGE

BREEDING FOR IMPROVED PROCESSING

- Area of untapped potential
- Some research has been done
- Improved food type hybrids
  - High yield, hard endosperm, better mold resistance, decreased pigments in pericarp, testa, associated pigments
- Future: Link breeders, food science, processors, farmers

IMPORTANT GRAIN TRAITS FOR PROCESSING?

- Within the world sorghum collection are thousands of different genotypes
- Types exhibit variation for kernel size, structure, shape, texture, hardness, pigmentation, starch recovery, peripheral endosperm fraction, protein, oil
- Is the natural variation sufficient for progress in the breeding program
- Resistance of mature grain to biotic and abiotic stress

INTSORMIL

Chemical Composition (%) of Sorghum and Its Anatomical Tissues

	Caryopsis	Endosperm	Germ	Pericarp
Caryopsis	100	84.2	9.4	6.5
Range	-	81.7-86.5	8.0-10.9	4.3-8.7
Protein	11.3	10.5	18.4	6.0
Range	7.3-15.6	8.7-13.0	17.8-19.2	5.2-7.6
Distribution	100	80.9	14.9	4.0
Fiber	2.7	-	-	-
Range	1.2-6.6	-	-	-
Distribution	100	-	-	-
Lipid	3.4	0.6	28.1	4.9
Range	0.5-5.2	0.4-0.8	26.9-30.6	3.7-6.0
Distribution	100	13.2	76.2	10.6
Ash	1.7	0.4	10.4	2.0
Range	1.1-2.5	0.3-0.4	-	-
Distribution	100	20.6	68.6	10.8
Starch	71.8	82.5	13.4	34.6
Range	55.6-75.2	81.3-83.0	-	-
Distribution	100	94.4	1.8	3.8

GRAIN MOLDS/WEATHERING

Red grain
Susceptible (L) and Resistant (R)

White grain
Resistant (L) and Susceptible (R)

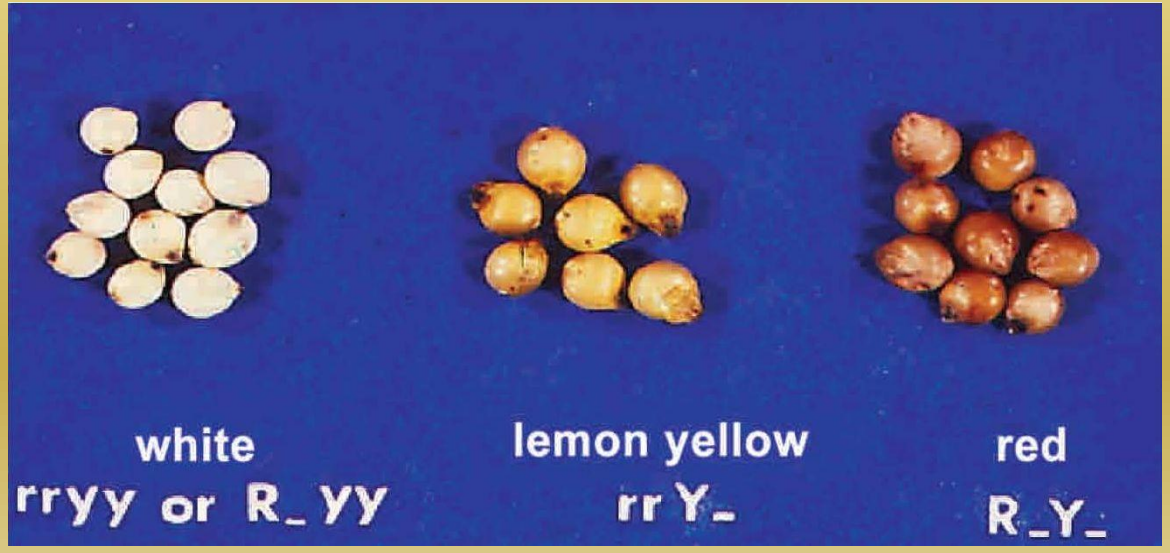
PLANT TRAITS THAT CAN EFFECT PROCESSING CHARACTERISTICS

- Plant color
  - Purple, red or tan
  - Differences in shade
- Glume color
  - Determined by plant color loci
  - Influence on white grain
- Grain color
  - Appearance influenced by several factors

