Low Glycaemic Index Rice: Its Potential Application in Diabetes Prevention and Management

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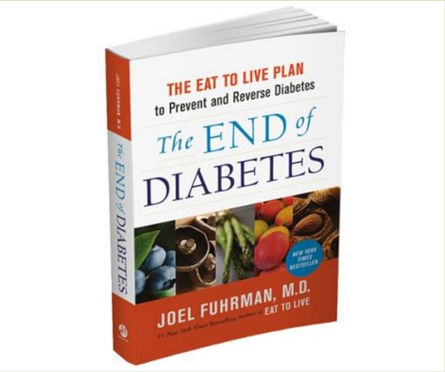
What can we offer to sugary world?

Is Diabetes Becoming the Biggest Epidemic of the Twenty-first Century ?

What are the drivers of diabetes ?



Introduction

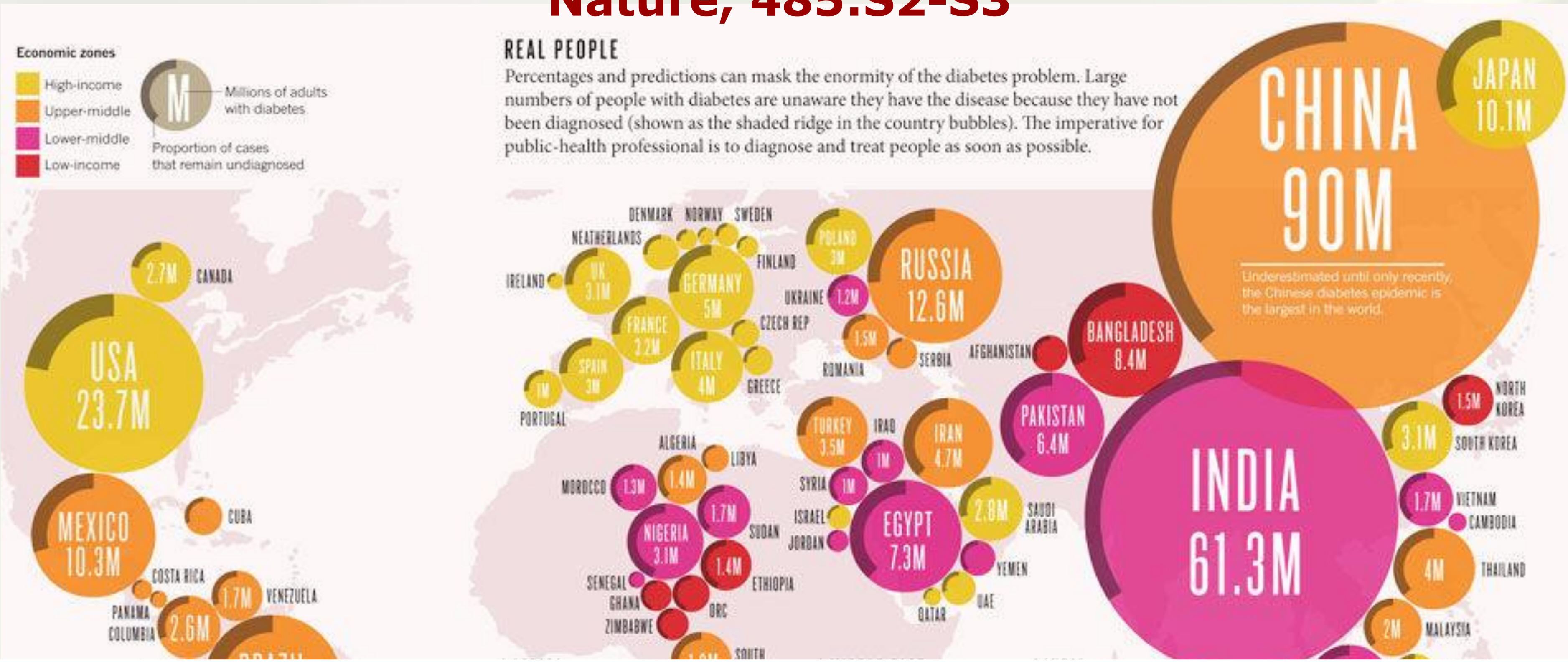
Food as medicine

What are the intervention matrix to counter raise in diabetes in Asia ?

Healthy Mantra
Diversified nutritious food and regular exercises

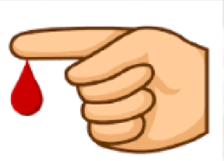
Diabetes in numbers 2012:

Nature, 485:S2-S3



Country	2015 Diabetes Incidences	2040 expected Diabetes incidences
China	**109.6 millions** out of 1.37 billion population	150.7 millions
India	**69.2 millions** out of 1.32 billion poulation	123.5 millions
USA	**29.3 millions** out of 323 million population	35.1 millions

Frequency of Diabetics: Why is so endemic to Asia?

