



# Improving Soybean Seed Properties for Enhanced Food Quality

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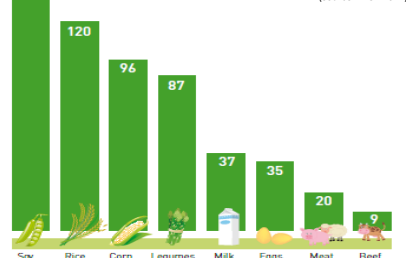


## Soybean and soy foods: benefits and limitations

Energy efficiency in production (measured in kcal)



Usable protein per acre of farmland (measured in kg)  
(Source: ENSA 2014)



### ➤ Health and nutritional benefits

- Whole-bean products
- Ingredients: wide food applications
- Bioactives: health/nutraceutical industries



### ➤ Environmental benefits

- resource-efficient: low input/GHG emission, greater land-efficiency → highest protein/acre of farmland)
- increasingly important in food security and combating metabolic conditions

### ➤ Limitations

- Anti-nutritional factors
- Lipoxygenases → sensory properties, acceptability and utilisation



**Table 1 | COCs and global PEMs of major crop and livestock products**

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	COC <sup>a</sup> (kg CO <sub>2</sub> per kg fresh weight)	PEMs (kg CO <sub>2</sub> e per kg fresh weight)	Total (kg CO <sub>2</sub> e per kg fresh weight)	Total (g CO <sub>2</sub> e per kcal <sup>c</sup> )	Total (kg CO <sub>2</sub> e per kg protein)
Maize	2.1	0.46	2.6	0.82	29
Rice (rough)	2.6	2.17	4.8	2.0	69
Wheat	1.9	0.69	2.6	0.9	23
Cassava	1.7	0.04	1.7	1.6	160
Potato	0.6	0.09	0.7	1.1	38
Soybeans	5.9	0.26	6.1	1.5	17
Pulses	10.5	0.55	11	3.1	47
Vegetable oils	9.7	1.3	11	1.2	Not applicable
Beef <sup>b</sup>	144	44	188	102	1,250
Cow milk	6.2	2.3	8.4	13.1	260
Pork	14	5.5	20	9.4	150
Poultry meat	11	3.7	14	8.4	110

Values are calculated using the carbon loss method and 4% time discounting.

<sup>a</sup>Includes peatland emissions.

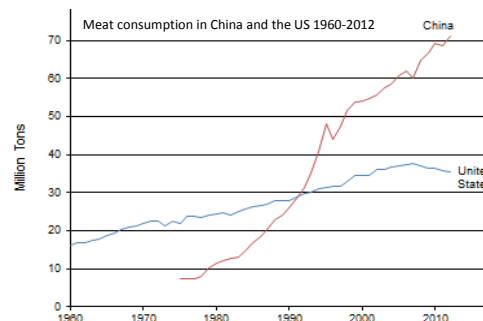
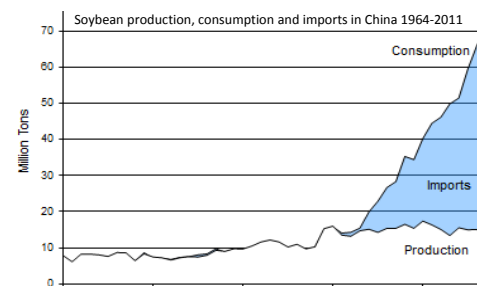
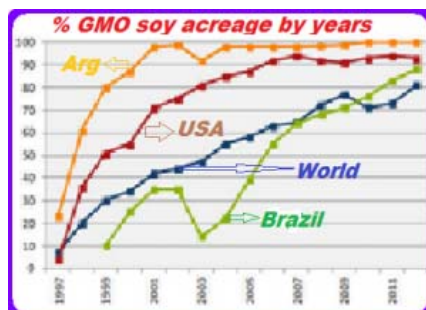
<sup>b</sup>Average, including meat from dairy animals.