SORGHUM GRAIN COLOR

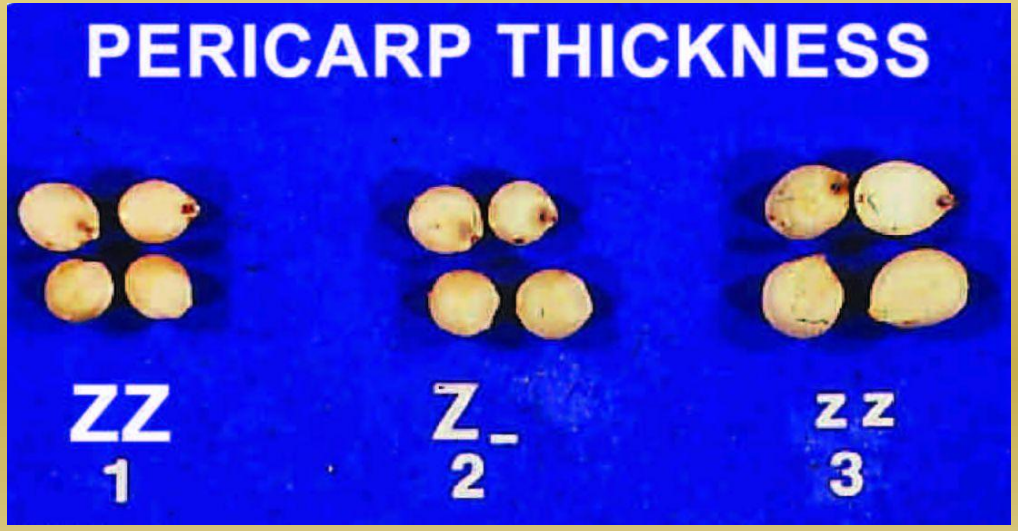
- Grain can appear different colors
  - red, white, lemon yellow, brown, pink

- There are only three grain colors



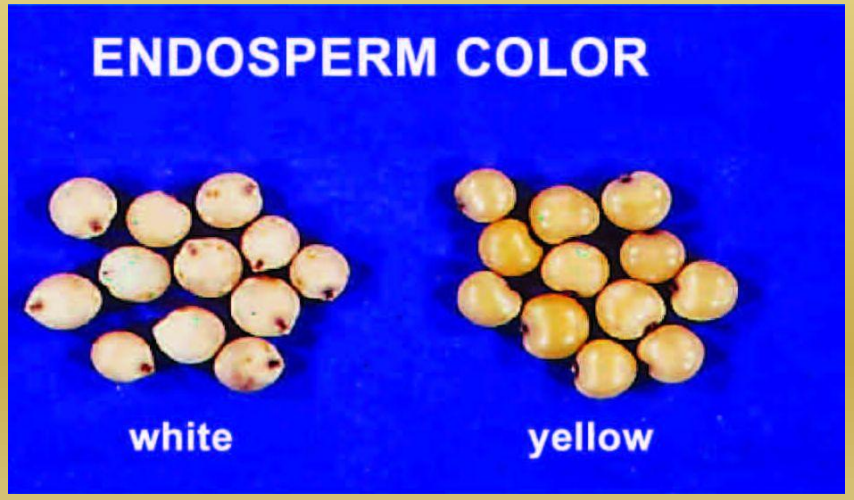
THICKNESS OF PERICARP (SEED COAT)

- Generally classed as thick or thin
- Many are intermediate
- Effect on end-use processing?