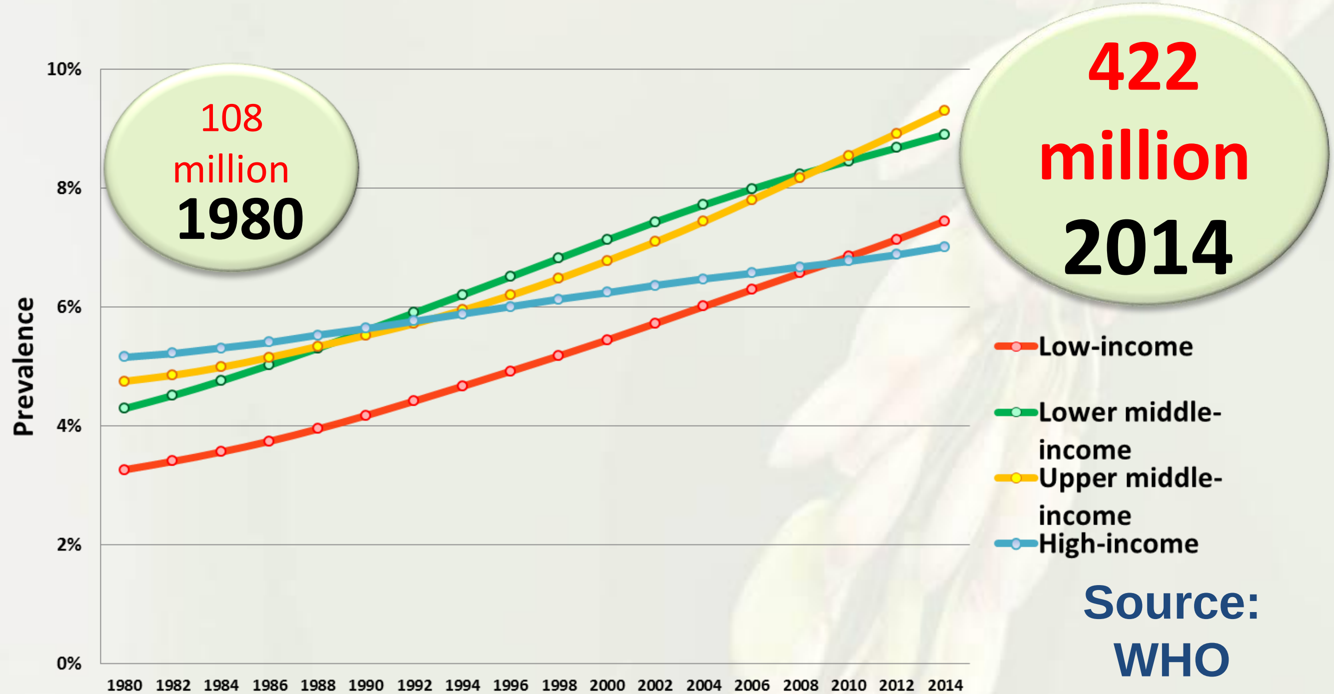


Prediction by 2035 : **592 million**

80% of people with diabetes live in **low- and middle-income countries**

WHO projects that diabetes will be the **7th leading cause of death in 2030**

Source: International Diabetes Federation



Source: WHO

Starch being staple food feeding the world- major energy source

Rice

68-94 GI

42% of all calories consumed by the entire human population

Wheat

70-90 GI

60 percent of the world's food energy intake

Maize

60-80 GI

Staple food for one third of world population

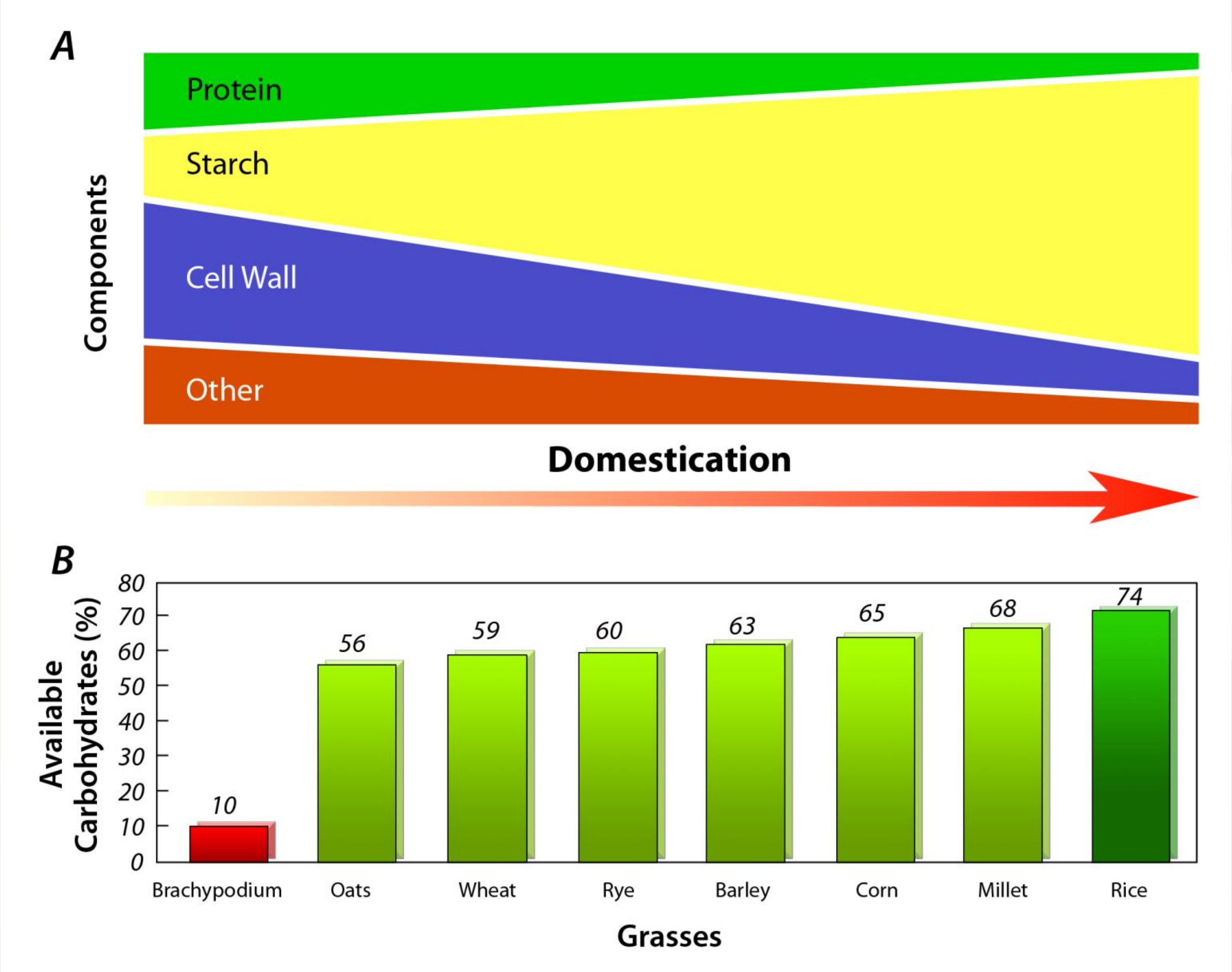
Potato

90 GI

Fourth largest staple food

STARCH

Diet diversification during domestication

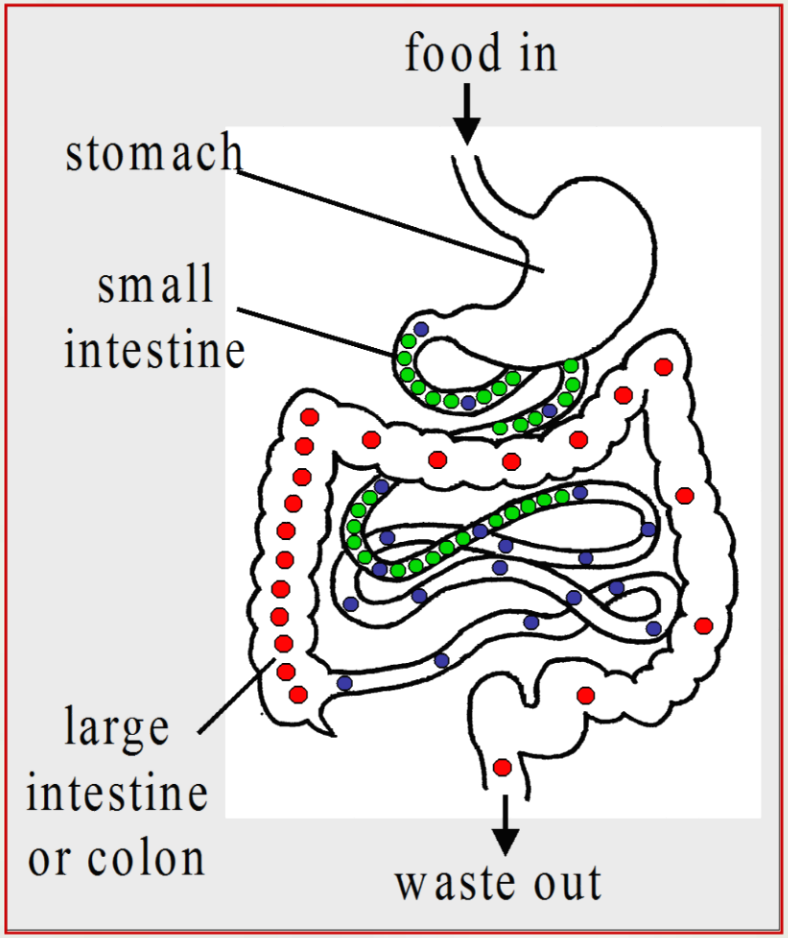


Butardo and Sreenivasulu, International Review of Cell and Molecular Biology (2016)

Rice seed composition:

Components	Composition	Health Benefits
Seed Storage Protein	4-11%	Source of protein and amino acid
Storage Starch	85-90%	Source of calorie Source of resistant starch Influences glycemic response
Non-Starch Polysaccharides	Trace	Source of dietary fiber
Storage Lipids	0.3-0.5%	Source of lipids and fatty acids

Starch digestibility



M. Morell

Site of digestion along the intestinal tract is a major determinant of glycemic impact:

Rapidly digested

[High Glycemic]

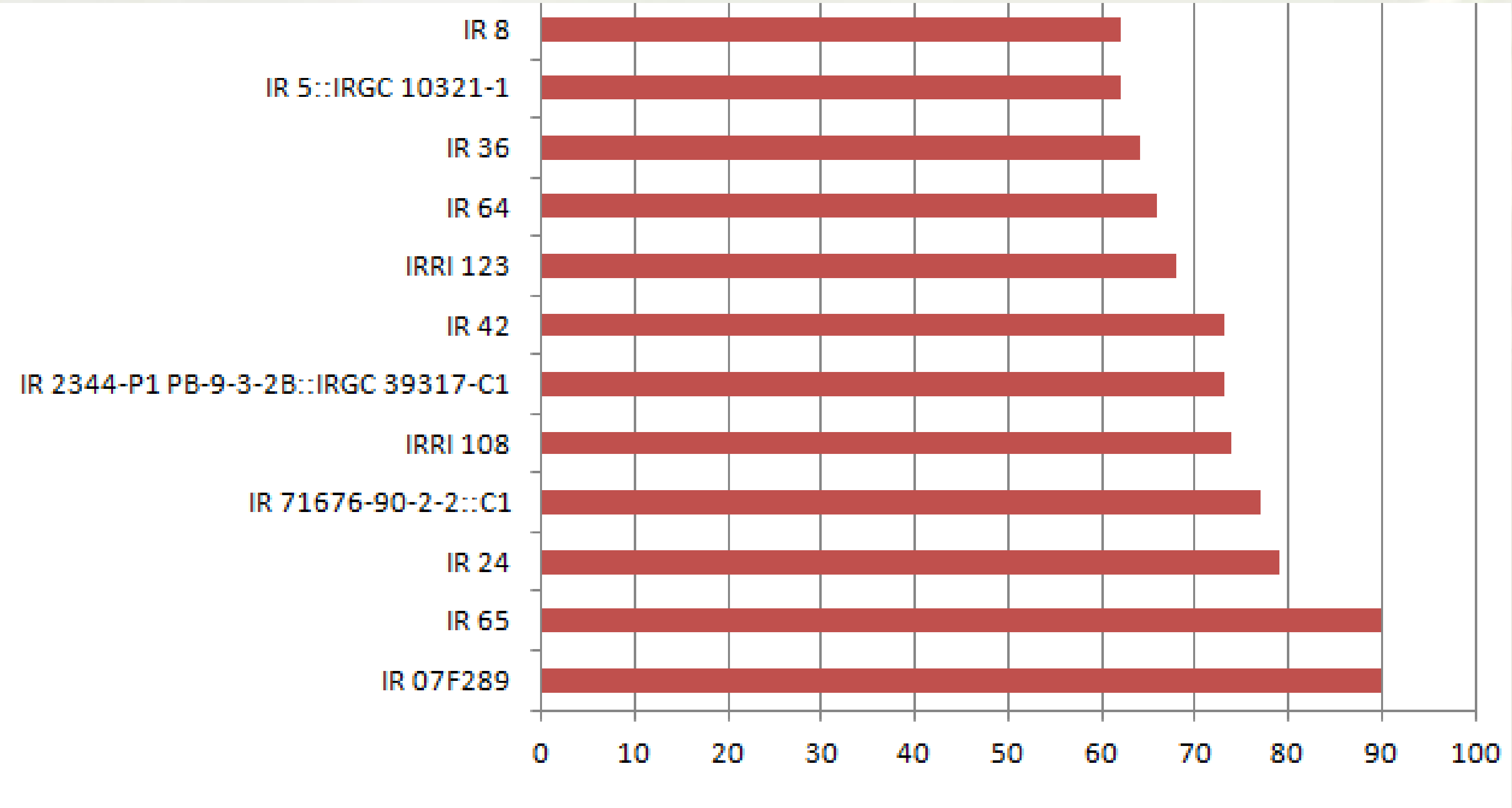
Slowly digested

[Low Glycemic]

Resistant

[Not Glycemic]

Glycemic index rice (GI) responses in popular varieties



GI of many of the popular varieties of Asia between 90 - 62.

Diet based intervention to tackle diabetes

Bloomberg | New Strains of Rice May Help Fight China's Diabetes Scourge

New Strains of Rice May Help Fight China's Diabetes Scourge

Photographer: Qilai Shen/Bloomberg

Glycemic Impact

In the Philippines, the International Rice Research Institute, or IRRI, has identified the genetic basis of a component of starch that may be used to counter the cereal's glycemic impact -- or propensity to spike blood-sugar, said Nese Sreenivasulu, head of the institute's grain quality and nutrition center.

IRRI found in 2012 that the glycemic index, or GI, of rice ranges from 48 to 92 across more than 200 varieties from around the world. The sugars of low-GI food are absorbed more slowly, resulting in a gradual and sustained release of glucose in the blood, reducing the need for a surge of insulin that can eventually lead to insulin-resistance and diabetes.

The global rise in diabetes incidences calls for urgent attention to diet-based nutritional interventions.

Development of staple grains with healthy Carbohydrates with low GI attributes

In vitro GI phenotyping techniques to screen large germplasm

Starch structure analysis, starch hydrolysis index, k-value estimation

Phenotyping tools of glycemic index prediction in rice

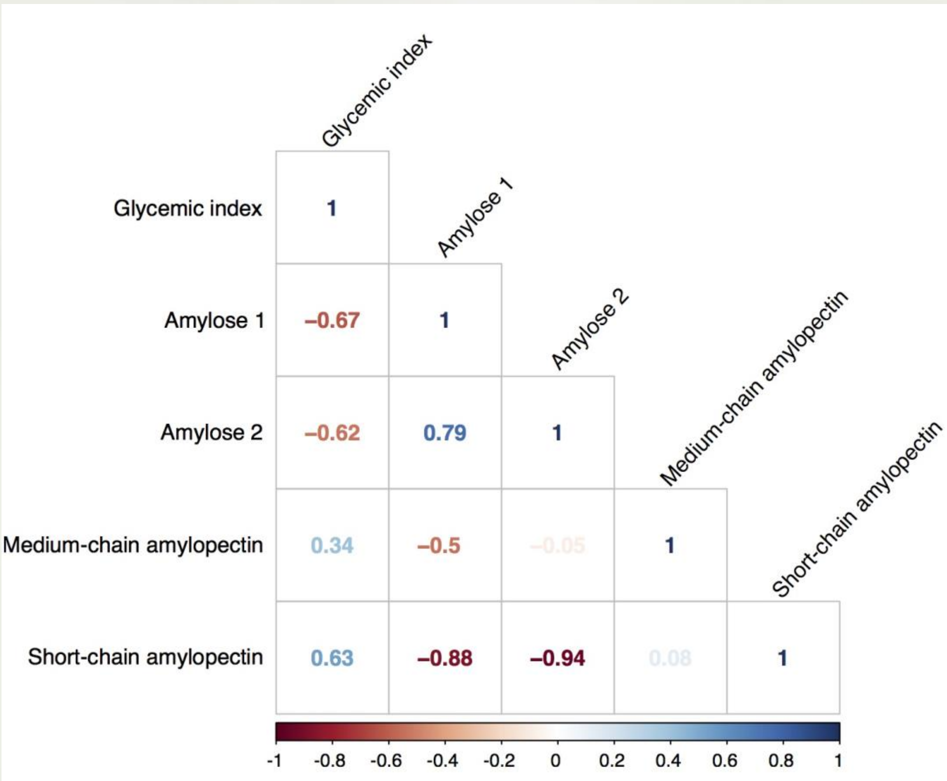
Comparing human starch digestion with starch mobilization process during seed germination

