Healthy grains and rice quality pre-breeding research at CSIRO

Healthy, safe, wholegrains for the food and beverage industries

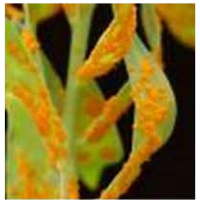
www.csiro.au **ZHONGYI LI, CSIRO AGRICULTURE AND FOOD, CANBERRA**

CSIRO Agriculture & Food

Our advantage – Integrated Agricultural and Food Research

Genome | Phenome | Breeding & Selection | Farming Systems | Landscapes & Environment | Markets | Society & Economy







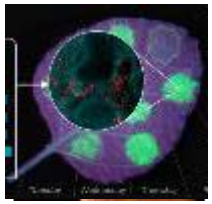
















CSIRO capability relevant to today's talk

CSIRO *Agriculture and Food*

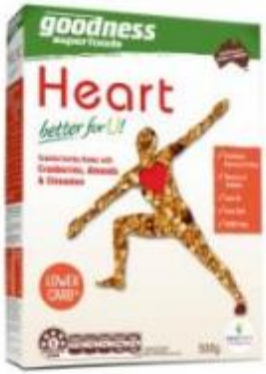
- Cereal Quality Traits

- Innovative Food Centre

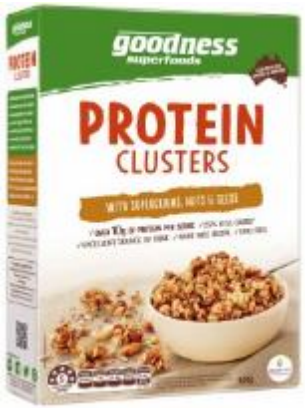
CSIRO *Health and Biosecurity*

- Nutritional and Health Substantiation

Some BARLEYmax products in Australia



BARLEYmax oat soughdough



Spin-out

the HEALTHY grain™

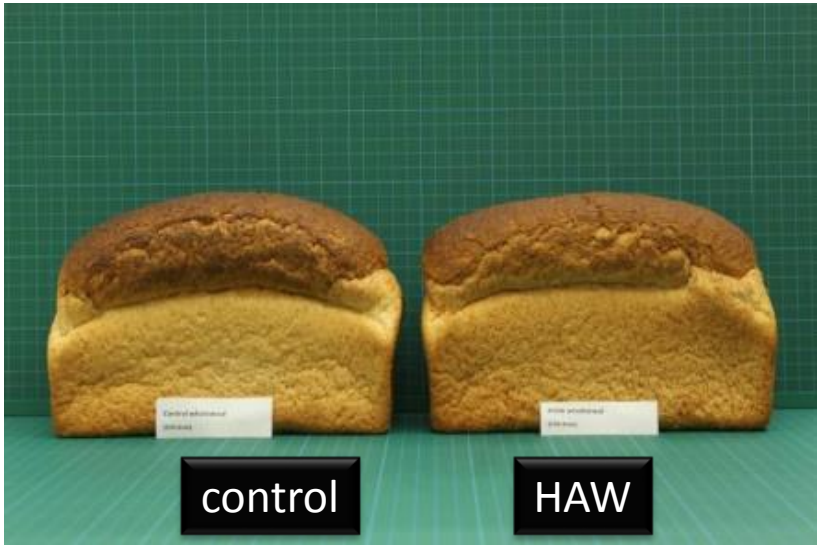
Japan first products launched August 2016

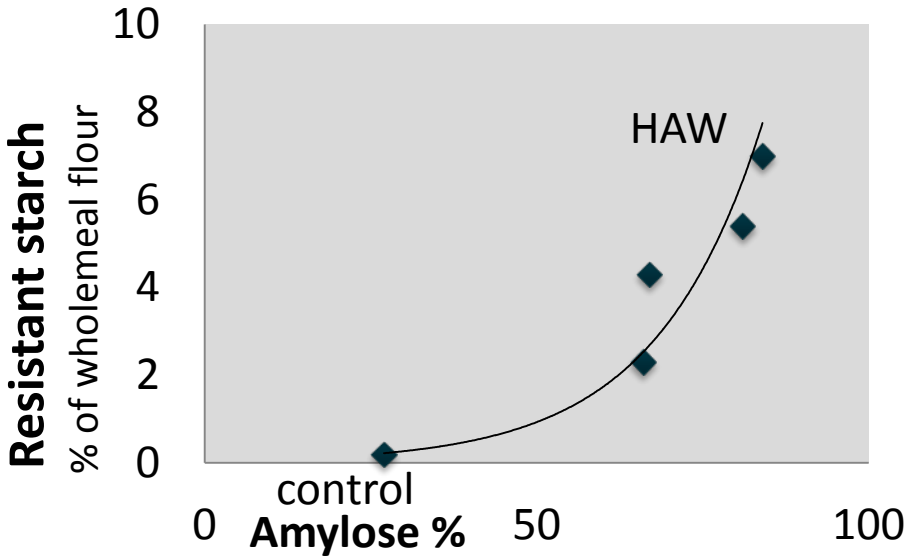
USA first products launched May 2017

Marcus Newberry

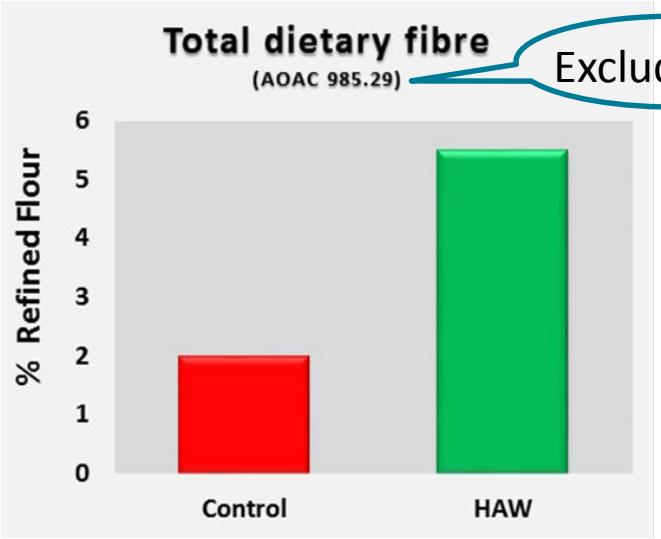
Ahmed Regina

ARISTA CEREAL TECHNOLOGIES





>>10 x resistant starch



3x TDF in refined flour
2x TDF in wholemeal

Hordein reduced >10,000x
56,000ppm to 3-5ppm
WHO *Gluten-free* target ≤ 20 ppm

Kebari

First the beer …….

Commercial release April 2016


Crispin Howitt


Greg Tanner


Malcolm Blundell

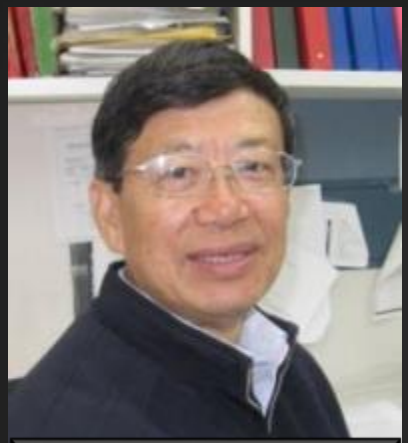
GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Today's presentation: Cereal Grain Traits

What we are doing:

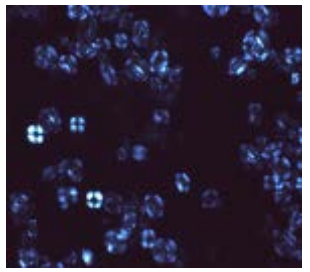
- Resistant starch barley
- Resistant starch rice
- Micronutrient dense rice
- Long shelf life rice

Resistant starch barley BARLEYmax



Zhongyi Li

Why resistant starch? – a fermentable fibre

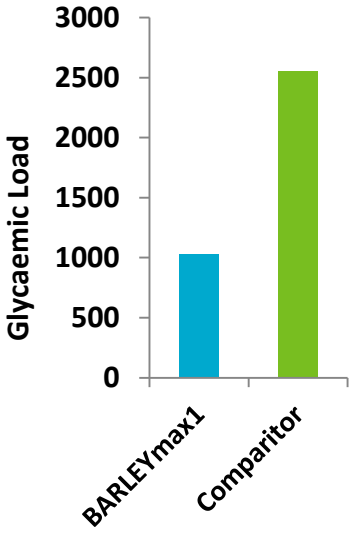


High amylose (>60%)