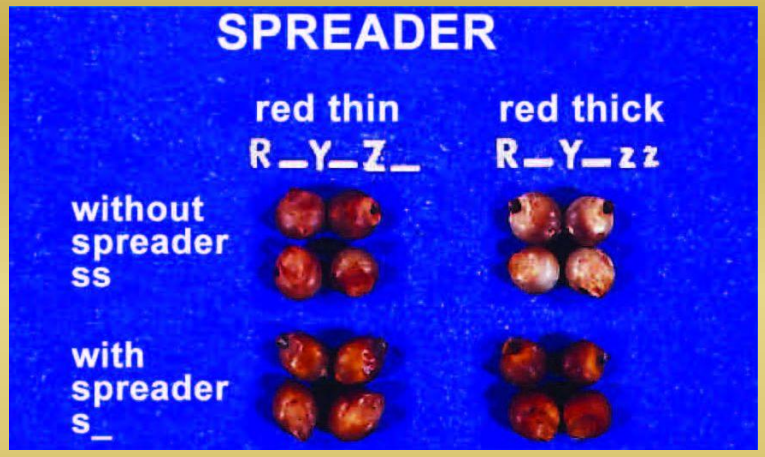
ENDOSPERM TYPES

- Normal (white) or yellow
- Influence on grain appearance
  - Yellow + thin red = Bronze
  - Yellow + thin white = Cream



SPREADER AND INTENSIFIER GENES

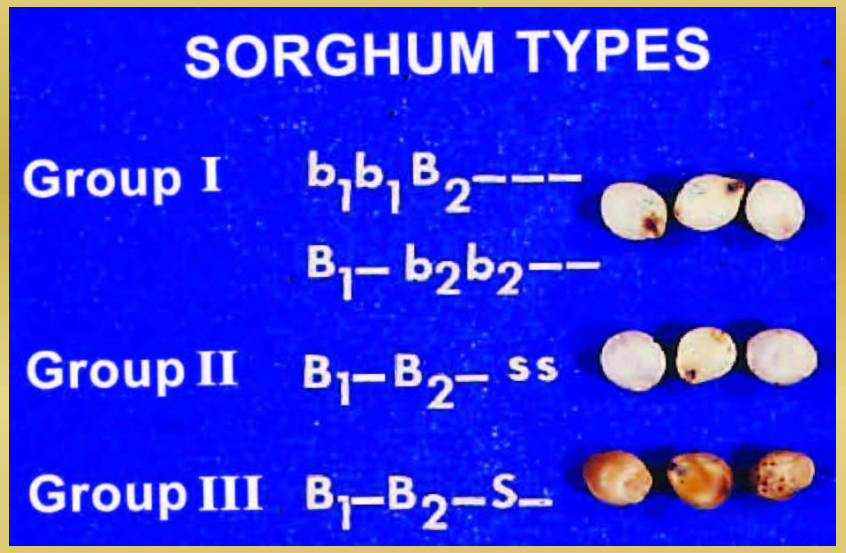
- Influence grain appearance
- Brown sorghum contains testa
- Spreader moves color into seed coat