Correlating several in vitro GI methods with in vivo GI results

Rice diversity for glyemic index response

27 diverse samples

$r^2 = 0.67$



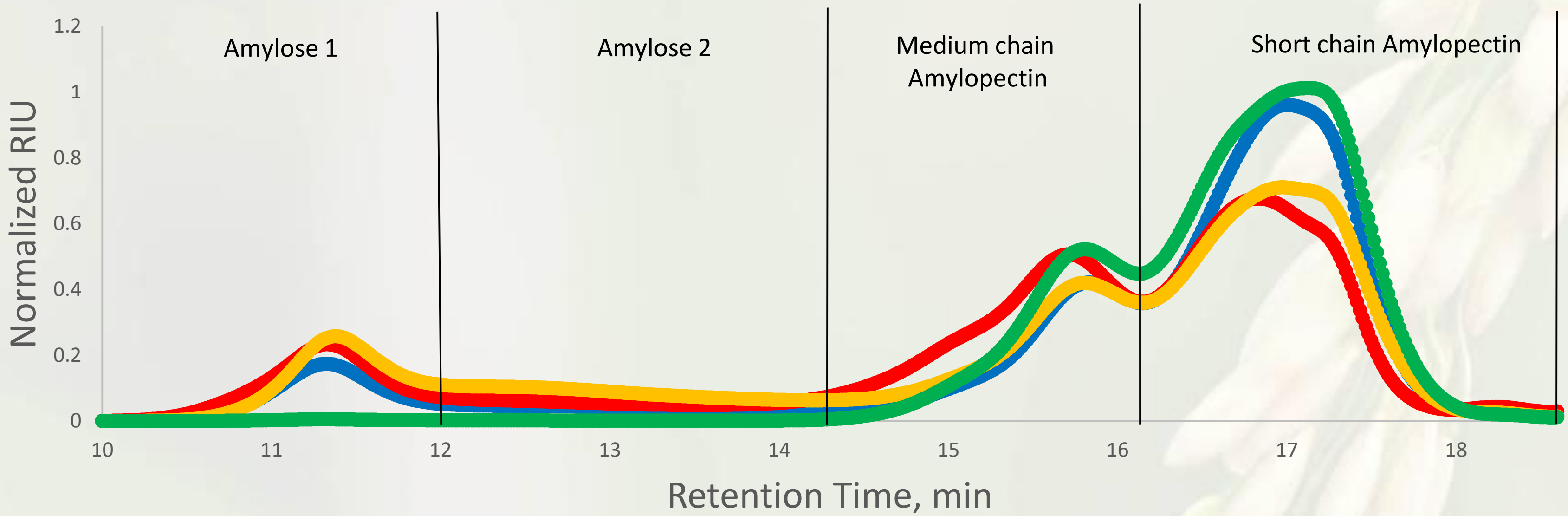
Guzman et al., 2017 Scientific Reports

Elevated amylose 1levels contributed to lowered GI.

Increased amylopectin contributed to elevate GI

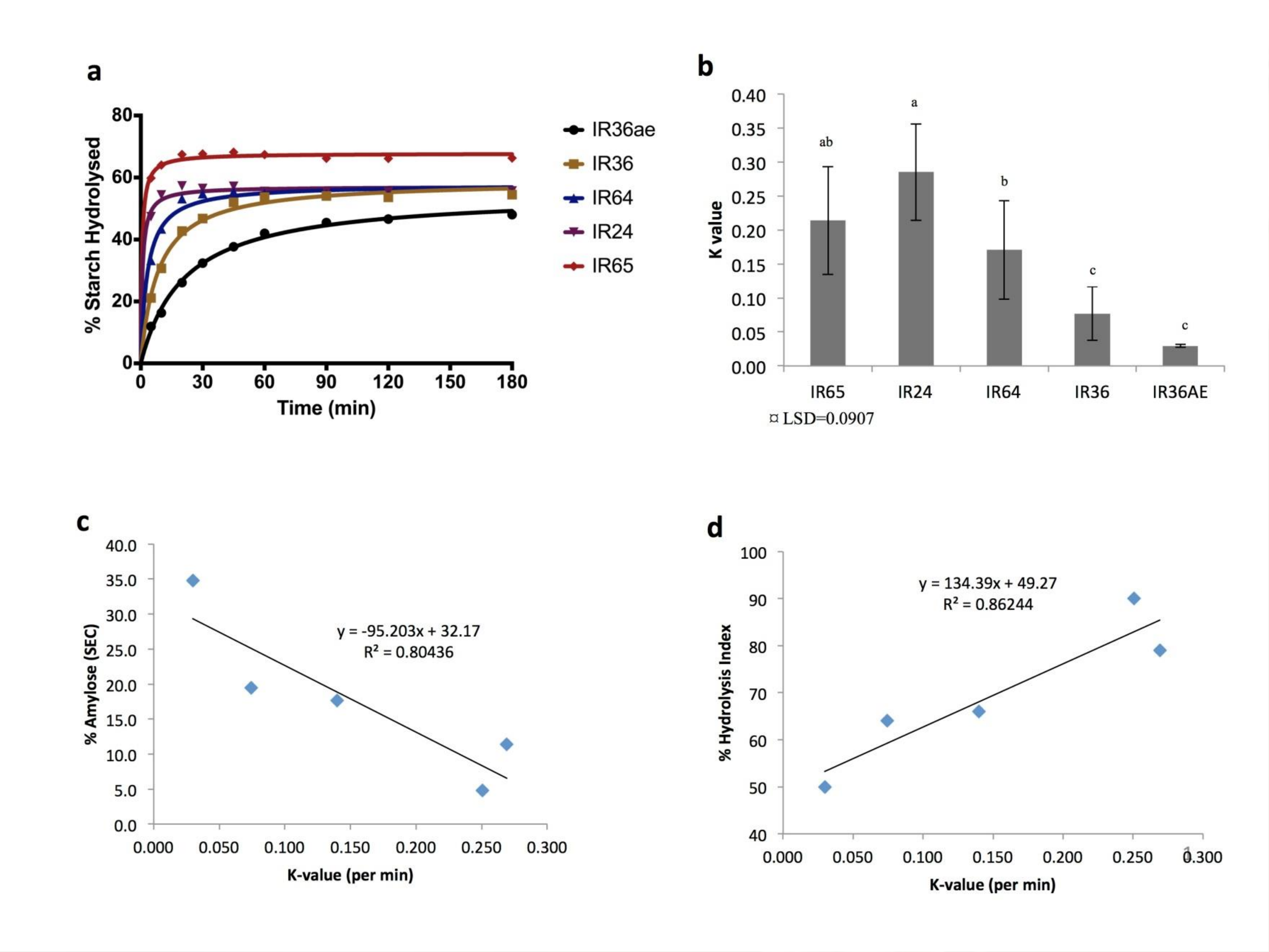
Therefore we need to consider starch structure information to alter the digestibility of starch and thus GI.

Glyemic index – Starch structure

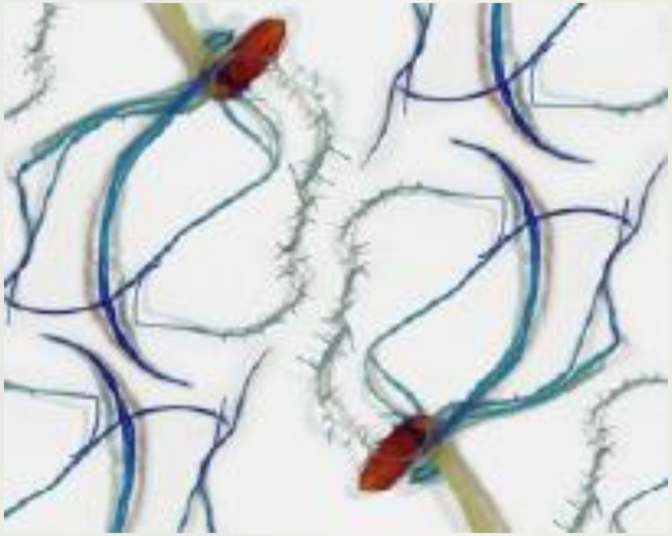


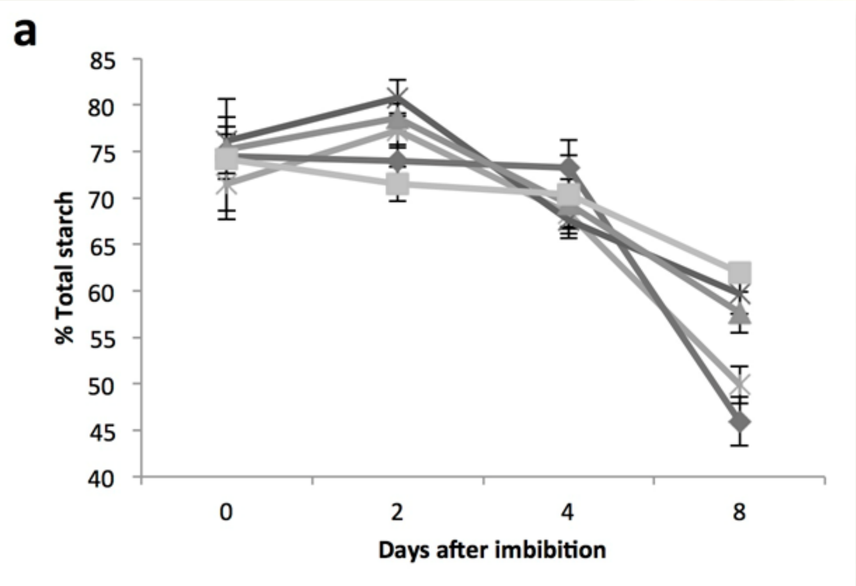
Low GI line 1 **Low GI line 2** **Intermediate GI line 5** **High GI line 10**

Glyemic index – phenotyping tools



Glyemic index – phenotyping tools





Summary of differentiating parameters for three GI categories

Parameters	Low GI	Intermediate GI	High GI
In vitro glycemic index measurement			
< 55 Predictive glycemic index value	●	○	○
<0.025 digestion rate constant *(k value)*	●	○	○
Mature grain (Day 0)			
≥ 2% Resistant starch	●	○	○
≥ 15% Amylose 1 (DP > 1000)	●	○	○
≥ 10% Amylose 2 (DP 121-1000)	●	○	○
≥ 50% Short-chain amylopectin (DP 6-36)	○	●	●

Positive results are marked with (●) and negative results with (○)

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Investigating glycemic potential of rice by unraveling compositional variations in mature grain and starch mobilization patterns during seed germination

Maria Krishna de Guzman[1], Sabiha Parween[1], Vito M. Butardo[1,5], Crisline Mae Alhambra[1], Roslen Anacleto[1], Christiane Seiler[2], Anthony R. Bird[3], Chung-Ping Chow[4,6] & Nese Sreenivasulu[1]

Rice lines with slower starch digestibility provide opportunities in mitigating the global rise in type II diabetes and related non-communicable diseases. However, screening for low glycemic index (GI) in rice breeding programs is not possible due to time and cost constraints. This study evaluated the feasibility of using *in vitro* cooked grain amylolysis, starch mobilization patterns during seed germination, and variation in starch structure and composition in the mature seed to differentiate patterns of starch digestibility. Mobilization patterns of total starch, resistant starch, amylose and amylopectin chains, and free sugars during seed germination revealed that the process is analogous to digestion in the human gastrointestinal tract. The combination of these biochemical markers can be used as an alternative measure to predict GI. Additionally, transcriptome analysis of stored mRNA transcripts in high and low GI lines detected differences in starch metabolism and confirmed the importance of seed storage pathways in influencing digestibility. Pathway analyses supported by metabolomics data revealed that resistant starch, cell wall non-starch polysaccharides and flavonoids potentially contribute to slower digestibility. These new insights can guide precision breeding programs to produce low GI rice with acceptable cooking quality to help mitigate the burden of diet-associated lifestyle diseases.