- Modifies starch granule structure to produce resistant starch

Resistant starch

- Resists digestion in the small intestine
- Reduces glycemic index and glycemic load
- Improves satiety



Fermented to short chain fatty acids in large bowel

- Acetate, proprionate, butyrate – preferred energy for colonocytes
- Lower bowel pH - increases good bugs and reduces the pathogenic
- Enhanced Mg and Ca absorption

Healthier colonocytes

- Reduced rates of bowel cancer
- Reduced absorption of pathogens

Chronic disorders in Australia

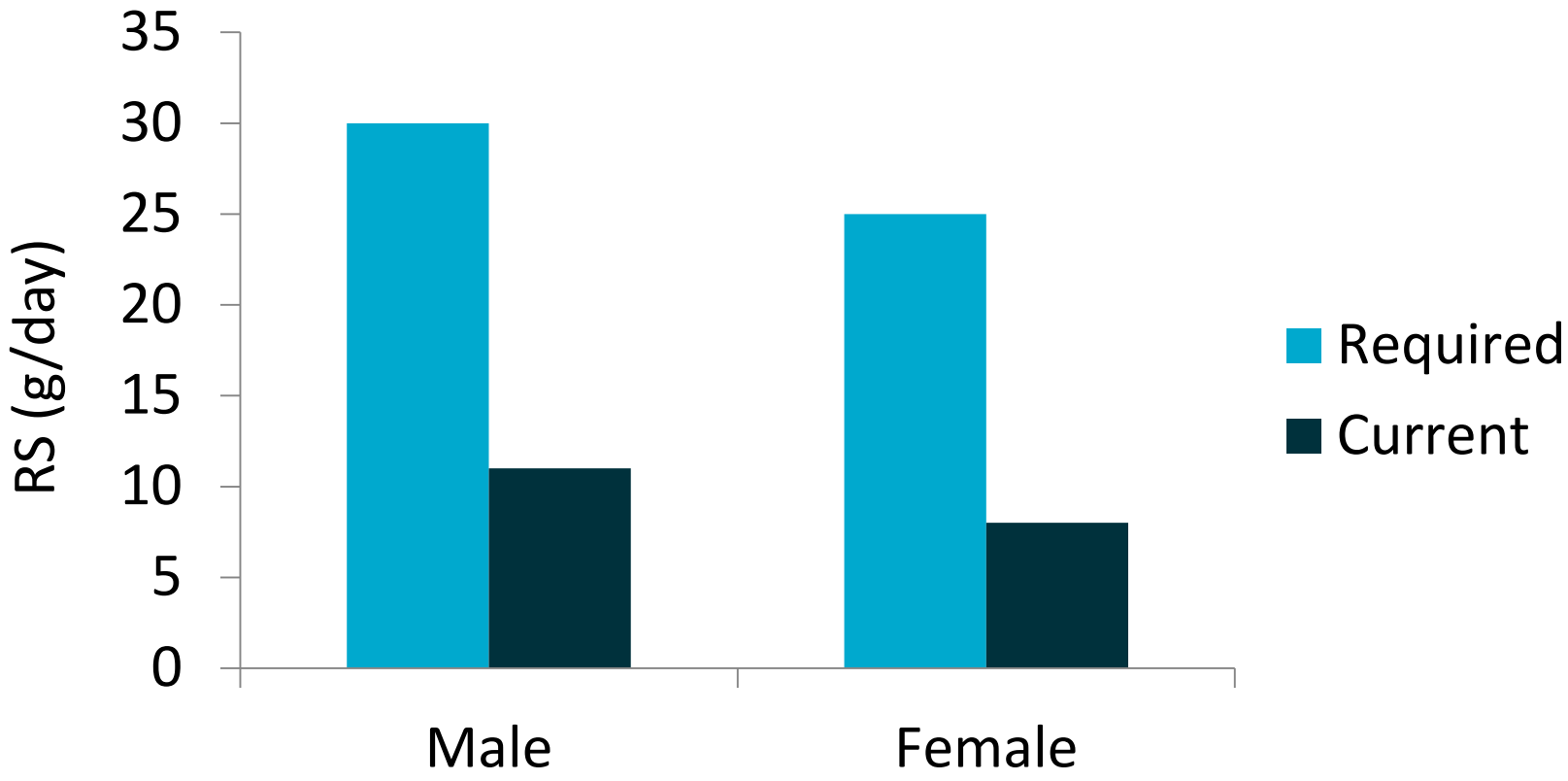
Cardiovascular disease
18% of Australians
$3.9 billion a year