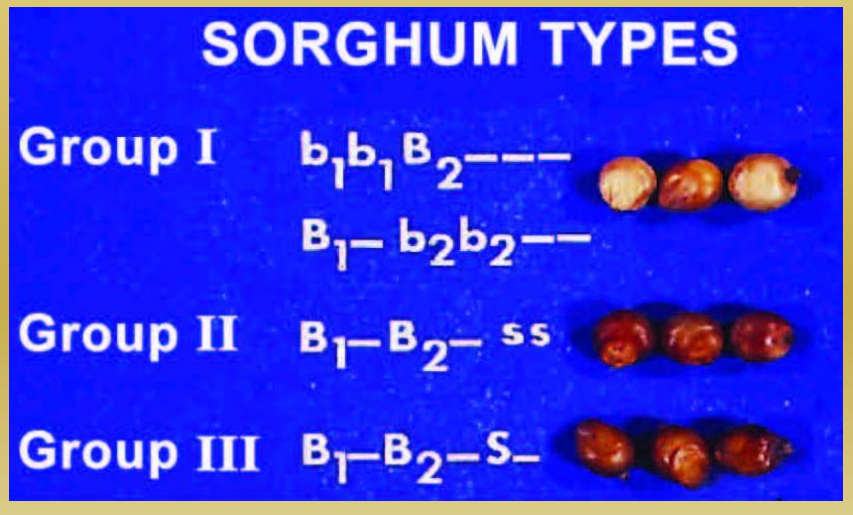


- Controls grain brightness
- Difficult to see in white or lemon yellow

GRAIN TYPES BASED ON TRAITS

- Type based on testa and spreader
- U.S. hybrids have no testa and no tannin
- Tannins bring interesting properties