<sup>c</sup>1 kcal = 4,184 J.

COCs: carbon opportunity cost  
PEMs: production emissions

## World soybean production

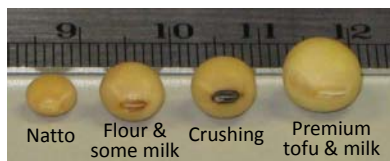
- 350+ MMT, driven by increased consumption (animal industry) in China
- Dominated by GM soybean for oil and animal feed (over 80%)
- Food industry still demand non-GM
- Australia as a niche and value producer



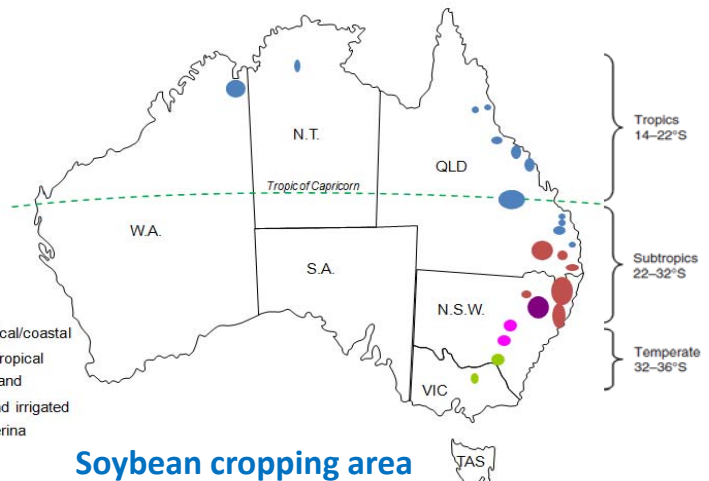
# Australia Soybean Improvement Program



**Environmental  
responsiveness**  
**Non-GMO**  
**Culinary use**



■ Tropical/coastal  
■ Subtropical  
■ Dryland  
■ Inland irrigated  
■ Riverina



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## Develop varieties with grain possessing enhanced functional and nutritional traits for culinary and feed uses



- Modified globulin contents of the major seed storage proteins for enhanced functionality (e.g. **gelling in tofu making**) and nutritional/health benefit (**improved lipid and sugar profile**)
- **Lipoxygenase (LOX)** null to improve flavour, taste and acceptability  
→ broaden applications
- **Sucrose accumulators** rather than raffinose and stachyose for improved acceptability

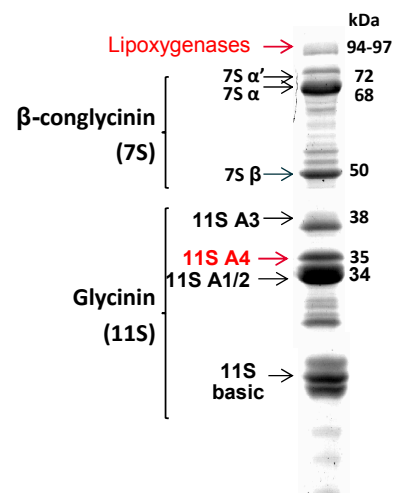
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## Grain proteins affect tofu quality

**Highest protein (>40%): major functional components** (gelling in tofu → texture, water holding capacity)

- Solubility
- Content and proportion of major storage proteins: 7S + 11S (65-80%), 11S/7S ratio
- Subunit composition of the globulins
- Lipoxigenases → beany/grassy/off-flavour
- Amino acid composition/sequence: nutrition