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Best combination of invitro GI phenotyping techniques to screen large germpsams

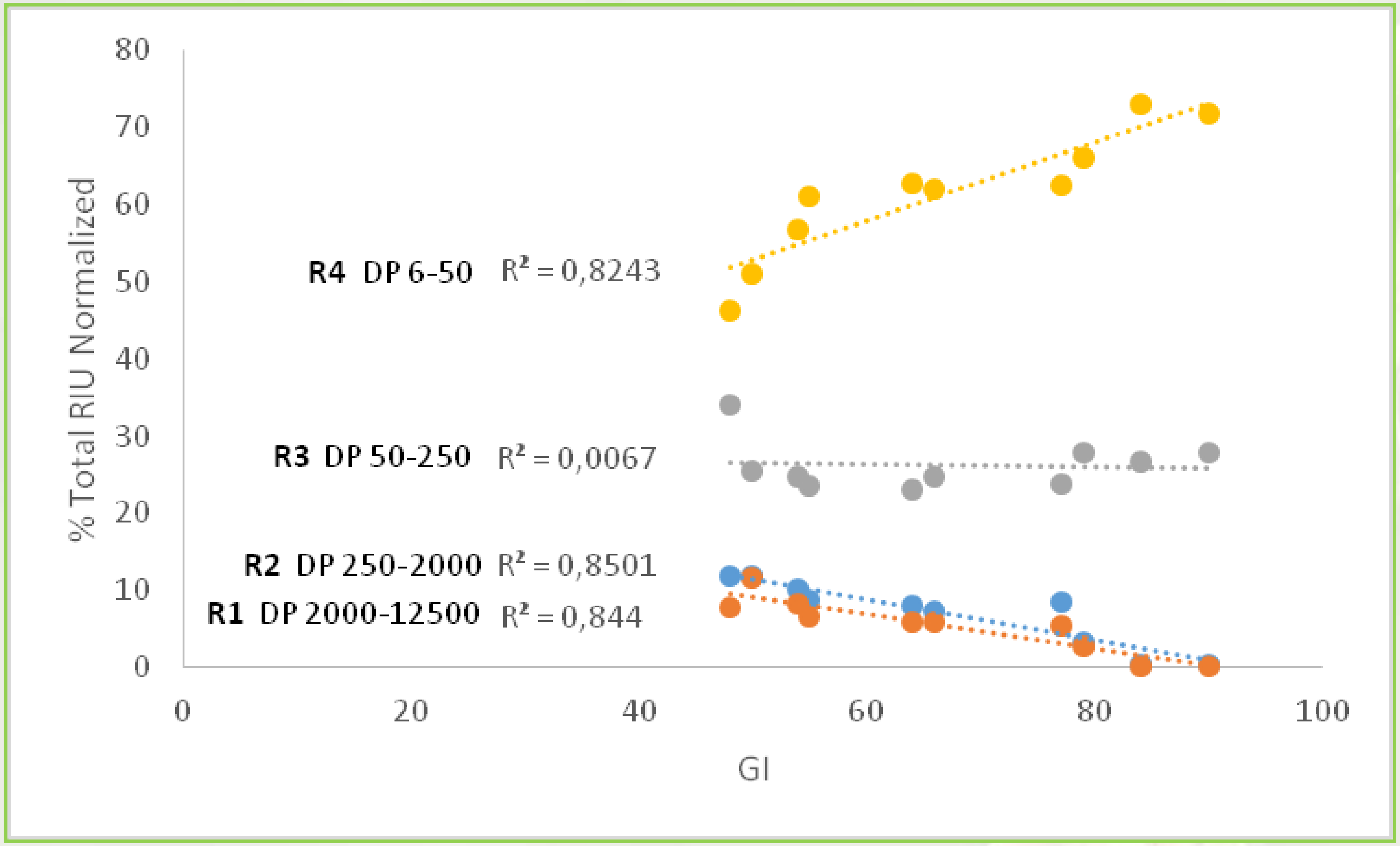
Use of high throughput genomics resources

Genetics of glycemic index In rice

Genes based markers to undertake marker assisted selection

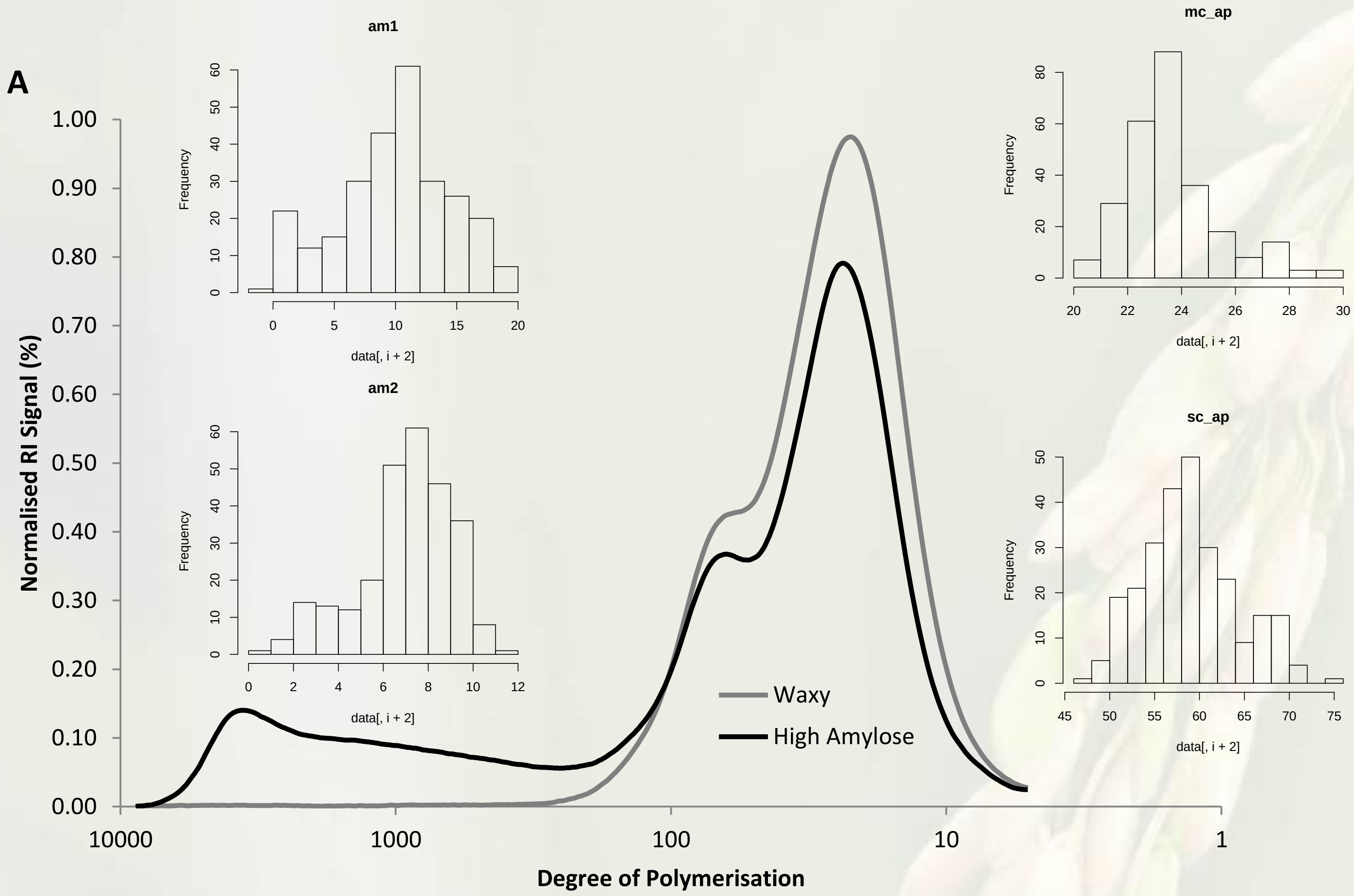
Glycemic index mechanisms – unravel pathways

Glyemic index – Starch structure



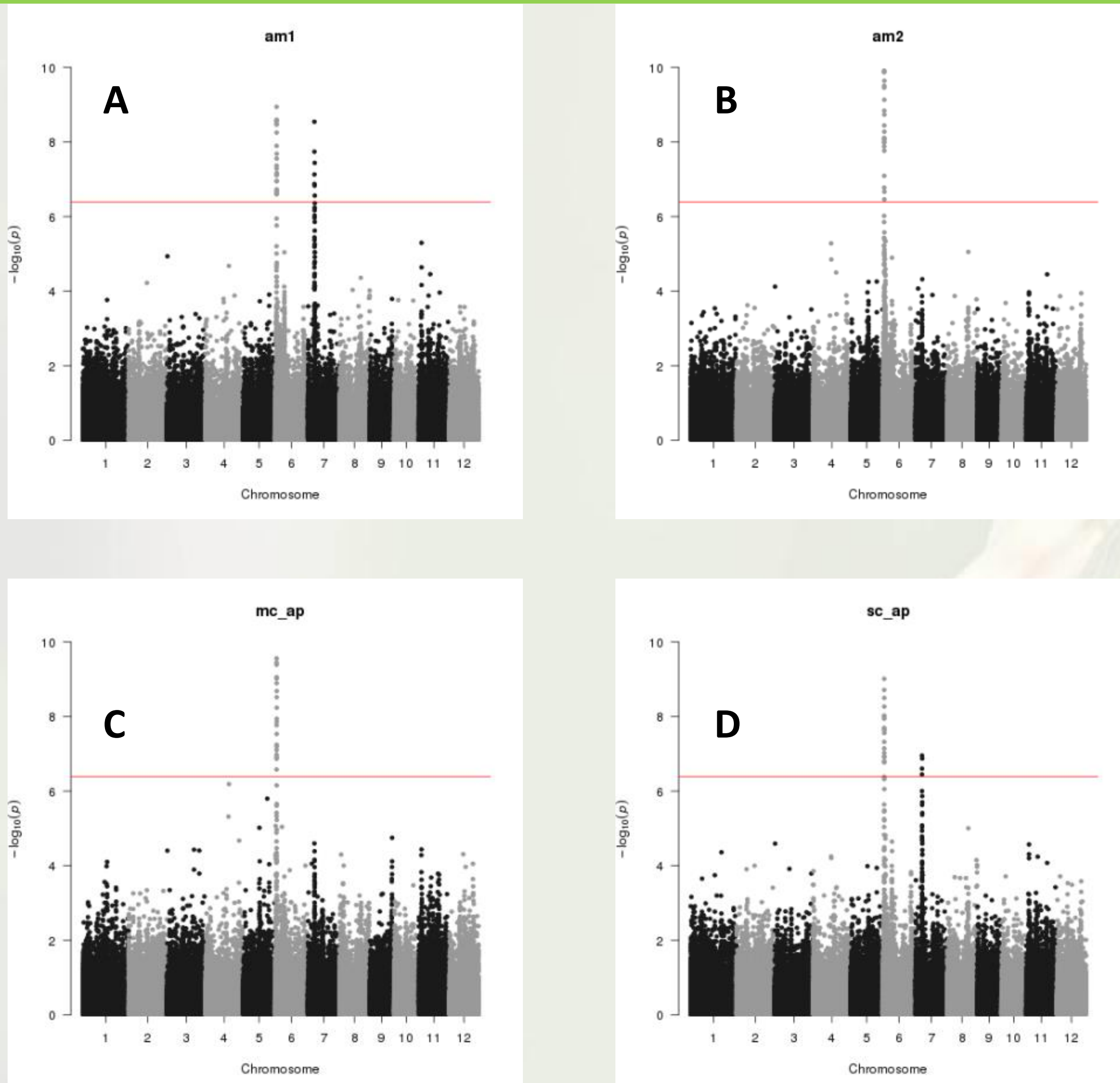
•The short chain amylopectin (Region 4) is positively correlated to elevated GI.
•Importantly, the two amylose fractions (Region 1 and Region 2) are inversely correlated to GI ($R^2_{Region\ 1}$ = 0.844; $R^2_{Region\ 2}$ = 0.8501).