GRAIN COLORS IN THE FIELD

- Red
- White
- White, YE
- Lemon Yellow
- Black

RED GRAIN PHENOTYPE

- Red, no uc, no sp
- Red, uc, no sp
- Red, uc, sp

WHITE GRAIN PHENOTYPE

- White
- White, uc, no sp
- White, uc, sp

EFFECT OF ENDOSPERM ON WHITE GRAIN

- Yellow endosperm
- Normal (white) endosperm

THE DIVERSITY OF SORGHUM





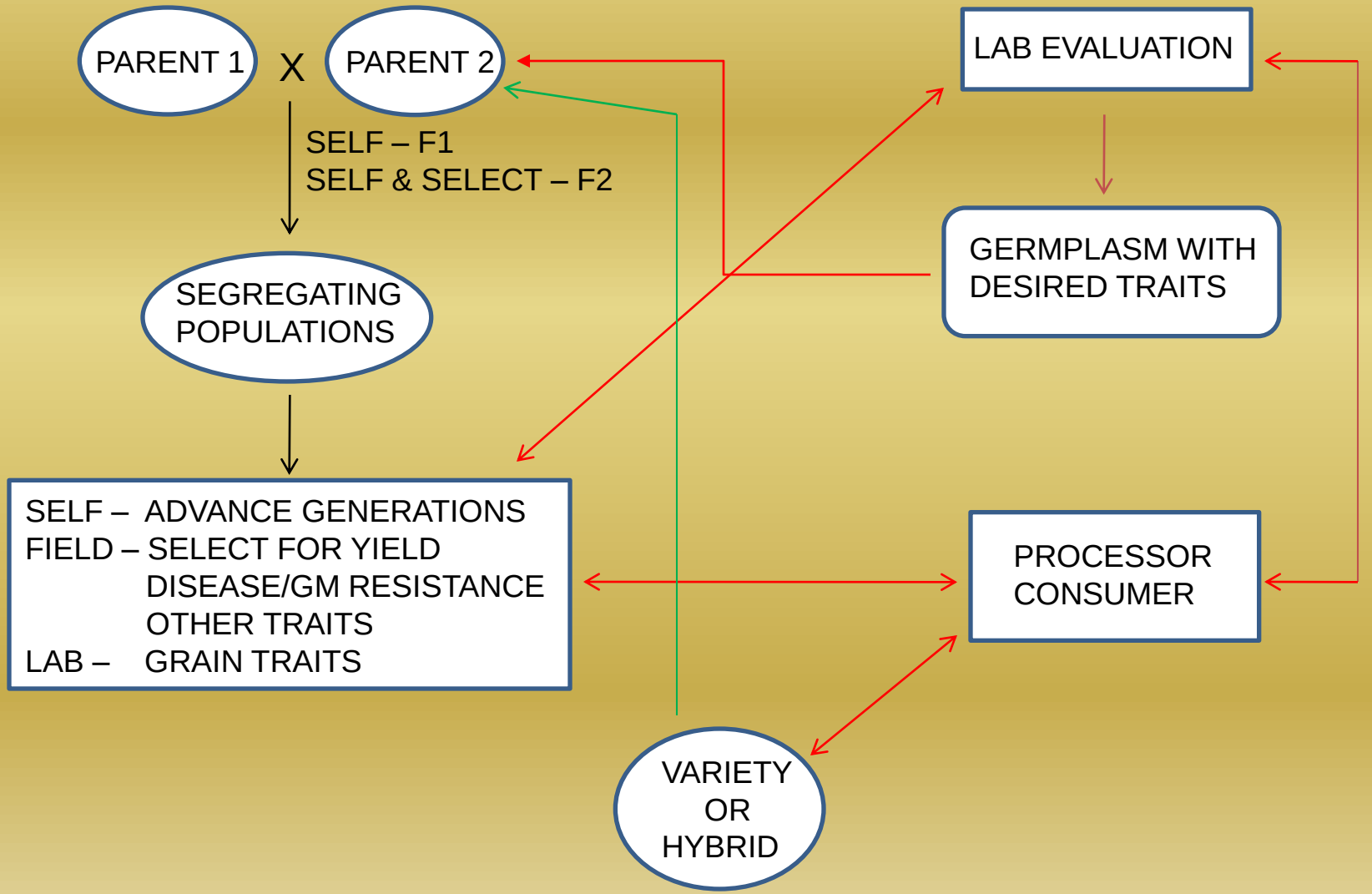

ROLE OF BREEDING PROGRAMS

- Knowledge of Crop
  - –Diversity
  - –Genetics
  - –Performance
- Develop new varieties and hybrids in response to need
- Bridge to link research, food science, processors, farmers, other scientists

BREEDING METHODOLOGY

- Screen lines
- Cross lines with needed traits
- Select for plant and grain traits
- Select progeny with grain traits
- Cross to new parents
- What are the traits(s) to evaluate for processing?
- How do the desired traits affect other traits?
  - Susceptibility to grain molds, reduced yield, etc
- What is the evaluation methodology?
- What will the farmer be paid for – yield or quality?

BREEDING METHODOLOGY



FOOD TYPE SORGHUMS

- White Pericarp
- Tan plant color
- Straw-color glumes
- Non-pigmented testa
- Intermediate to hard endosperm
- Milled into products with bland flavor, white color, no off colors

TO DEVELOP NEW GERMPLASM WITH ENHANCED END-USE TRAITS

- Short-term: existing germplasm
- Medium/long-term: screening, inheritance, new germplasm
- New research avenue for breeding programs, little existing activity
- Need
  - Selection protocol
  - Funds to conduct research
  - Knowledge of what to select for

PREVIOUS RESEARCH

- Modest research on proteins
- Less on starches present in sorghum
- Little to improve content or functionality of other components, e.g. lipids, fiber, minerals, antioxidants
- Protein and starch content and composition vary due to genotype and agronomic conditions
- Pericarp rich in fiber; germ high in protein, fat, ash; endosperm contains mostly starch, some protein, small amounts of fat and fiber

RESEARCH TO COMBINE HIGH DIGESTABILITY AND WAXY TRAITS

- Example of the type of research that is on-going or can be initiated
- Dr. Dirk Hays and graduate students – Texas A&M University
- Multiple funding sources – INTSORMIL, SunGrant Initiative, AgriLife Research

PROBLEM

- Assay to phenotype HD trait is time consuming and variable
- Gap in knowledge of major constgraints in development of sorghum cultivars with optimal endosperm matrix of bioethanol conversion