Colorectal cancer
4,400 death pa,
cost $2 billion a year

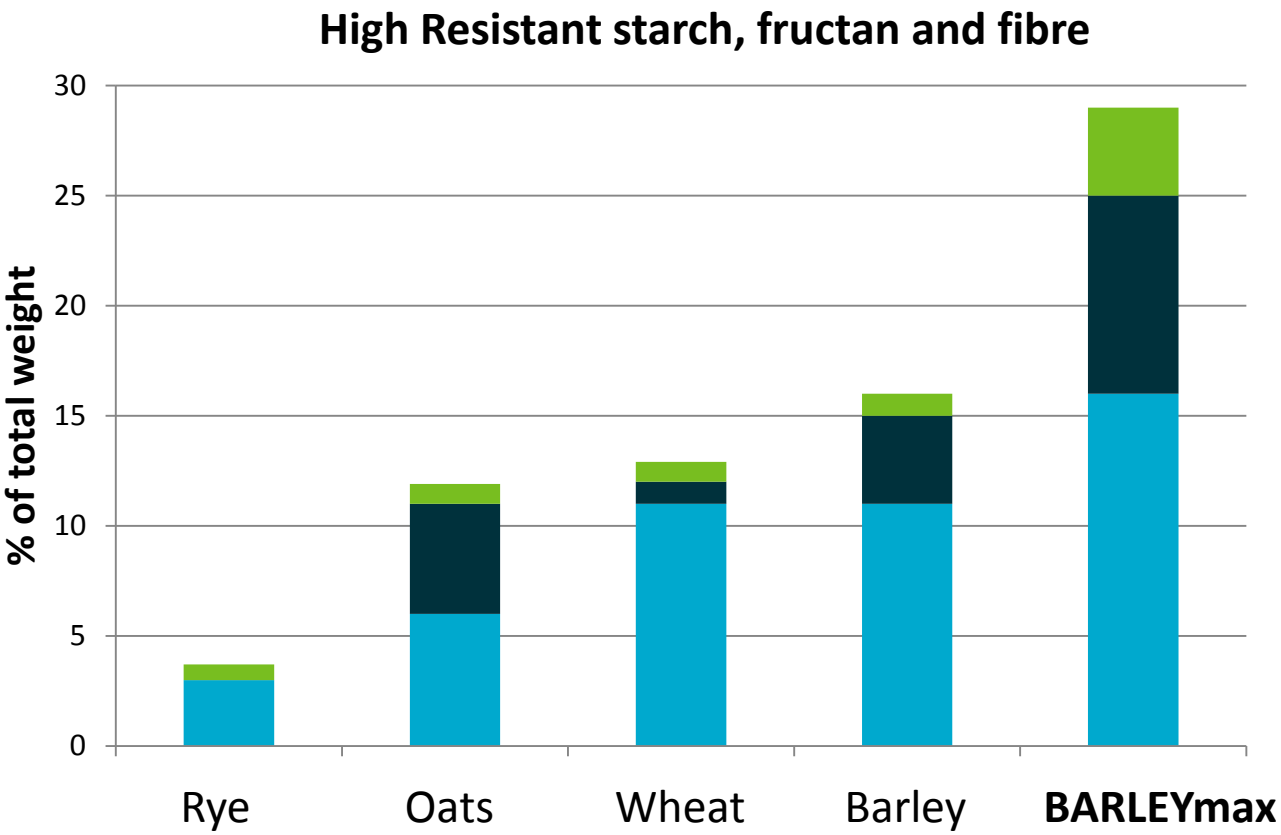
overweight or obese
64% men,
47% women

Type II diabetes
8% of Australians,
cost $3 billion a year

Adequate RS intake in Australia



More fibre than any other cereal grain

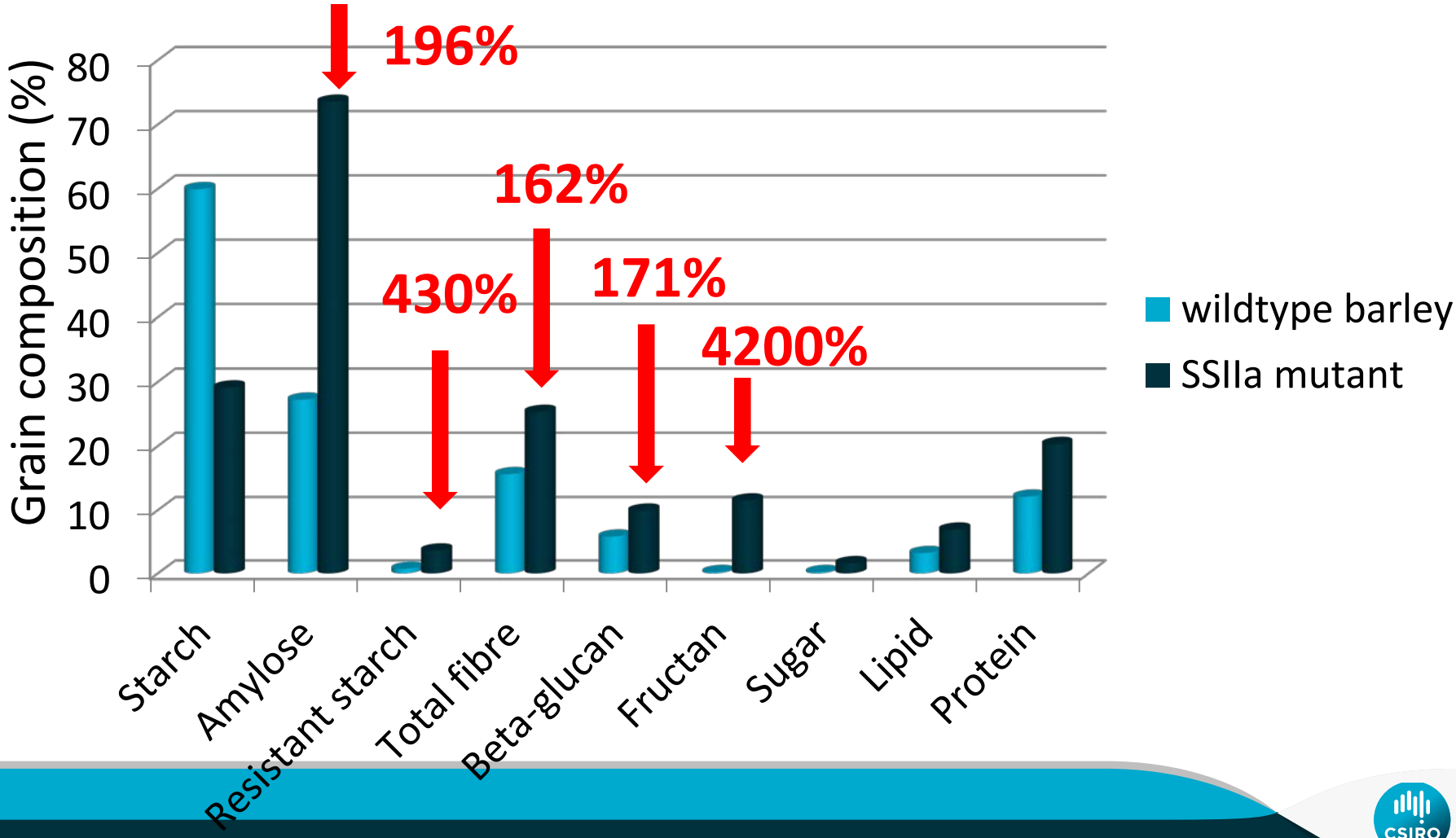


Resistant Starch

Solube Fibre

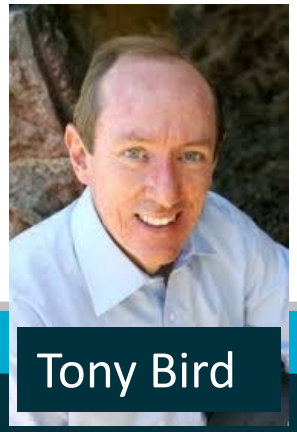
Insoluble Fibre

SSIIa mutants in barley increase resistant starch, β-glucan, fructan and total fibre



Clinical substantiation

- Reduced blood glucose concentration – lower GI (humans)
- Reduced plasma lipids (pig trial)
- Reduced pH in the large bowel (pig trial)
- Increased SCFA concentration in the large bowel (pig trial)