## Silken tofu processing and gelation mechanism of proteins

Soak and grind with water



Heat at 98-100°C



Extract/Filter → **Soy milk**



Add coagulant

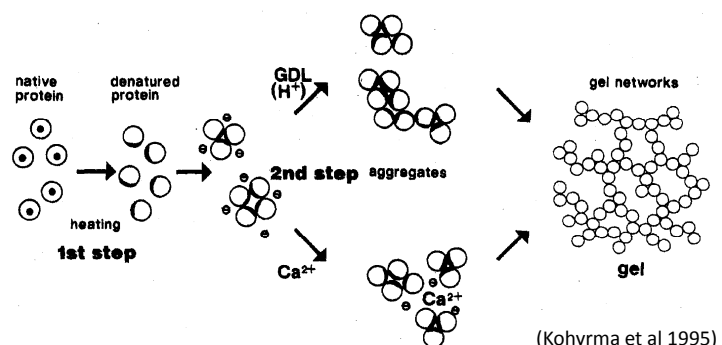


Curd formation at 85°C



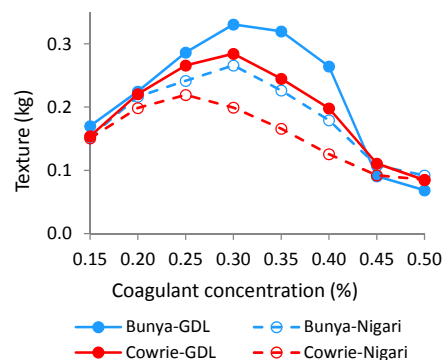
Store at 4°C → **Silken tofu**

**Key step in extracting seed proteins into soymilk: protein solubility**



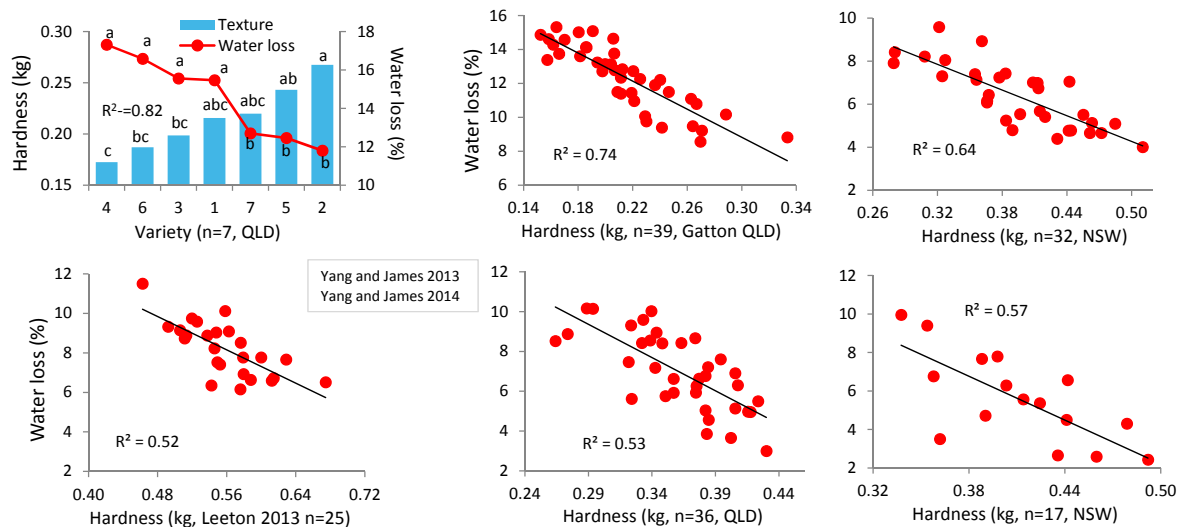
## Globulin subunit composition and processing conditions affect tofu properties

	No nulls (n=6)	7Sα null (n=3)	7Sα' and 11SA4 null (n=3)	11SA4 null (n=6)
<b>Seed protein (%)</b>	<b>40.98 b</b>	41.49 b	42.55 a	<b>41.37 b</b>
<b>Globulin subunit</b>				
7Sα'	7.06 b	-	-	8.05 a
11SA4	6.37 b	6.95 a	-	-
7S	22.1 b	20.2 c	22.9 b	26.5 a
11S	44.7 b	46.5 a	43.1 b	40.7 c
7S+11S	66.8	66.7	66.0	67.2
11S/7S	2.05 b	2.33 a	1.90 c	1.55 d
<b>Tofu hardness (kg)</b>	<b>0.334 c</b>	0.363 b	0.361 b	<b>0.388 a</b>
<b>Tofu water loss (%)</b>	<b>8.30 a</b>	7.42 b	7.24 b	<b>5.30 c</b>