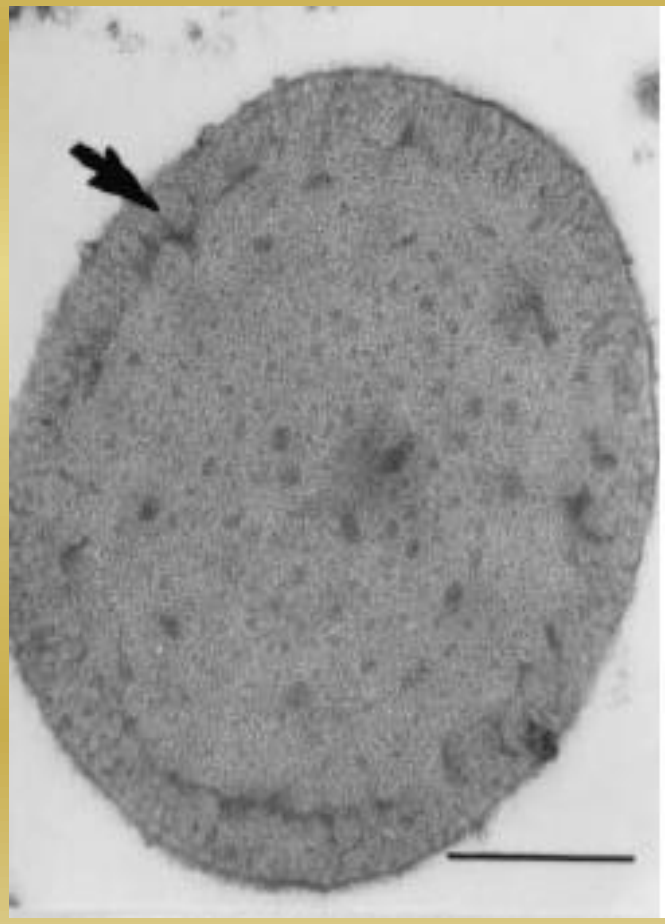
SOLUTION

- Develop designer sorghums that optimize the grain's endosperm matrix for low energy bioethanol conversion and improved grain distiller's feed value

- Combing high digestability and waxy optimize the grain for bioethanol conversion

WILD TYPE SORGHUM

- α-kafirins form the center of protein bodies surrounded by γ-kafirins and β-kafirins (fig: Oria et al., 2000)
- α-kafirins are highly digestible (Hamaker)
- γ-kafirins have plenty of disulphide bounds
- Resistant to digestion after cooking (Oria et al 1995b)
- γ-kafirins form enzyme resistant layer around α-kafirins



HD MUTANT SORGHUM

- A highly digestible protein (HD) / high lysine lines derived from a high lysine chemical mutant (P271Q) (Weaver et al., 1998; Mohan, 1975)
- 10-15% higher protein digestibility when uncooked
- 25% higher digestibility when cooked
- α-kafirin digestibility increased to 90-95% (Weaver et al., 1998)

HD MUTANT SORGHUM

- Rearrangement of the γ-kafirins
- Found only in pockets of folds (fig: Oria et al., 2000)
- The interior α-kafirins are exposed
- More total surface area available for hydrolysis
- DDGS produced has higher lysine content (Xiaroang et al., In press)

WAXY TRAIT

- It is associated with little or no amylose in the endosperm
- Starch is nearly amylopectin (100%)
- It gives appearance of candle wax, hence the name “waxy” (Rooney and Miller, 1982)
- This trait was recognized in 1933
- Due to absence or inactivation of granule-bound starch synthase (Pedersen et al., 2005)

WAXY LINES

- Relatively weak endosperm protein matrix
- Better for brewing and bioethanol (Del Pozo-Insfran et al., 2004)
- Waxy and heterowaxy need shorter times (Figueoroa et al., 1995)
- Attributed to the lower starch gelatinization temperatures
- 69.6 °C - waxy
- 71.1 °C - heterowaxy
- 71.1-73.3 °C - wild types

COMBINE HD AND WAXY TRAITS

- Solves the four major limitations:
  - –Inhibitory kafirin protein matrices surrounding the starch granules
  - –High temperature to starch gelatinization
  - –High temperature enzymatic hydrolysis
  - –Low lysine DDG protein composition