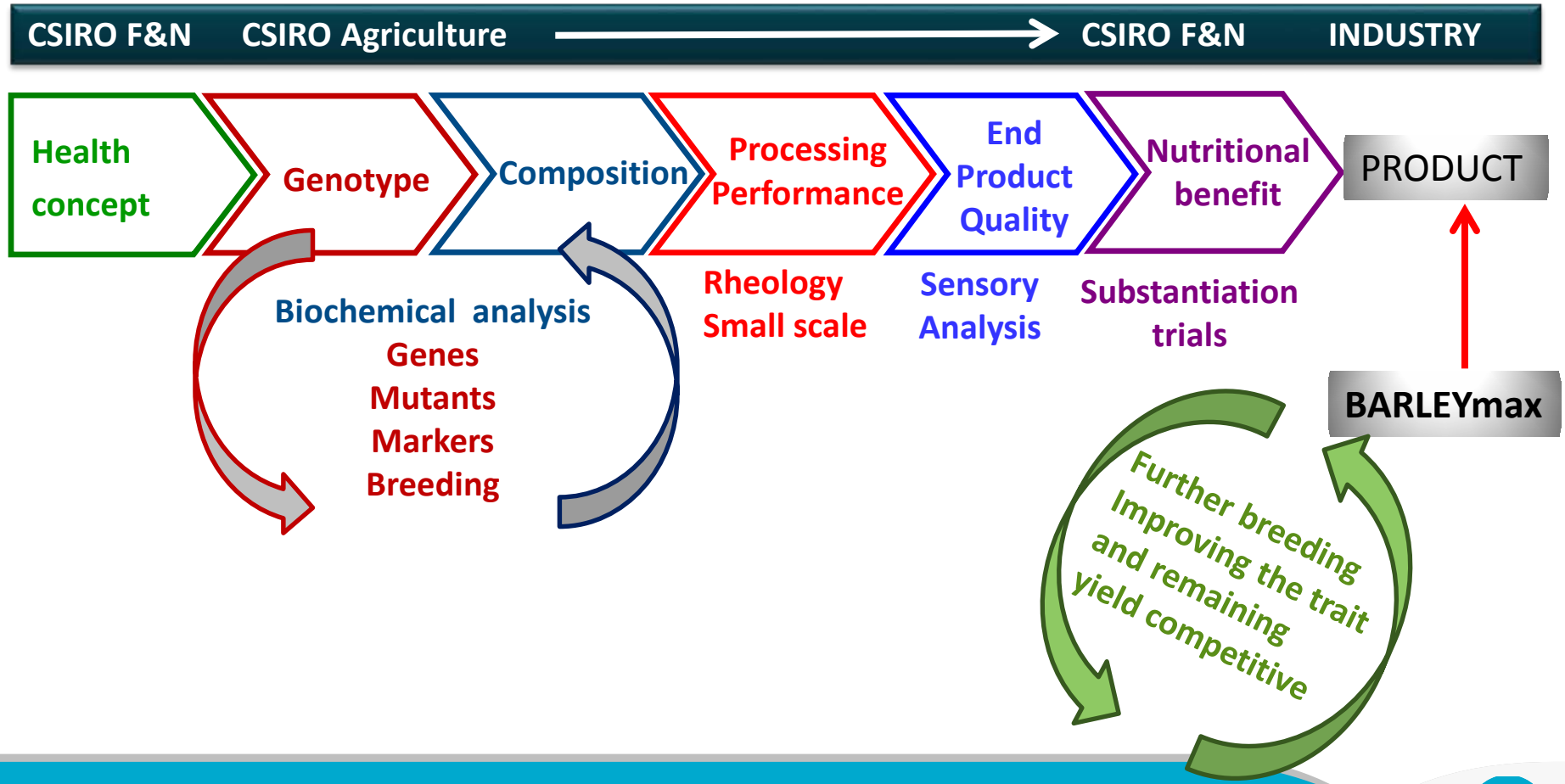


Tony Bird

David Topping

BARLEYmax – path to market and impact

The Healthy Grain



BARLEYmax 1, 2 and 3

Commercial rights with *The Healthy Grain*

http://www.thehealthygrain.com/

CEO: Robert Burbury

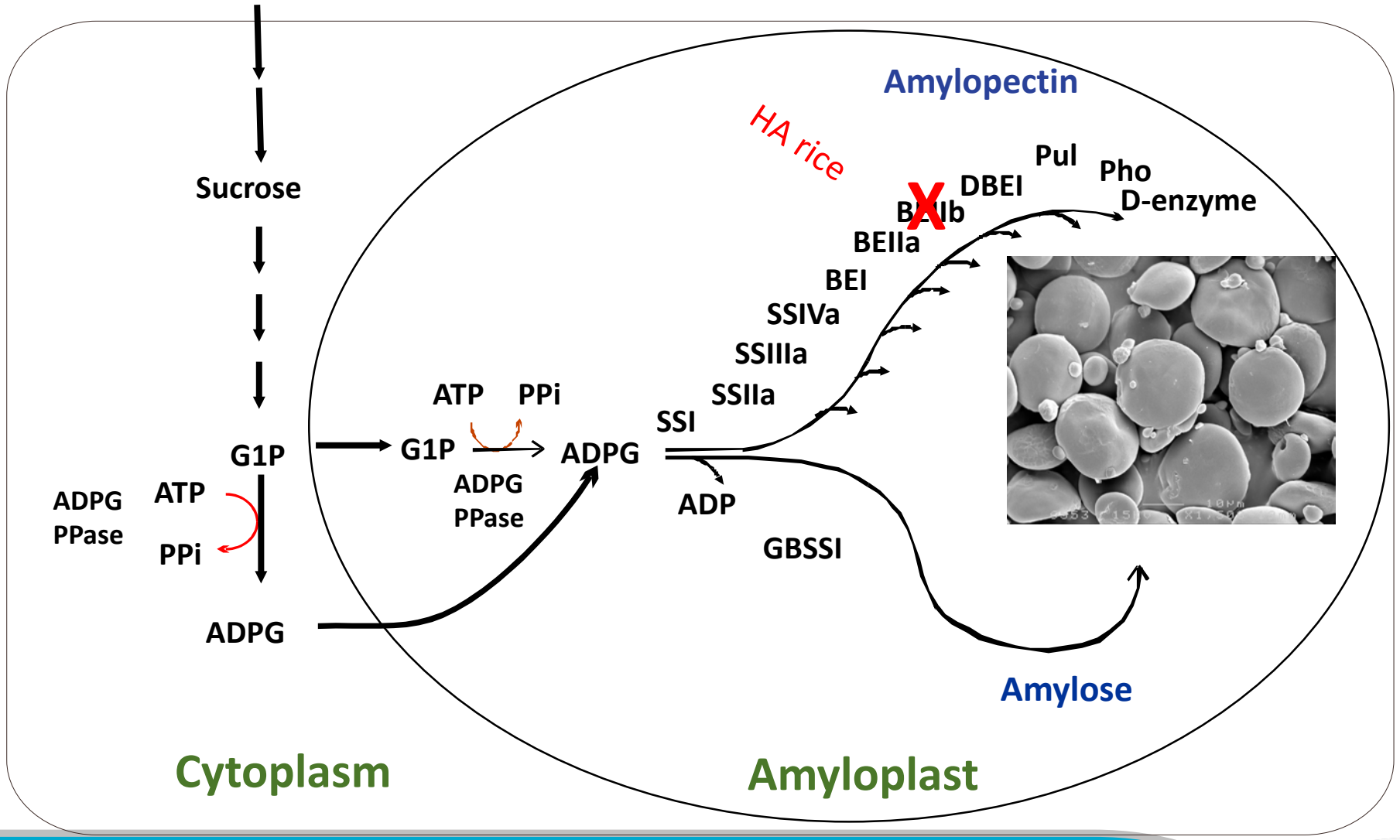
Technical Business Manager: Dr Paul Sims


Resistant starch rice

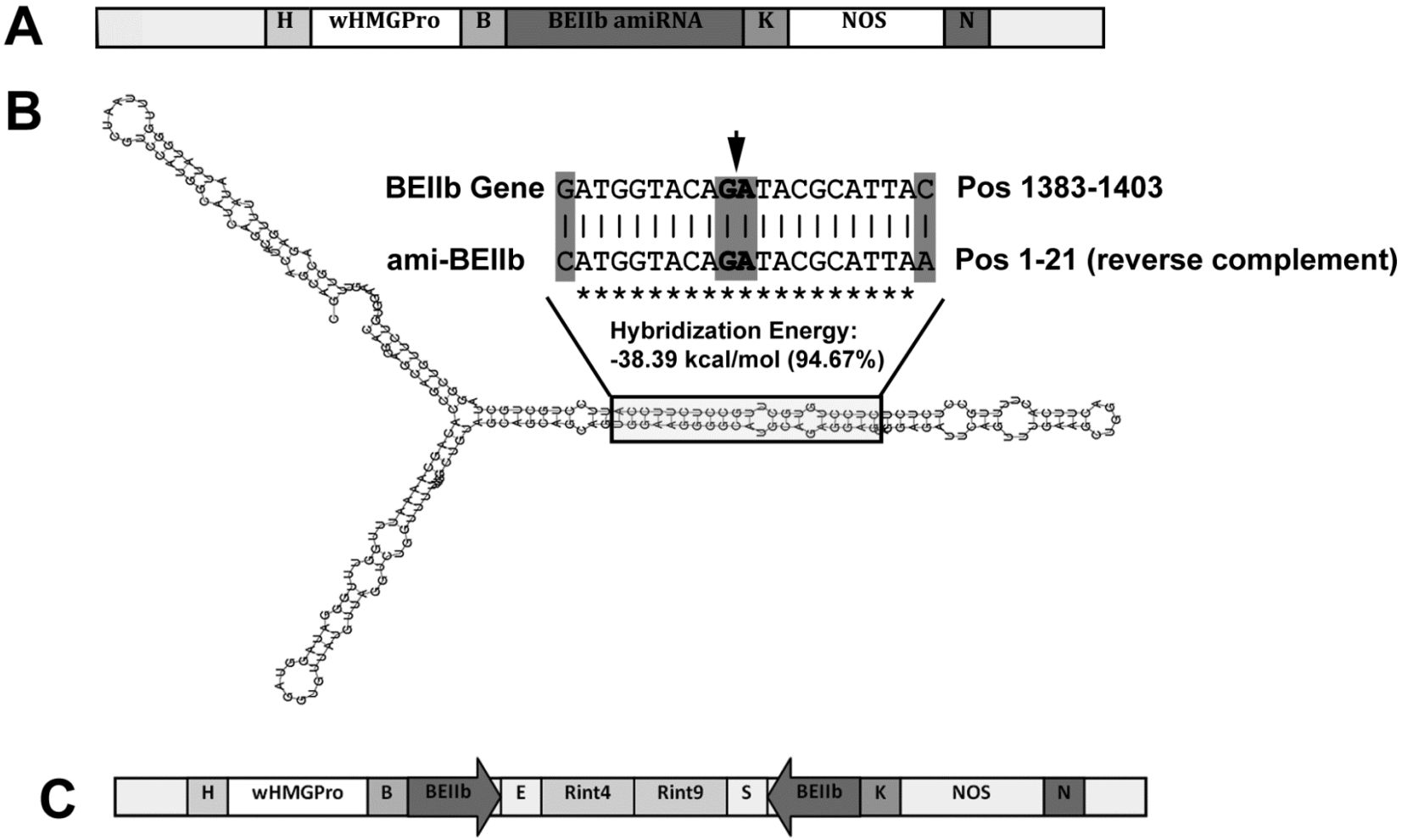
Increasing amylose content in rice grain through down-regulating the expression of SBEIIb by RNAi and amiRNA approaches

Vito Butardo

Increase amylose in rice



RNAi and amiRNA were used



Increasing amylose content in rice grain through combining different starch synthetic gene alleles