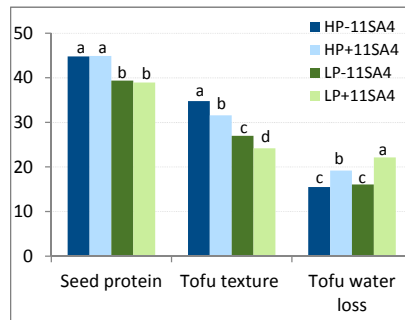
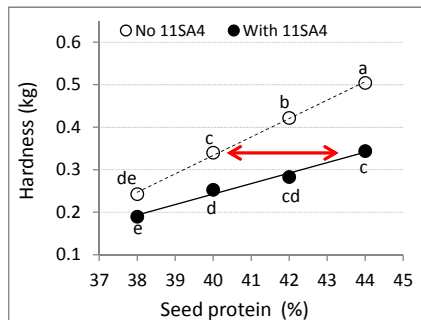


Yang and James 2013

## Negative correlation between tofu texture and water loss



## Protein content and 11SA4 null affect functional properties in soy foods

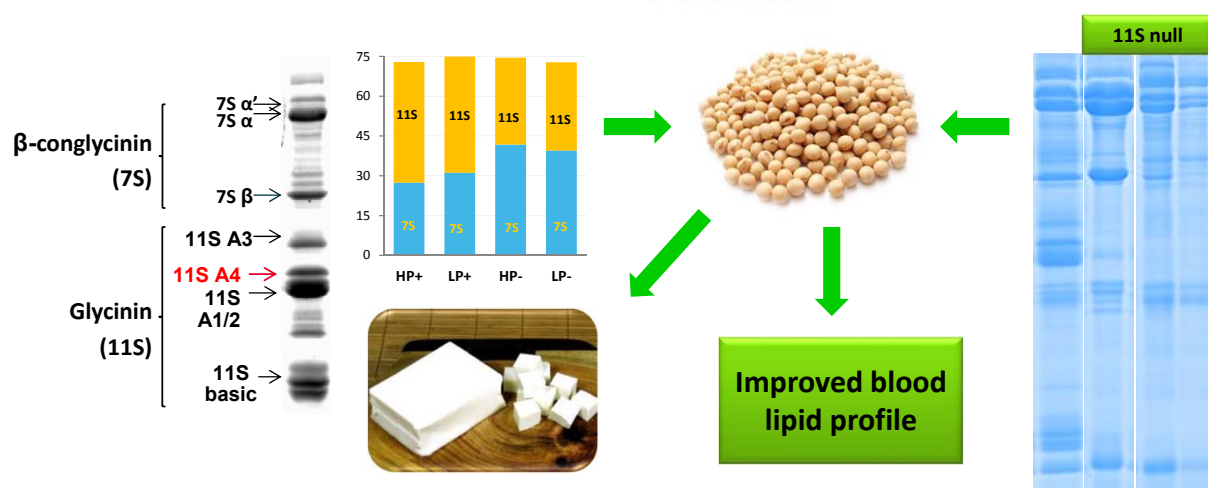


	Bunya – 11SA4	Cowrie + 11SA4
Seed protein (%)	38.55*	43.00
Soymilk protein (%)	43.88*	46.72
Tofu protein (%)	47.77*	52.43
Tofu hardness (kg)	0.277*	0.229
Tofu water loss (%)	12.30*	18.75