Rice diversity for glyemic index response
Starch structure analysis

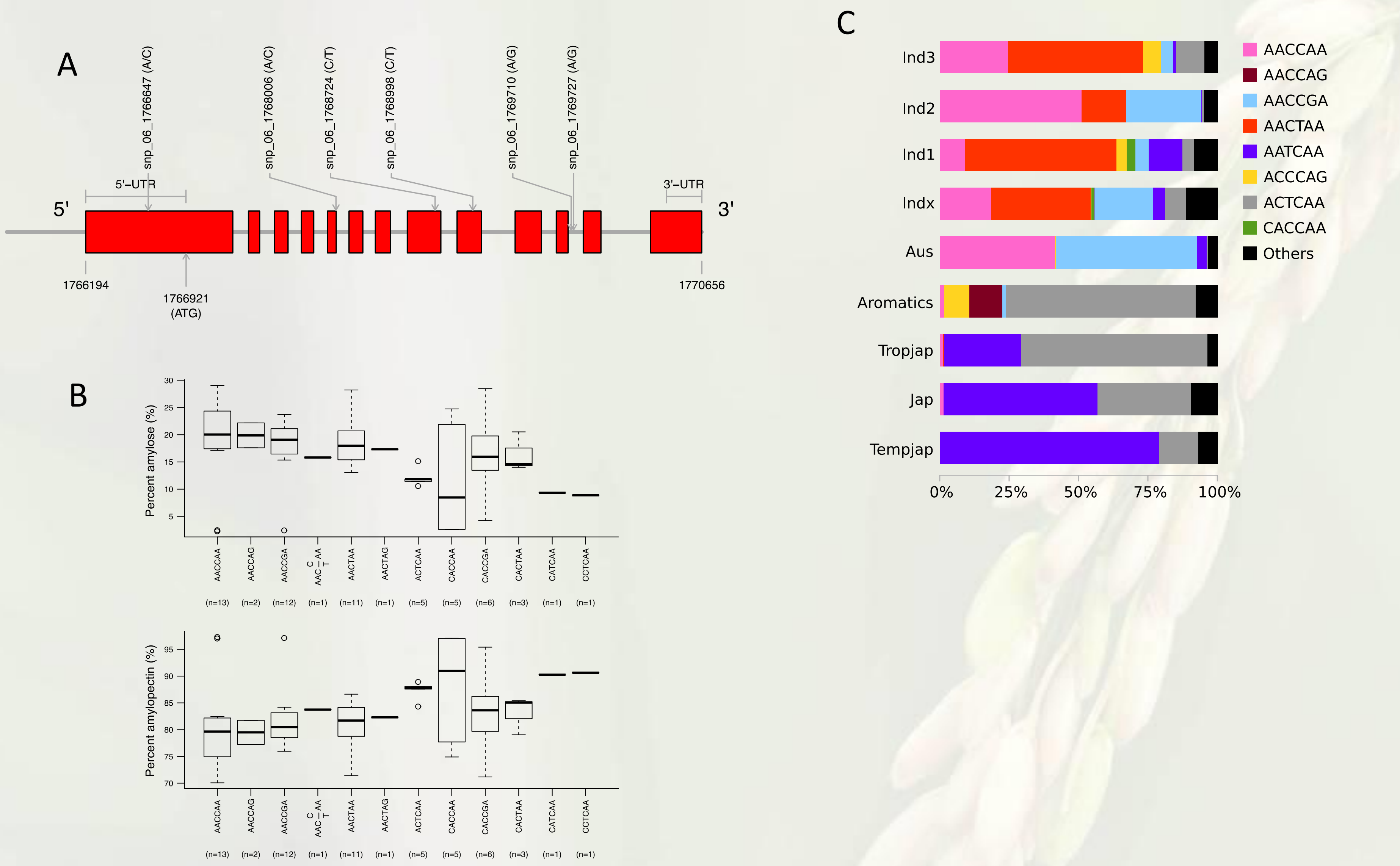


Butardo et al., Plant Physiology (2017)

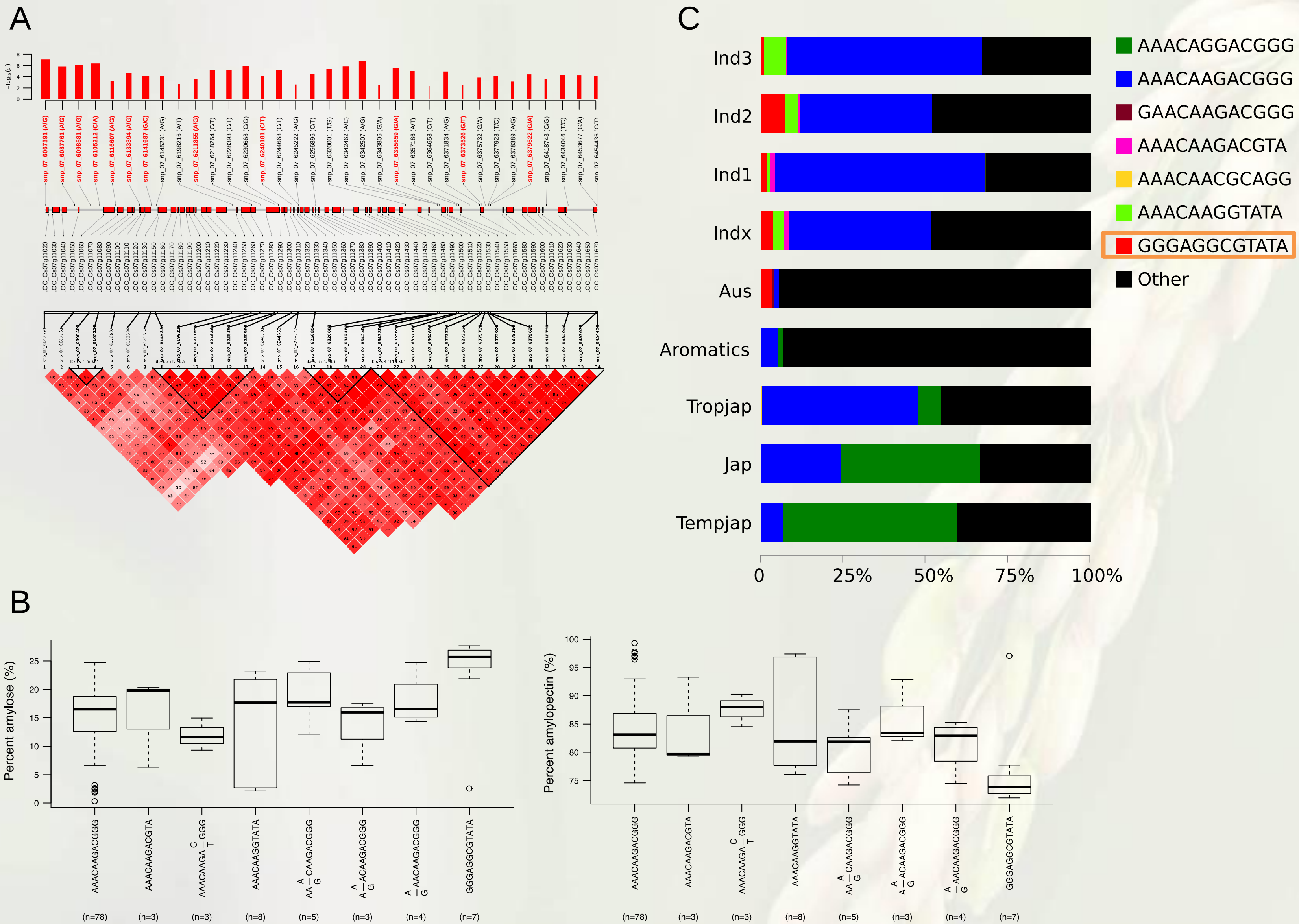
GWAS: genetic regions influencing % amylose and % amylopectin