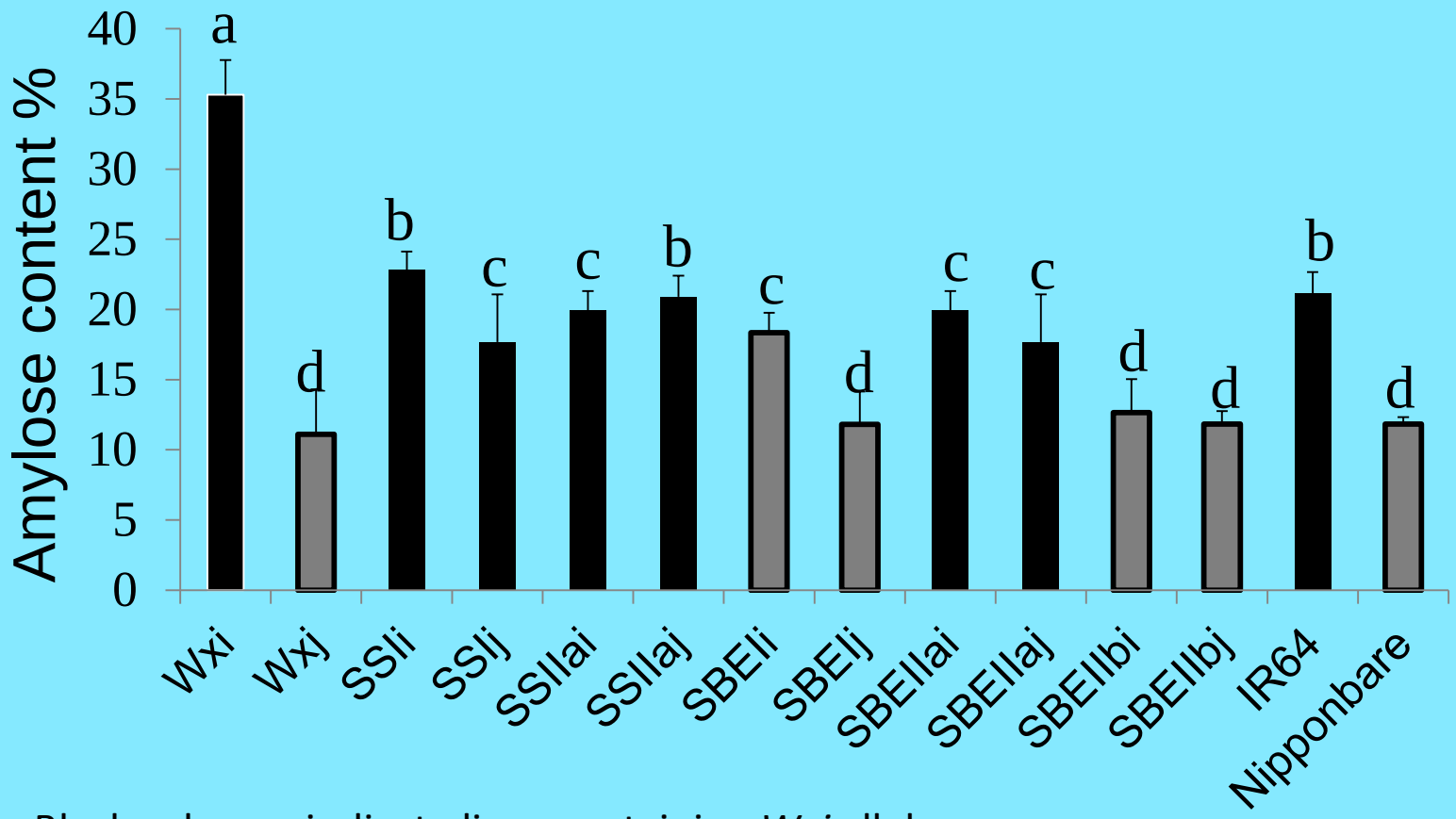
Jixun Luo

RILs following cross between IR64 (*indica*) and Nipponbare (*japonica*)
Genotypes of RILs of six starch biosynthetic enzyme groups

Geno-type	*Wxi*	*Wxj*	*SSIi*	*SSIj*	*SSIIai*	*SSIIaj*	*SBEIi*	*SBEIj*	*SBEIIai*	*SBEIIaj*	*SBEIIbi*	*SBEIIbj*
Wx	i	j	i		i		j		i		j	
SSI	i		i	j	j		i		j		i	
SSIIa	i		i		i	j	i		i		i	
SBEI	i		i		i		i	j	i		i	
SBEIIa	j		i		j		i		i	j	i	
SBEIIb	i		j		j		i		j		i	j

'i' and 'j' are abbreviations for *indica* (IR64) and *japonica* (Nipponbare) genotypes of each enzyme

Producing higher amylose rice grain through combining different starch synthetic gene alleles



Black columns indicate lines containing *Wxi* allele;
Grey columns indicate lines containing *Wxj* allele.

RILs following cross between A203 and 3-12

Genotypes of RILs of four starch biosynthetic enzyme groups

A203
***SSIIa*^{jap}*SSIIa*^{jap} / *SBEIIb*^{DR}*SBEIIb*^{DR}**
(opaque)

×

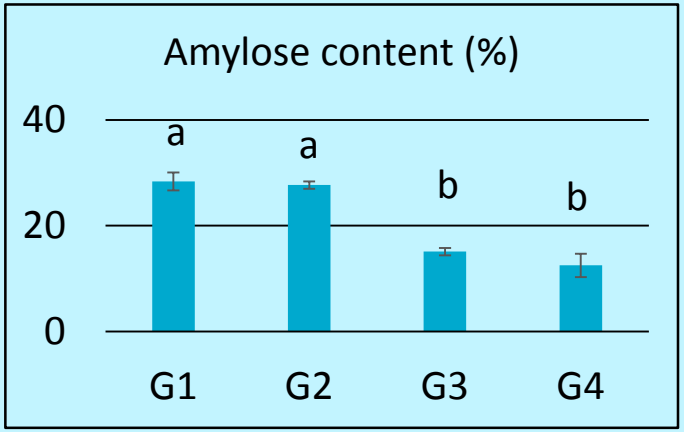
3-12
***SSIIa*^{ind}*SSIIa*^{jap} / *SBEIIb*^{WT}*SBEIIb*^{WT}**
(translucent)

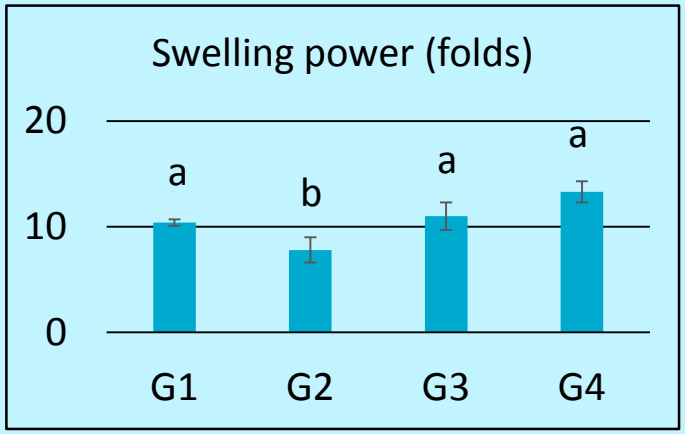
Parents

	SSIIa	*SBEIIb*	*Wx*	Seed colour
G1:	*ind*	*- ve*	*jap*	opaque
G2:	*jap*	*- ve*	*jap*	opaque
G3:	*ind*	*+ ve*	*jap*	translucent
G4:	*jap*	*+ ve*	*jap*	translucent

F3

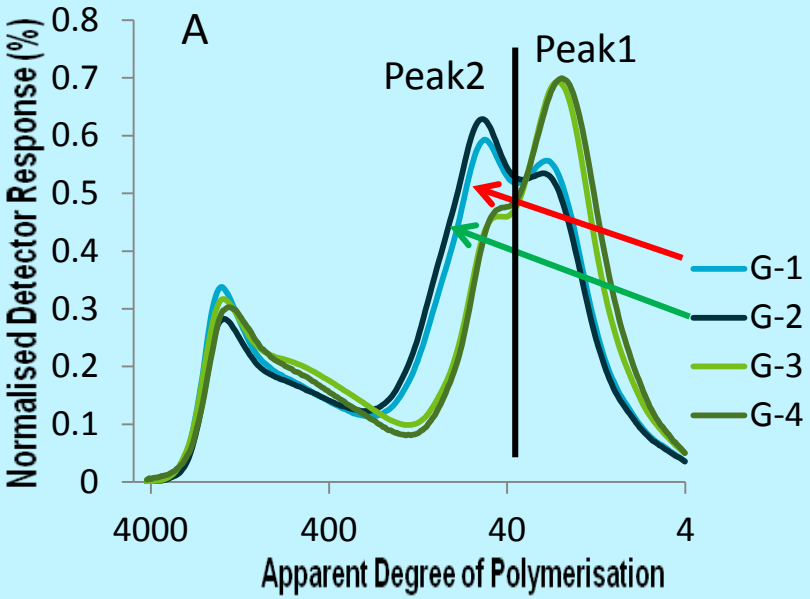
The impact of the *indica SSIIa* allele on the starch properties of high amylose starch from rice grains