**Practical significance:** ↓ pressure for selecting for high protein which is negatively correlated with yield

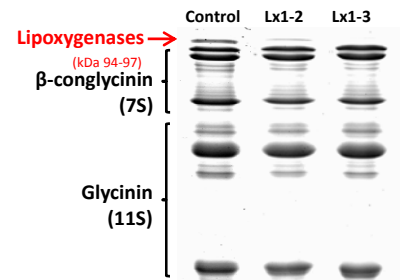
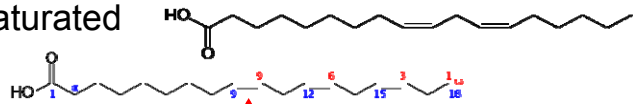
Yang and James 2013  
Yang and James 2014  
James and Yang 2014  
James and Yang 2016

## Modified globulin profile for improved functionality and health benefit



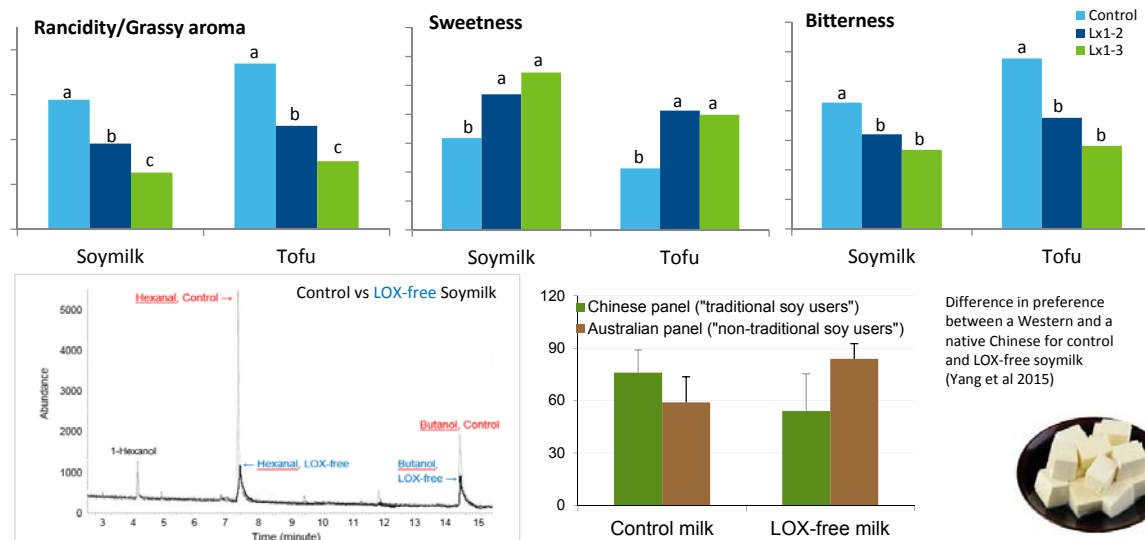
## Lipoxygenase (LOX) and sensory properties of soy foods

- Soybean oil (~20%) highly unsaturated (~50% 18:2, 10% 18:3)
- Richest source of LOX
  - Hydroperoxides
  - aldehydes/ketones/alcohols
  - Undesirable beany/grassy/rancid
- Developed lines without LOX (Lx1-2, Lx1-3)
- Soy foods evaluated by GC-MS and descriptive sensory panel



SDS-PAGE profile of soybean seed proteins

## Improved sensory properties of soy foods from LOX-free soybeans



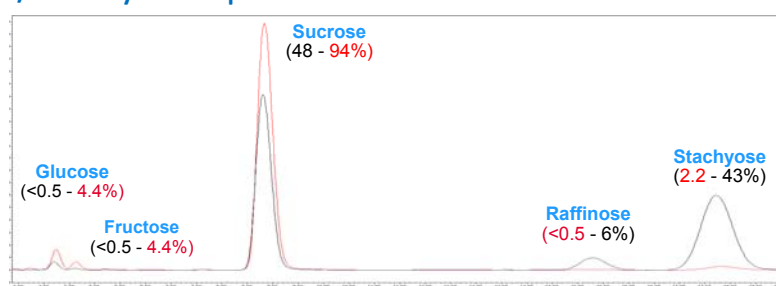


## Soybeans with improved sugar profile

- Proteins: content (40%+) and major storage proteins → functionality  
lipoxygenases → beany/grassy/off-flavour
- Lipids (20%) and its interaction with LOX → nutrition profile, stability