Chromosome 6, TGAS of starch structure on GBSS1

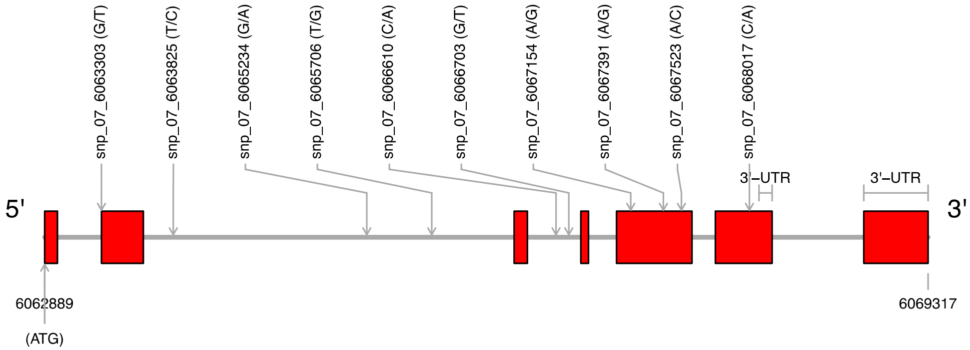


GWAS of starch structure on chromosome 7

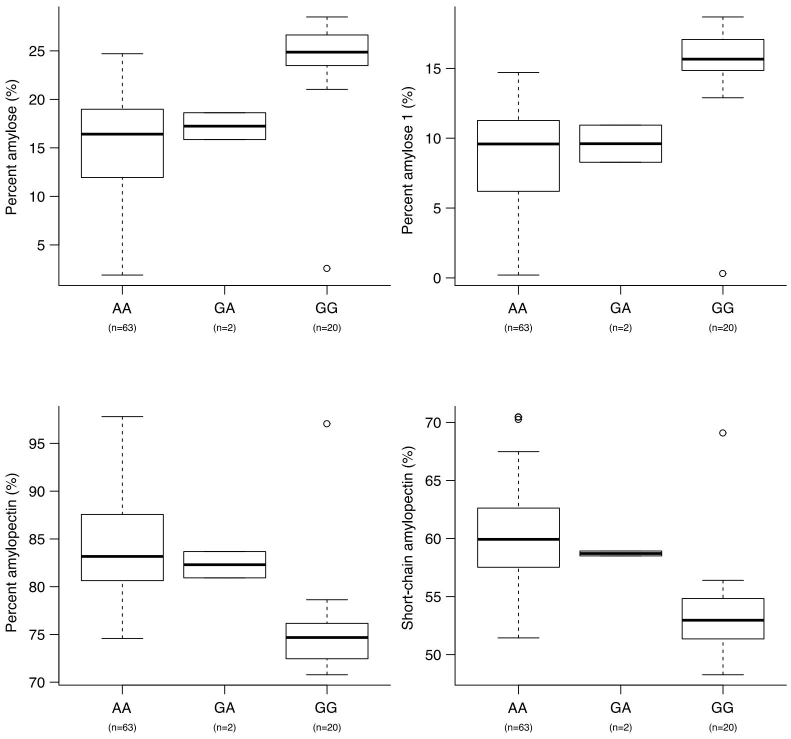


TGAS of starch structure on bHLH

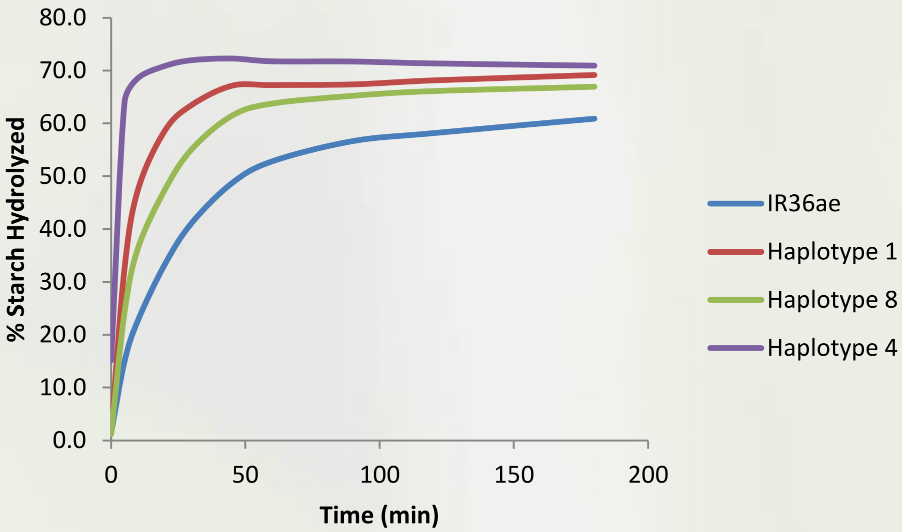
A

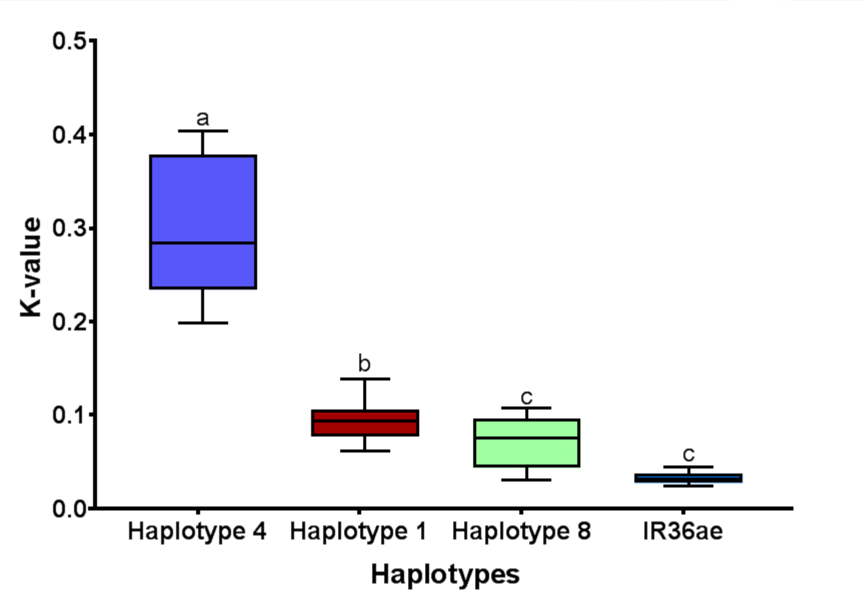


B

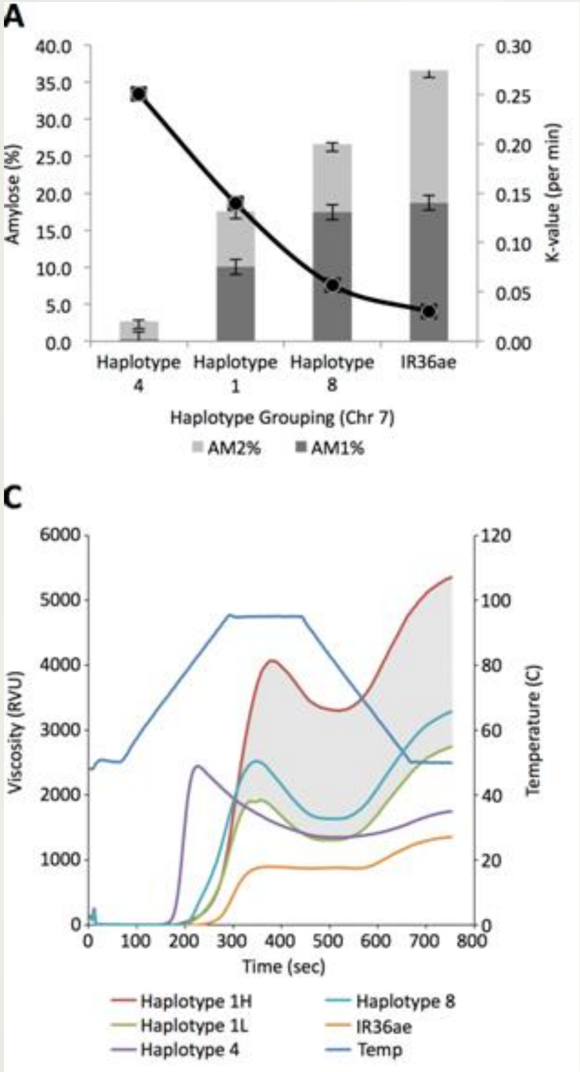


Low glycemic index red coloured rice

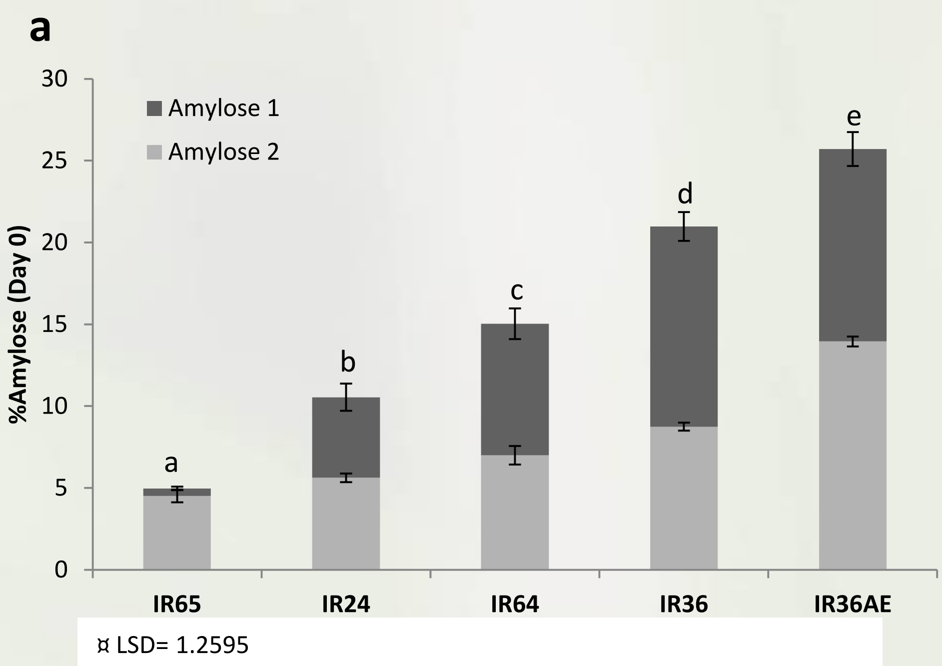


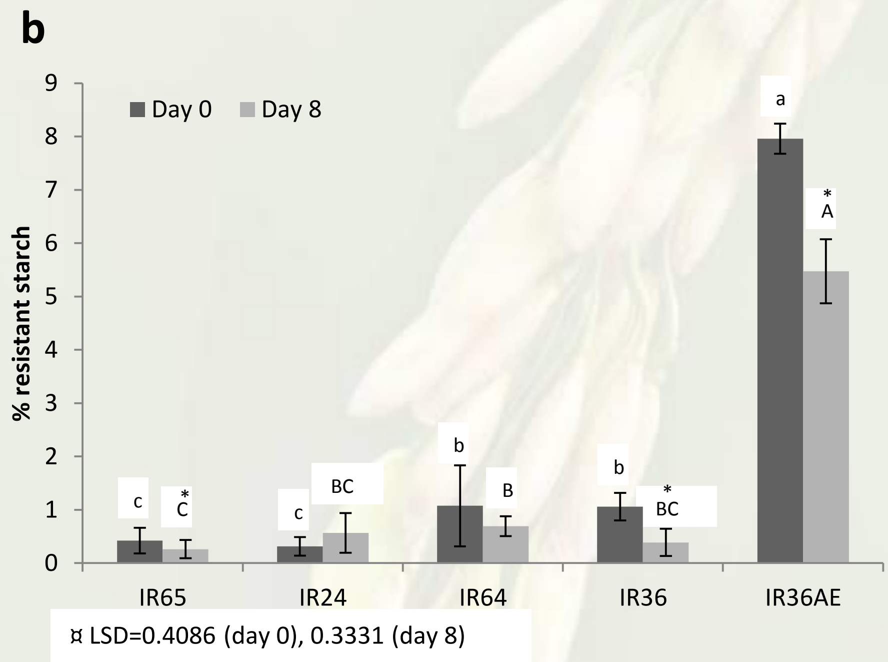


Low glycemic index red coloured rice



IR36 amylose extender (IR36ae) a low GI mutant

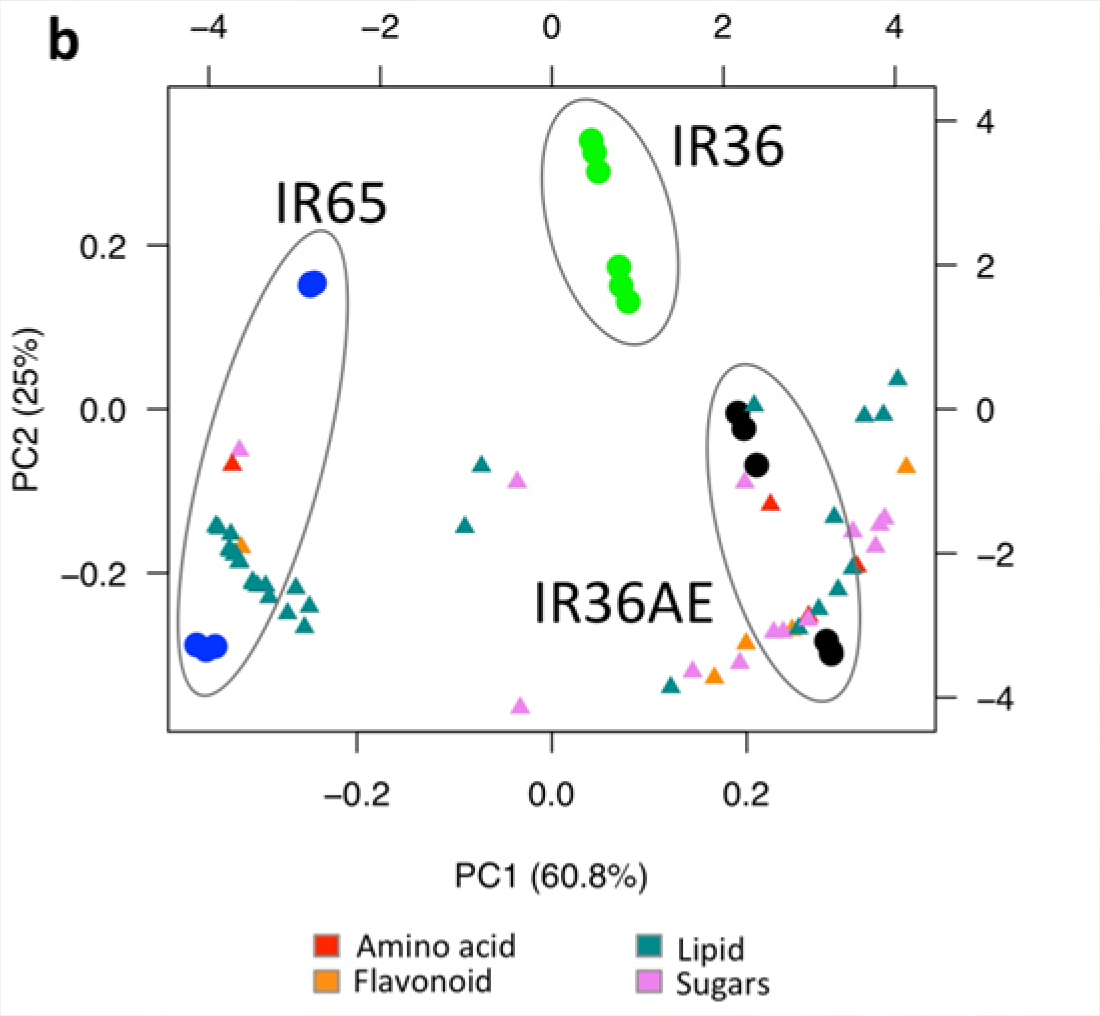