OBJECTIVES

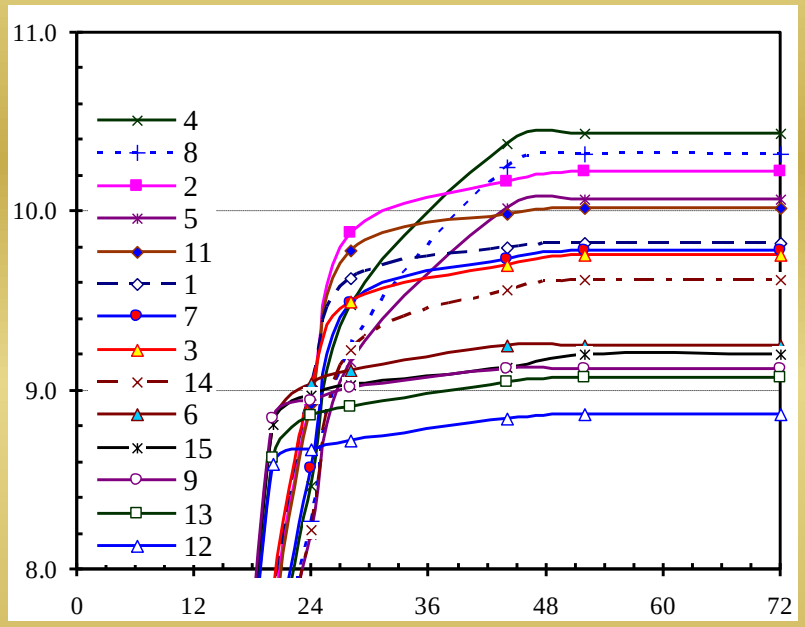
- Phenotyping of HD trait in RIL population
- Validate and fine map QTLs regulating HD trait in NILs

RESEARCH METHODOLOGY

- RIL population developed
- Protein digestibility assay
- Different method of phenotyping to visually identify selections for presence of traits
- DNA extraction of individual lines of RIL
- Phenotypic and genotype data used to identity, validate, fine map HD QTLs

HD X WAXY SORGHUM

- Combination of the two modified endosperm traits HD and waxy
  - 62% faster efficiency at 24 hr
  - 15% greater final efficiency at 72 hr
- Maintains 100% higher lysine content in DDG
- HD combined with waxy trait also increases the FAN and beer making quality of sorghum



Genotype	% Efficiency	
	24 hr	72hr
HD	75	82
HD x WAXY	96	92
WAXY	59	91
WT	57	81

RESEARCH TO DETERMINE PROCESSING QUALITIES OF EXISTING VARIETIES

- Dr. Bruce Hamaker and graduate students (Purdue University) in collaboration with INRAN (Niger)
- Use of an incubation concept to transfer processing technologies to entrepreneurs in Niger

CONCEPT

- Sorghum and pearl millet are important food crops but have made little progress in processed product markets
- Expanded market to sell surplus grain will generate income
- Processing technologies exist to transform grain into high quality flours, etc

METHODOLOGY

- Research was conducted toward optimization of flour, grit and agglomerated products

- Couscous color of sorghum cultivars at 80% decortication compared to wheat couscous

PROCESSED FOOD PRODUCTS FROM SORGHUM ARE NOT NEW TO SOUTHERN AFRICA

WHAT PROPERTIES ARE NEEDED IN CULTIVARS IMPROVED FOR PROCESSING?

- Grain yield and quality
- Resistance to molds/weathering/headbugs
- Tan plant, straw glumes
- Bright white or red color, no pigmented testa
- Milling yield – hardness, spherical shape, white

HOW CAN BREEDERS CONTRIBUTE TO DEVELOPING NEW PRODUCTS?

- Provide end-users with germplasm to evaluate for processing into products
- End-users provide feedback on the best germplasm for their product(s)
- Determine the traits needed and inheritance
- Collaborate with food scientists to develop screening methodology
- Develop new germplasm with enhanced traits

SORGHUM IS THE CROP OF THE FUTURE