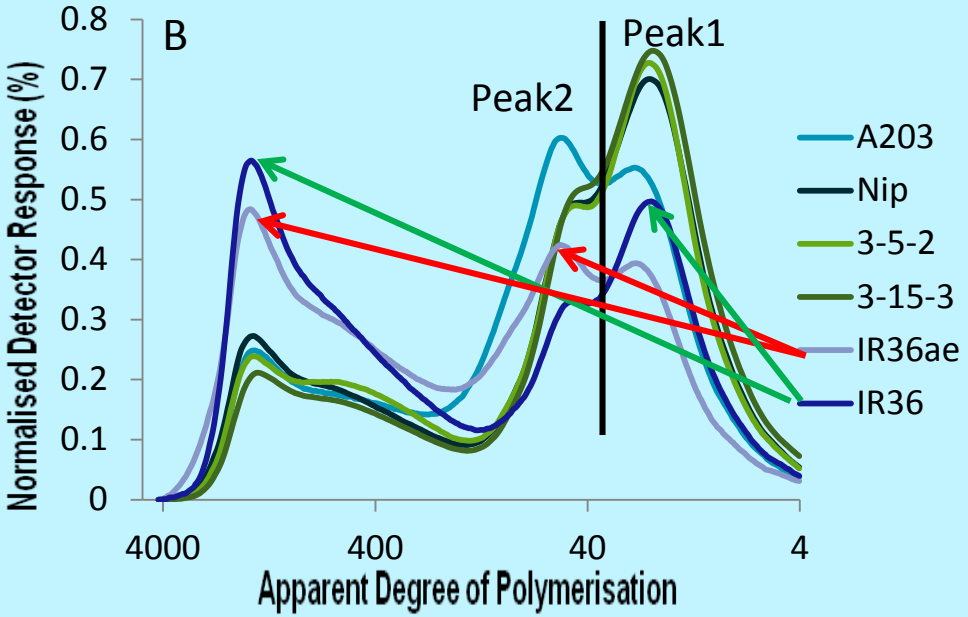




	SSIIa	*SBEIIb*
G1:	*ind*	*- ve*
G2:	*jap*	*- ve*
G3:	*ind*	*+ ve*
G4:	*jap*	*+ ve*

Two different mechanisms for increasing amylose content in rice grains



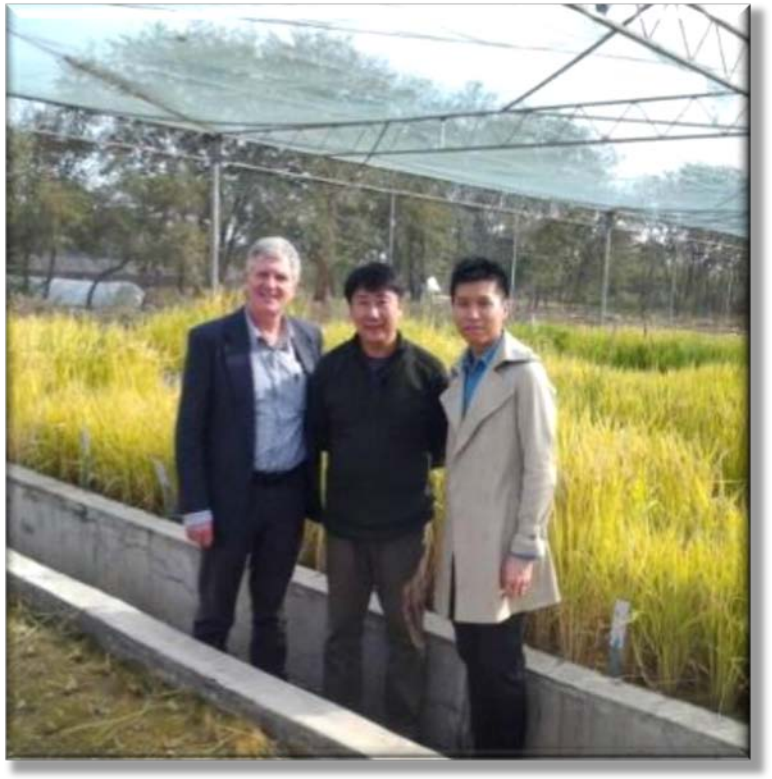


	SSIIa	*SBEIIb*	*Wx*
G1:	*ind*	*- ve*	*jap*
G2:	*jap*	*- ve*	*jap*
G3:	*ind*	*+ ve*	*jap*
G4:	*jap*	*+ ve*	*jap*

	SSIIa^{jap}	*SBEIIb*	*Wx^{jap}*
A203:	*jap*	*-ve*	*jap*
Nip:	*jap*	*+ve*	*jap*
3-15-3:	*jap*	*+ve*	*jap*
3-5-2:	*ind*	*+ve*	*jap*
IR36ae:	*ind*	*-ve*	*ind*
IR36:	*ind*	*+ve*	*ind*

Summary for manipulating starch in rice grain

- Both suppression of SBE IIb expression and gene recombination can increase amylose content.
- High amylose trait can be achieved through two different mechanisms.
- The *indica* SSIIa can improve starch properties for high amylose starch from rice grain through down-regulation of SBEIIb.



Micronutrient dense rice

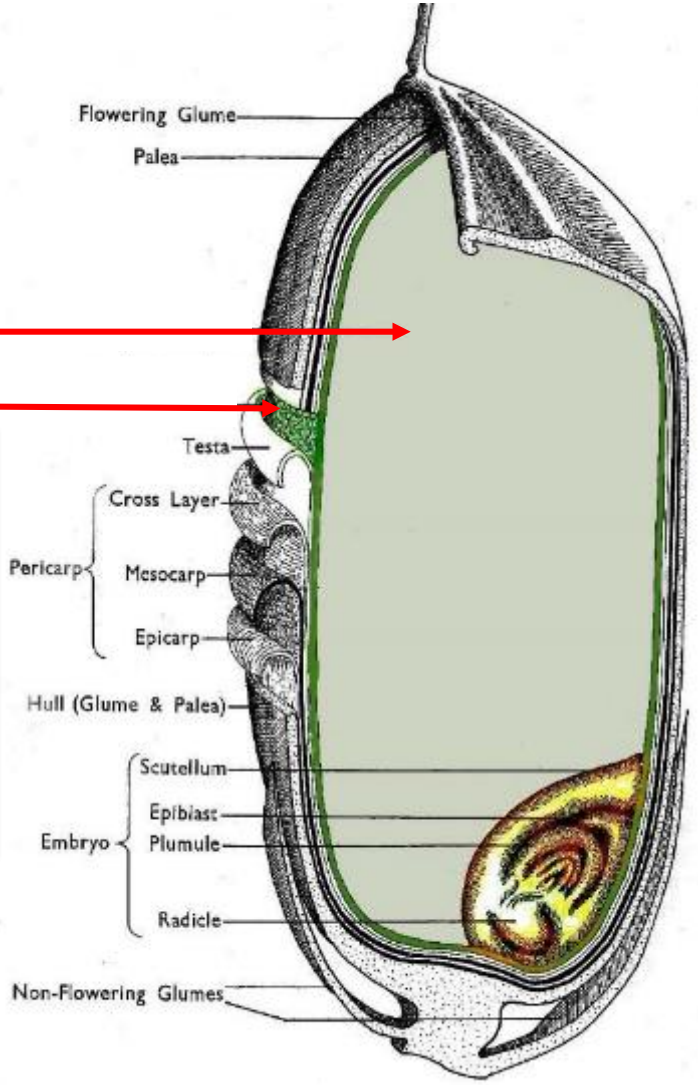
IB–CAS
中国科学院植物研究所
INSTITUTE OF BOTANY, THE CHINESE ACADEMY OF SCIENCES