Protein content: 11.75%

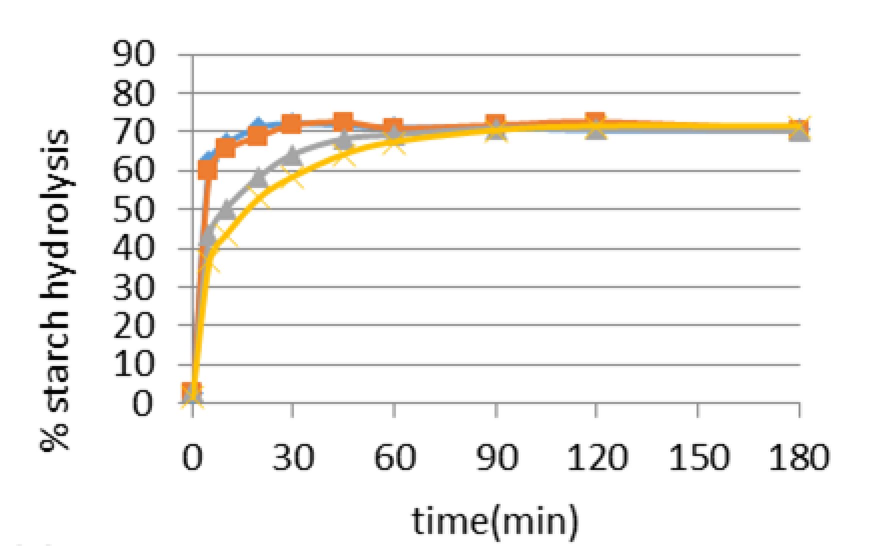
Guzman et al., Scientific Reports (2017)

Metabolioc responses of IR36ae low GI mutant

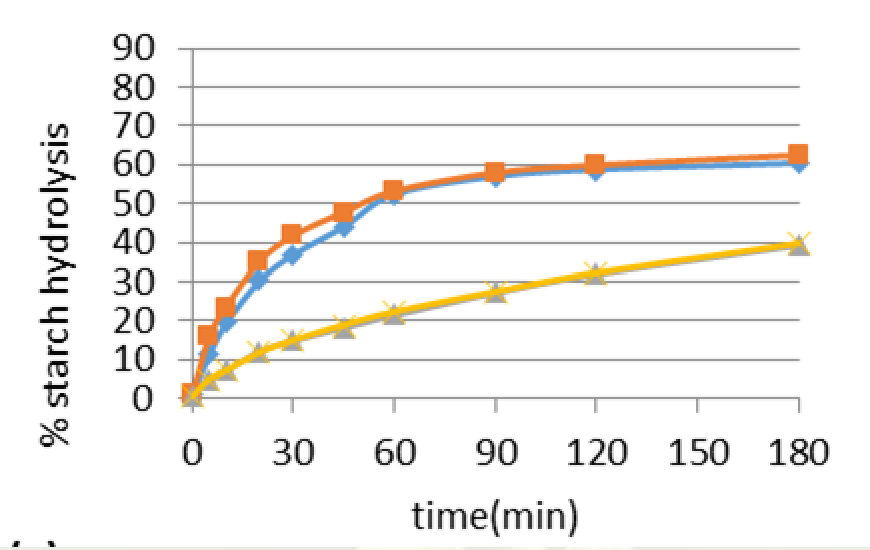


Retrogradation impact on lowering GI response of varieties

IR65 (low amylose)



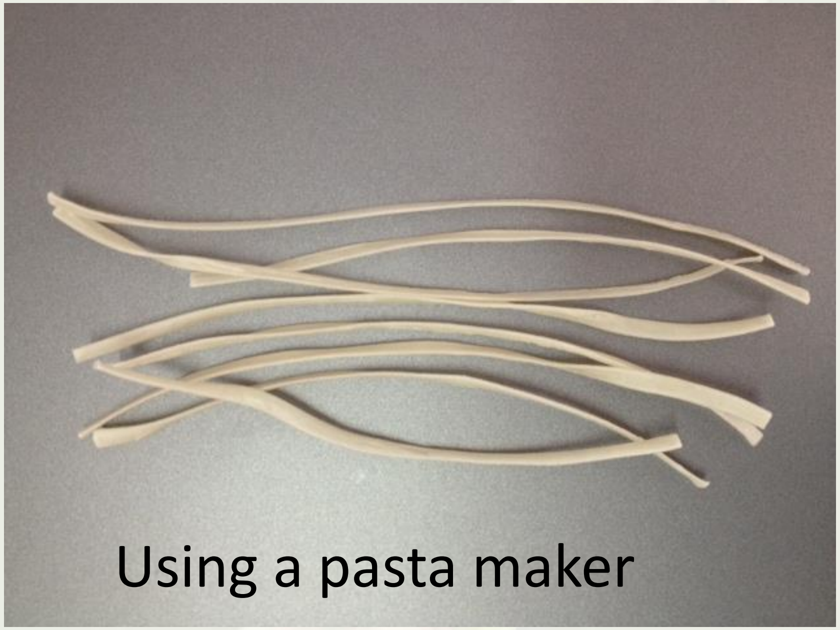
IR36ae (high amylose)



F FwL R RwL

IR36ae (amylose extender)

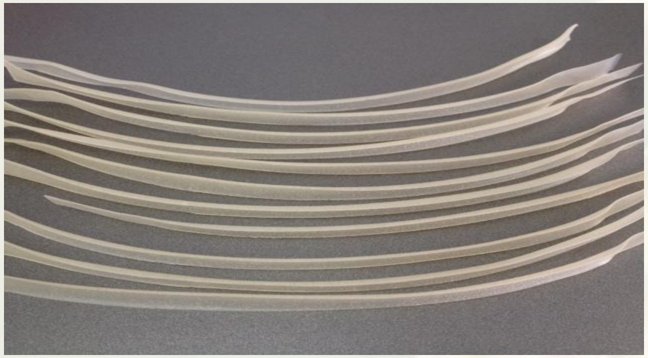
- Mutant rice, low glycemic index
- Undesirable to use it as cooked rice due to its hard and rough texture and fast rate of retrogradation