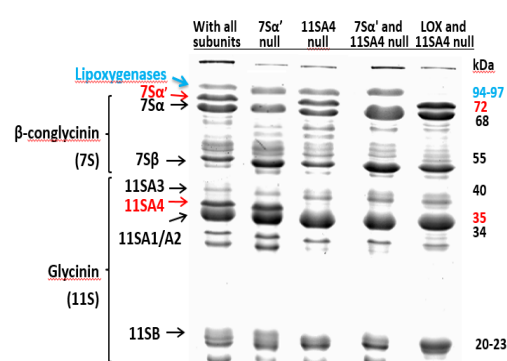
- **Carbohydrates: 30%, < 20% soluble sugars**  
sucrose > 50%, raffinose/stachyose up to 50%

↑ sucrose  
 ↓ raffinose/stachyose  
 ↑ improved taste  
 nutrition  
 acceptability



## We have developed soybean genotypes

- With high (~45%) or low (~39%) protein content
- Null in 11SA4 and/or 7Sα', 11S
- Lacking two (Lx1-2) or all three (Lx1-3) major isomer of lipoxygenases
- Containing greatly reduced raffinose (<0.5%) and stachyose (~2%) and increased sucrose (~94%)



SDS-PAGE profile of soybean seed proteins containing all globulin subunits, lacking 7Sα' and/or 11SA4, or lipoxygenase



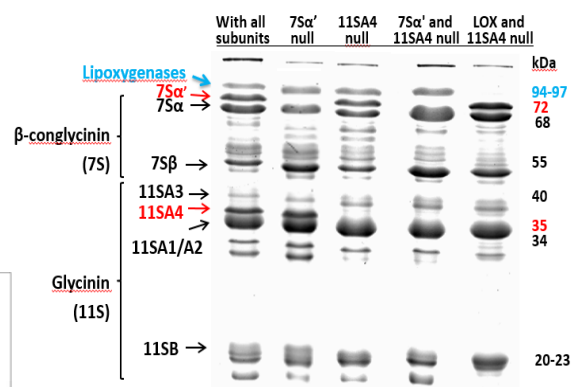
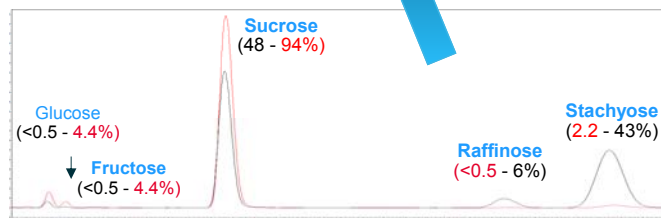
## Soybean genotypes with improved quality attributes

- Higher proteins content and 11SA4 deficiency consistently improved textural and water holding properties of tofu.
- Firmer silken tofu also had better water holding capacity - important for silken tofu manufacturers.
- 11SA4 null → compensatory accumulation of 7S globulins → similar 7S + 11S in soybeans.
- Soybeans lacking lipoxygenases → soy foods with decreased negative (grassy/rancid) and increased positive (sweet) aroma → more acceptable and broaden applications in foods.
- Currently assessing these novel genotypes as aqua feed.



## Improved grain properties for better soy food quality

Superior functionality,  
nutrition, taste,  
acceptability



SDS-PAGE profile of soybean seed proteins containing all globulin subunits, lacking 7Sα' and/or 11SA4, or lipoxygenase



Thank you!