CSIRO

New type of rice - thick aleurone mutants

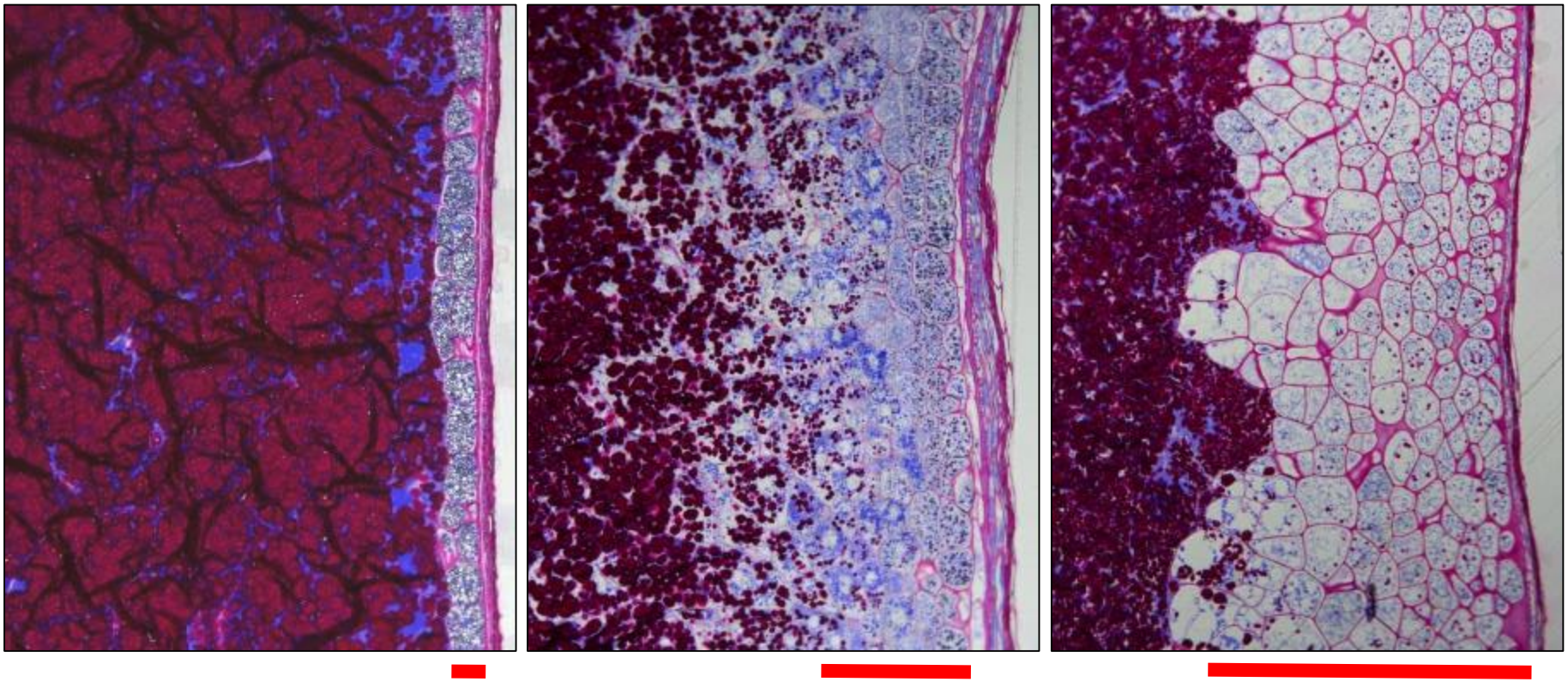
Rice dominant diets:
Zn and Fe deficient
5th and 6th most important contributors to disease in developing countries (WHO, 2002)

Dietary fibre
Proteins, enzymes
Phenolics, lignans
Vitamin E
B group vitamins
Minerals and phytic acid
Lipids, plant sterols



Aleurone important sink for micronutrients

ta-1 and *ta-2* showed increased aleurone layers



ZH11 *ta1* *ta2*

27 days after pollination

Nutritional analyses of *ta2* mutant wholemeal flour compared to normal wholemeal flour

50% increase in lipid

≥20% increase in Zn, Fe, Mg, K, P, S

80% increase antioxidant capacity

60% increase in Vitamin B6 & B9

30% increase in fibre

20% increase in Vitamin B3

Summary for micronutrient dense rice

- Micronutrient dense rice has been generated through increasing aleurone sink for micronutrients in rice grain.
- Thick aleurone rice grain also contains more dietary fibre and vitamins.
- Patent application is in place.