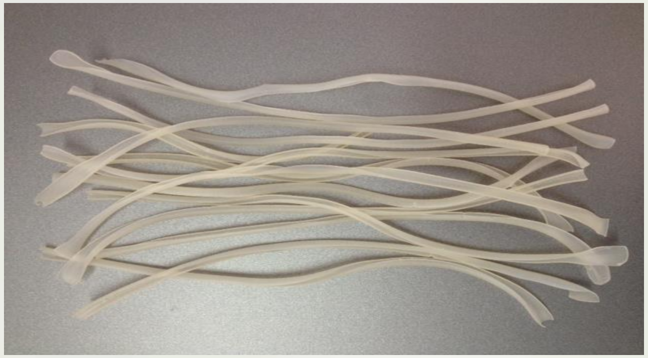
Using a pasta maker

IR36ae application in rice noodles

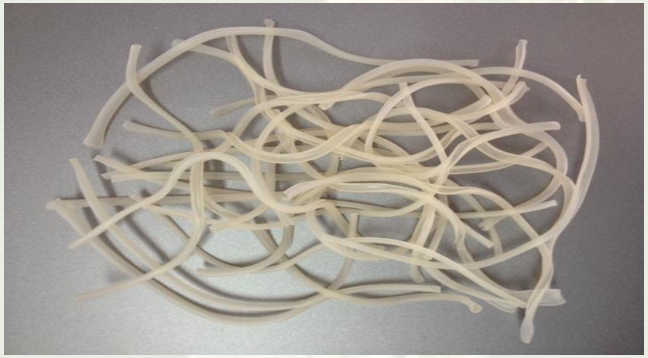
20% IR36ae, 80% IR64



50% IR36ae, 50% IR64

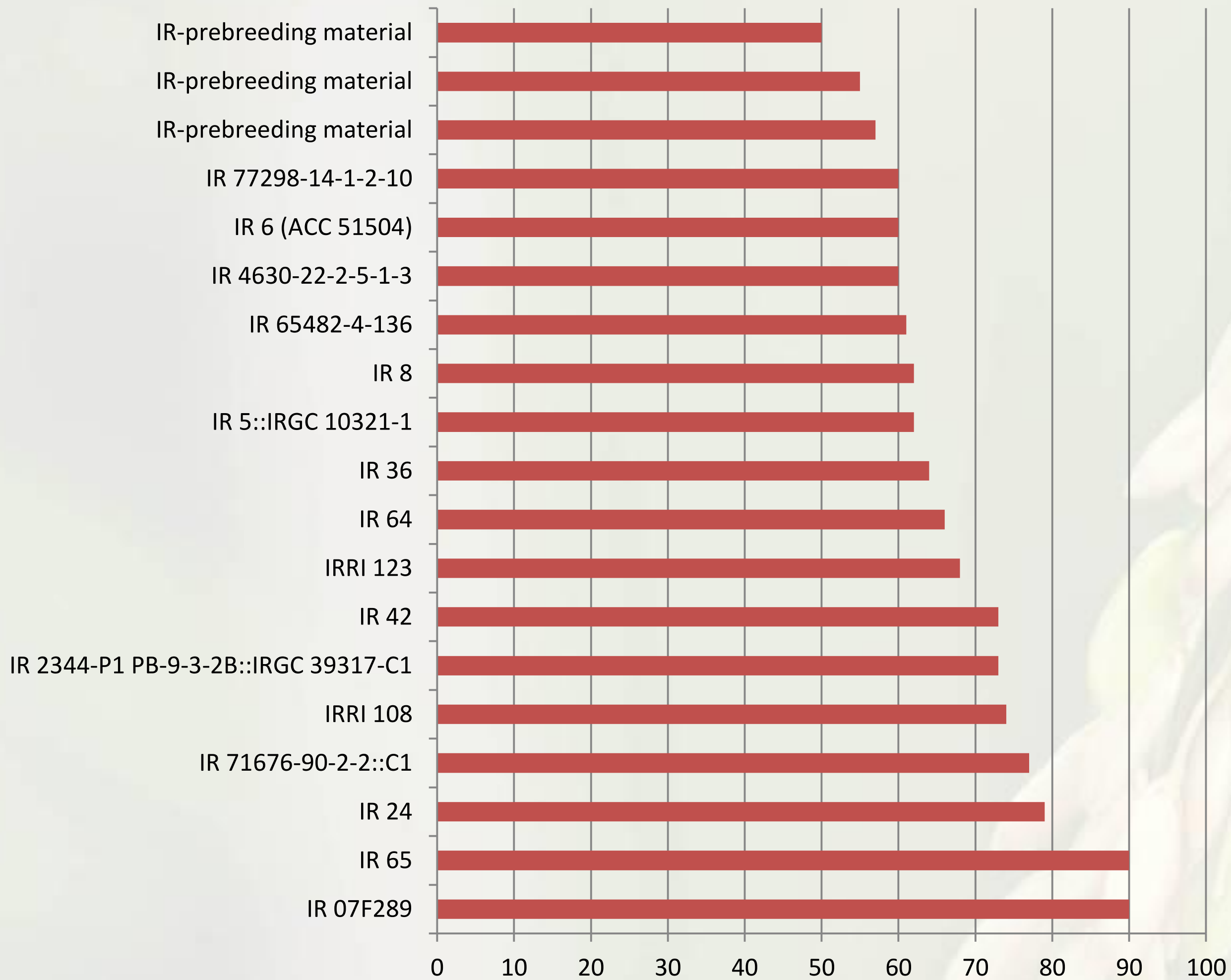


75% IR36ae, 25% IR64

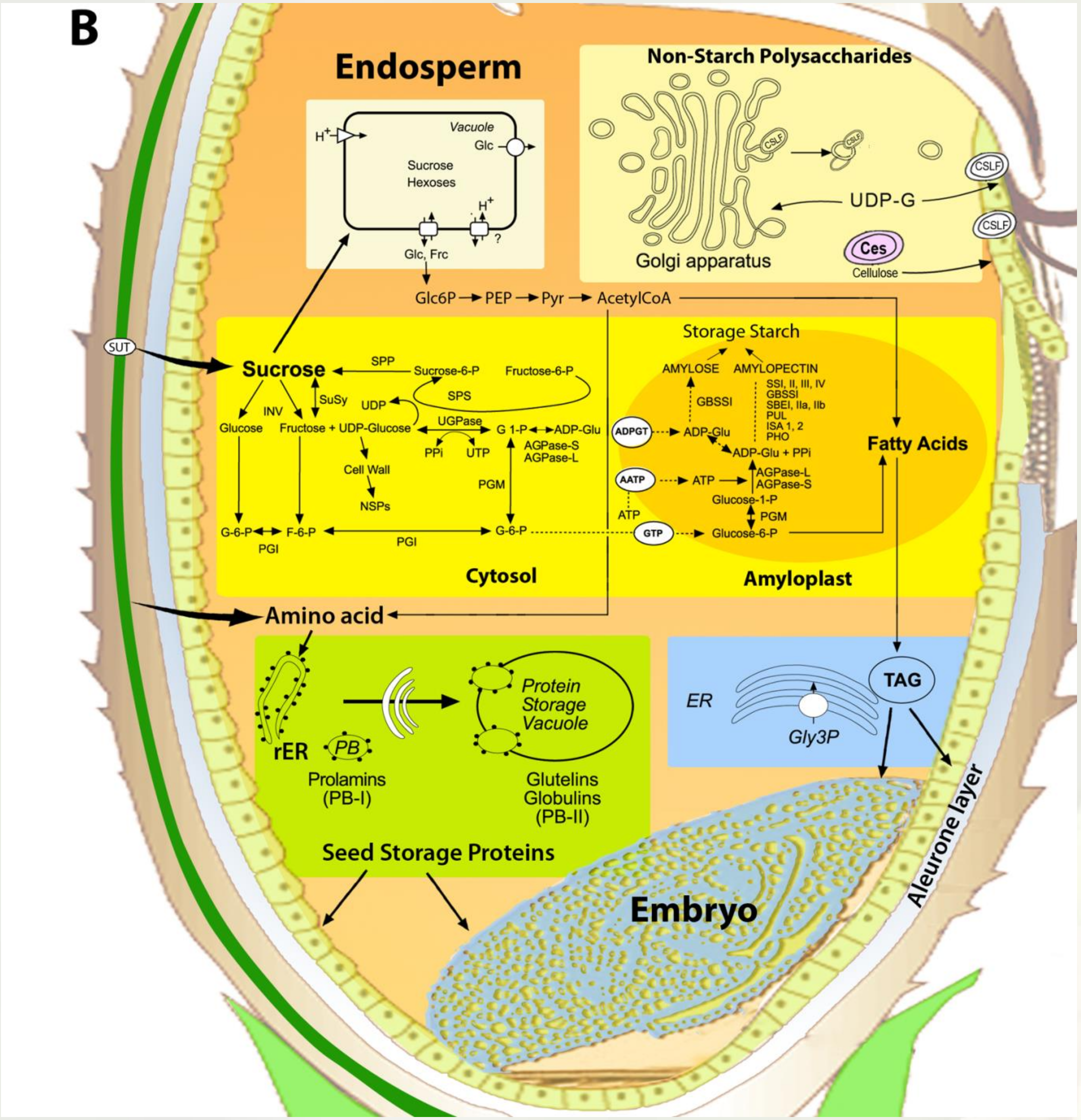


100% IR36ae

Predictive glycemic index responses of IR varieties and pre-breeding material: International Rice Research Institute



Rice seed composition intervention



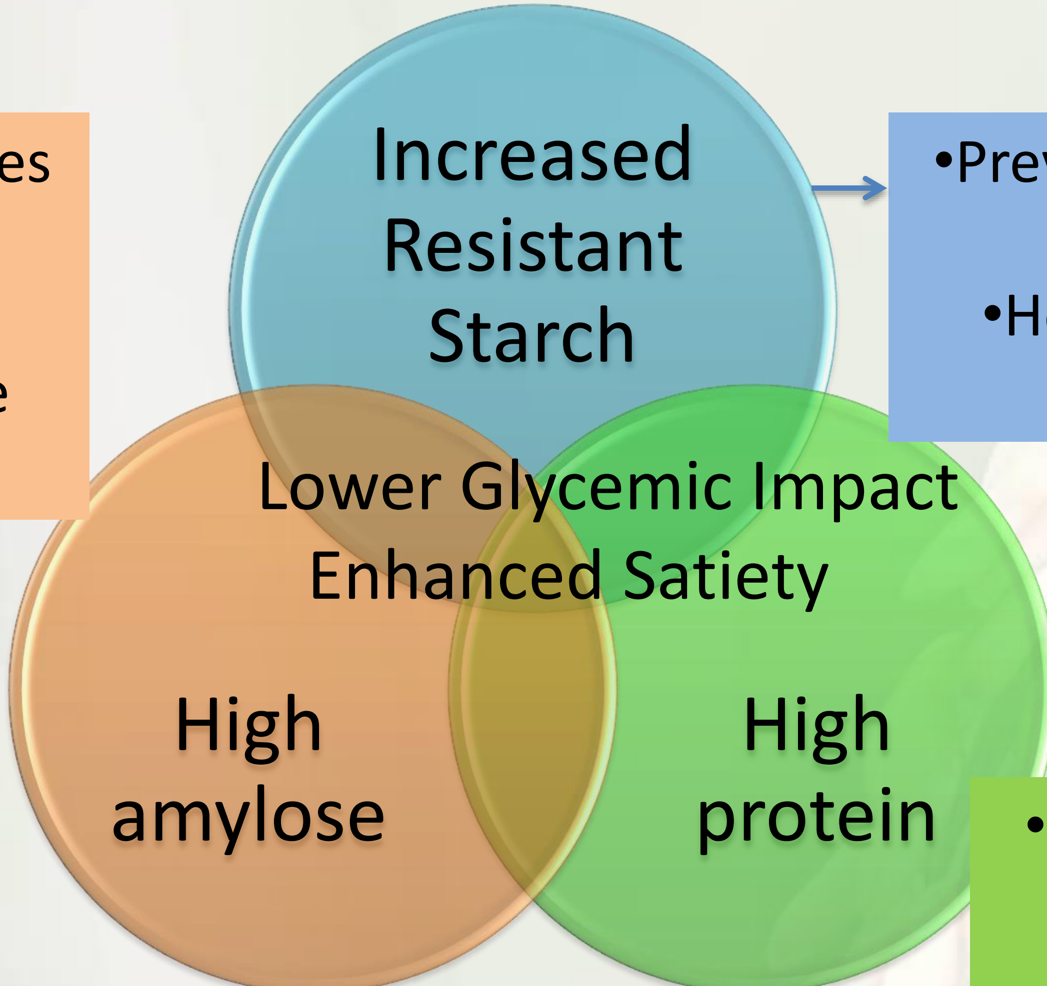
DF+RS:
20% contribution

Starch structure:
65% contribution

Protein:
15% contribution

Rice seed composition intervention

- Reduce diabetes incidences
- Prevent non-communicable diseases



- Prevent colorectal cancer
- Healthy bowel function

- Prevent Celiac Disease
- Gluten Intolerance

Modifying Glycaemic potential of Rice

We have the background information and tools to modify glycaemic index and resistant starch content in rice

Established alternative phenotyping tools to estimate starch structure predictive glycemic index, %amylolysis, rapid digestable carbohydrates and resistant starch in rice core collection

Genetic basis of starch structure is established and major haplotypes identified on chromosome 6 and 7

Identified rare accessions with lower glycemic index and higher resistant starch in rice pools

Pre-breeding initiatives are underway to create targets related to low GI and moderate resistant starch in Sambha Mahsuri-sub1 background

Investment is needed to generate non-GM solutions that have no yield penalty and are accepted by consumers

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