Long shelf life rice

Oil oxidation

Oxidation stages

Oleic acid
Linoleic acid
Linolenic acid

Autoxidation Stage 1

Autoxidation Stage 2

Good Oil **Oxidation process** **Bad Oil**

Hydroperoxides

Aldehydes
Carboxylic
Alcohol
hydrocarbons

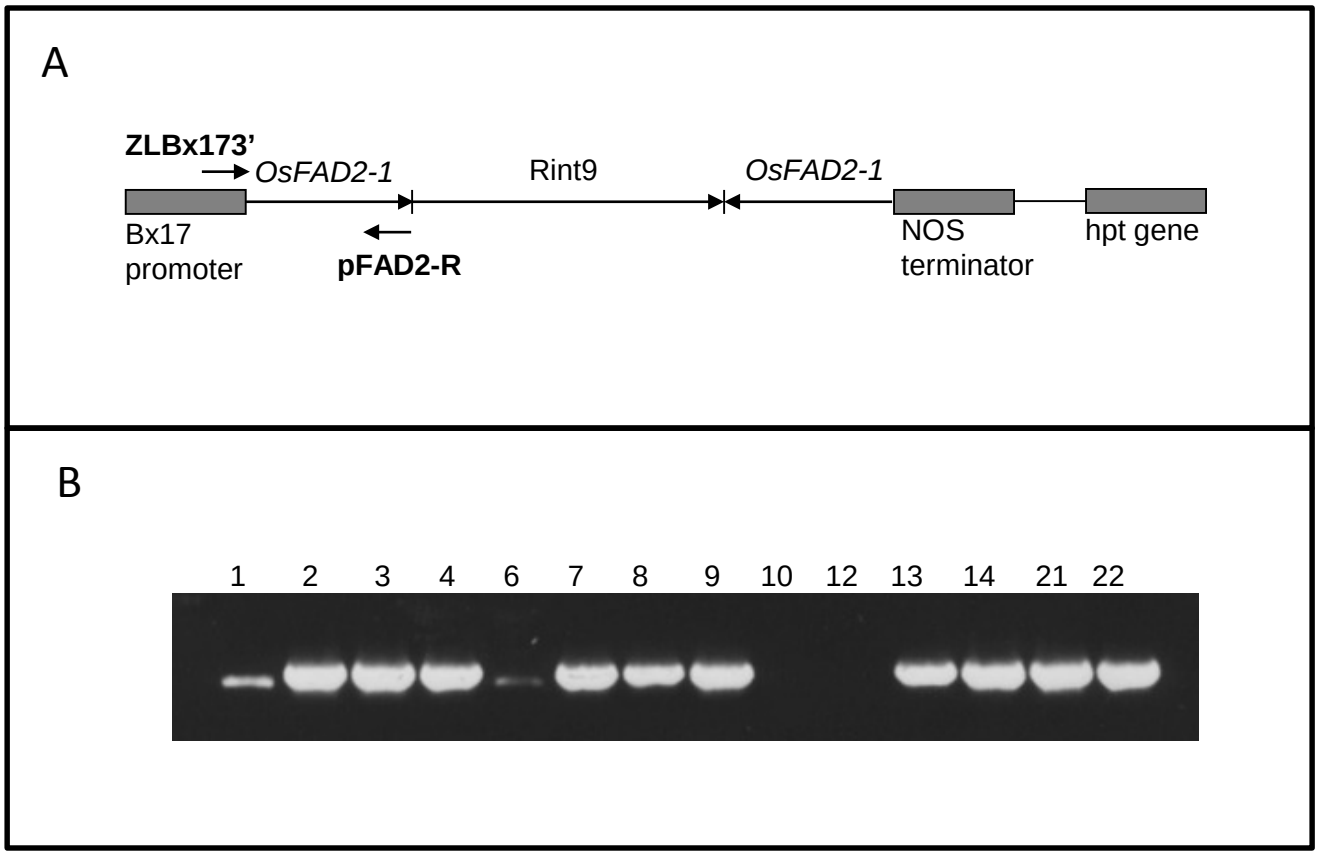
Products

eg. For Linoleic acid
9-Hydroperoxide
13-Hydroperoxide

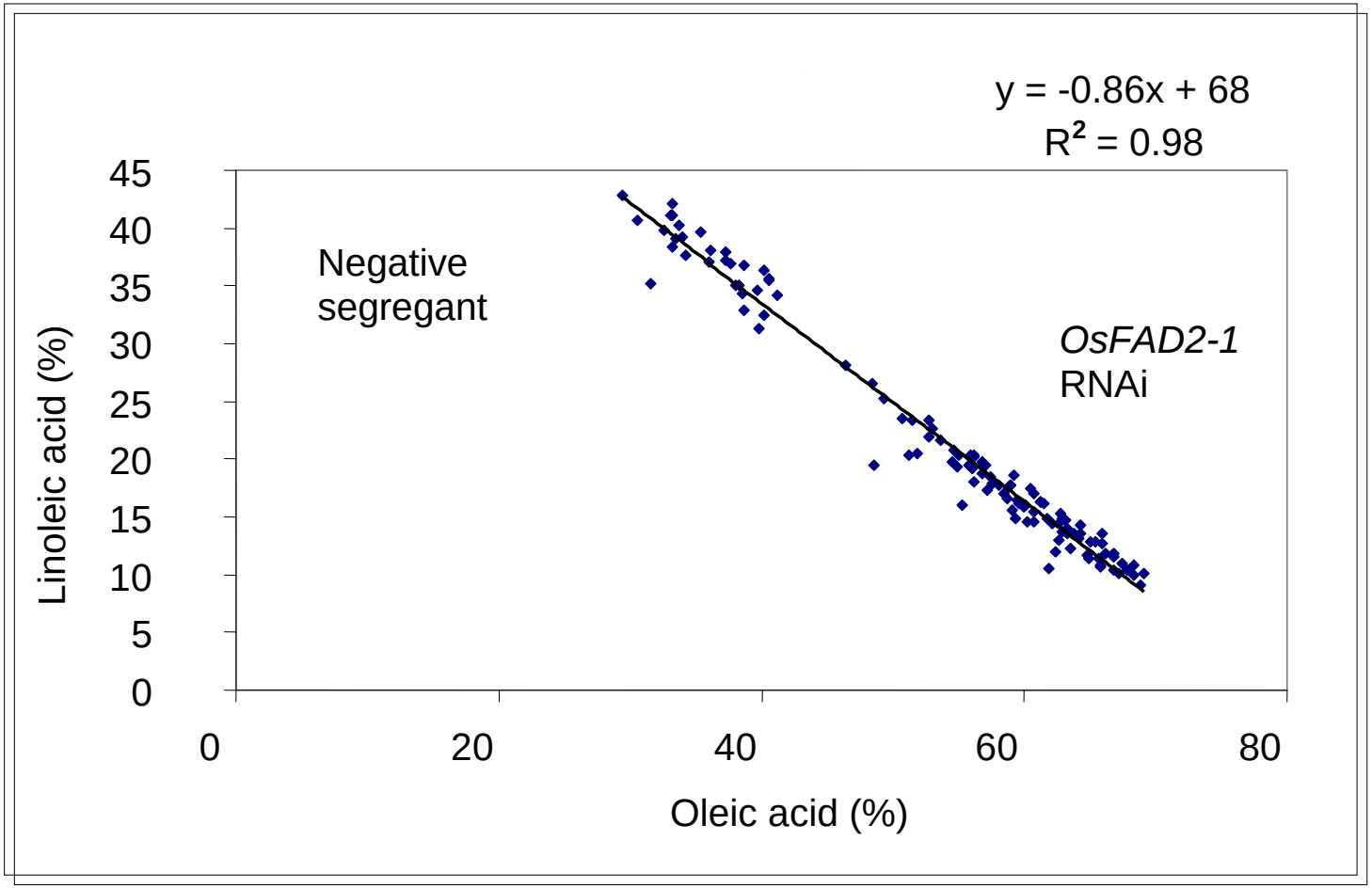
eg. For Linoleic acid
Pentanal
Hexanal
2,4-decadiental

eg. soybean and corn oil contain 23.5% Hexanal in volatile compounds

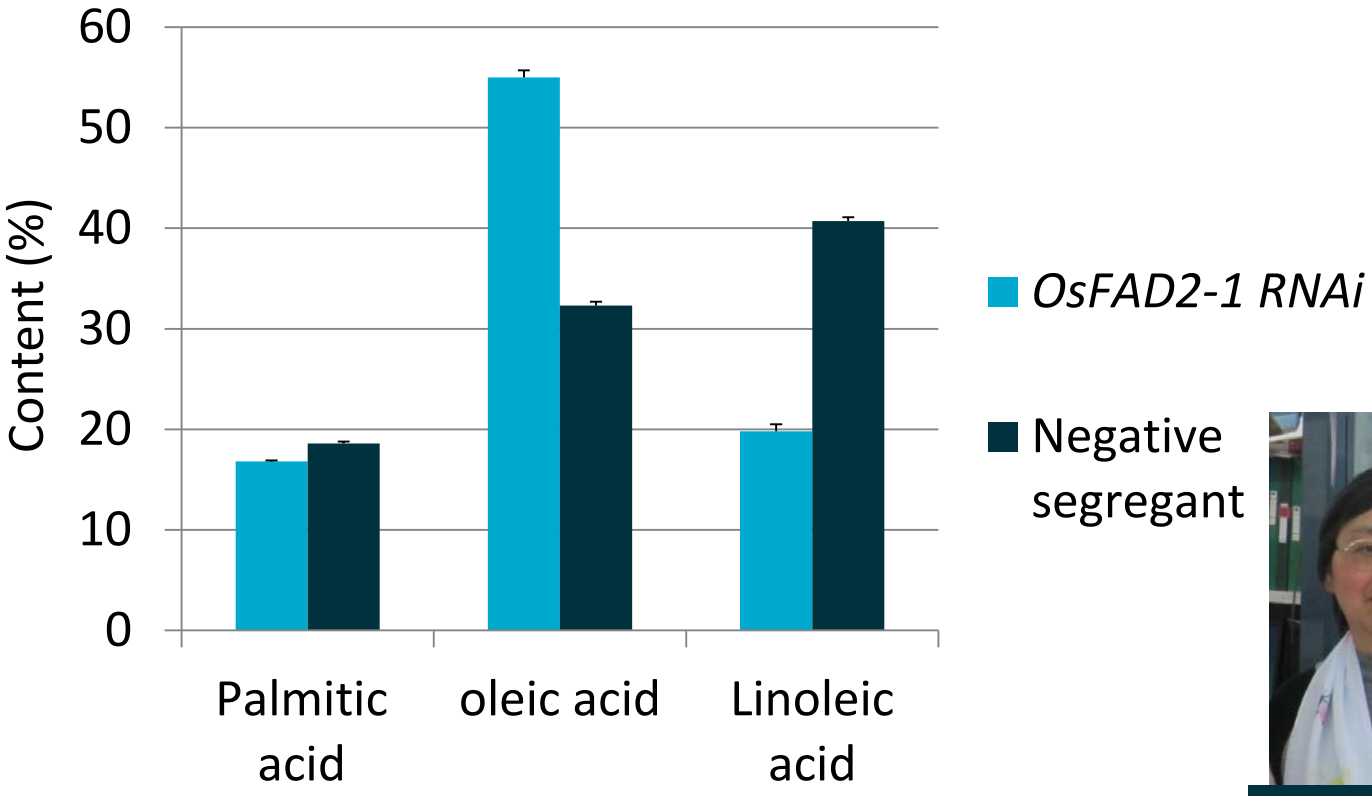
PCR screening of *OsFAD2-1* RNAi T_0 plants (Nipponbare)



Linear relationship between linoleic acid and oleic acid content for *OsFAD2-1* RNAi and negative segregant T_1 grains



Increased oleic acid and reduced linoleic acid contents of T_4 grains for *OsFAD2-1* RNAi lines



Hong Wang Ming Huang

Summary

- Producing BARLEYmax, HA wheat and Kebari grains containing novel traits that are commercially available.
- Developed rice grain with increased RS and low GI.
- Developed micronutrient dense rice.
- Producing long shelf life rice grain.
- Looking for the opportunities to work with other partners for improving rice grain quality.

Acknowledgement

Russell Heywood
Mark Cmiel
Oscar Larroque
Behjat Kosar-Hashemi
Emmett Leyne
Chris Konik-Ross

Sadiq Rahman
Qing Liu
Peter Chandler
Steve Jobling
Matthew Morell

ACVL Ltd (BARLEYmax JV, BARLEYmax Enterprises, The Healthy Grain)
Austgrains
Popina Food Services (Goodness Superfoods, Freedom Foods Group)

Limagrain (ARISTA)

Rob Defeyter
Lindsay Adler
Paul Sims

CSIRO Plant Industry
CAISO Food Future Flagship
CSIRO Agriculture Flagship

Thank you

CSIRO Agriculture Flagship
Presenter Name: Zhongyi Li
Presenter Title: Manipulating starch in cereal grains

Cereal quality traits Group

t +61 2 6246 4951
e zhongyi.li@csiro.au
w www.csiro.au