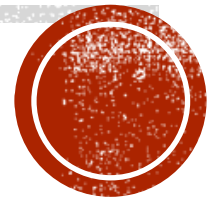


Structure-function-nutrition relationships of carbohydrates: generating value from SK crops

Yongfeng Ai

Associate Professor and Ministry of Agriculture Endowed
Research Chair in Carbohydrate (CHO) Quality & Utilization
Department of Food and Bioproduct Sciences



Land acknowledgements

As we gather here today, we acknowledge we are on Treaty 6 Territory and the Homeland of the Métis. We pay our respect to the First Nations and Métis ancestors of this place and reaffirm our relationship with one another.

Agenda

- **What are carbohydrates (CHO)?**

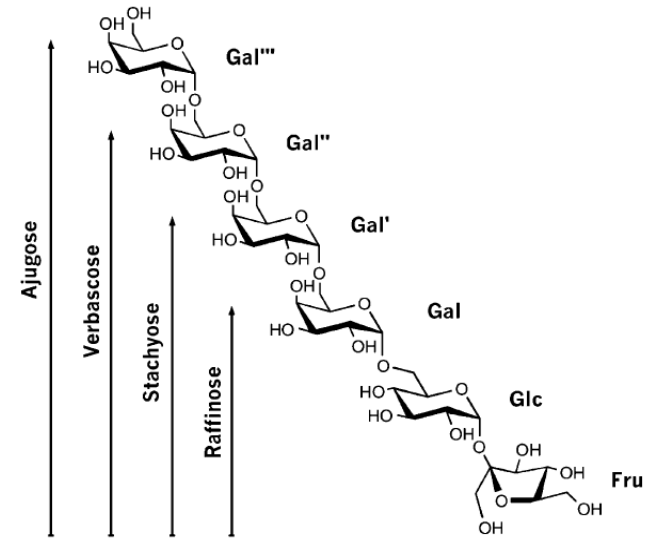
How to study CHO?

- **Research themes with signature projects**
- **Take-away messages**

What are CHO?



Sugars



Raffinose family oligosaccharides



Starch

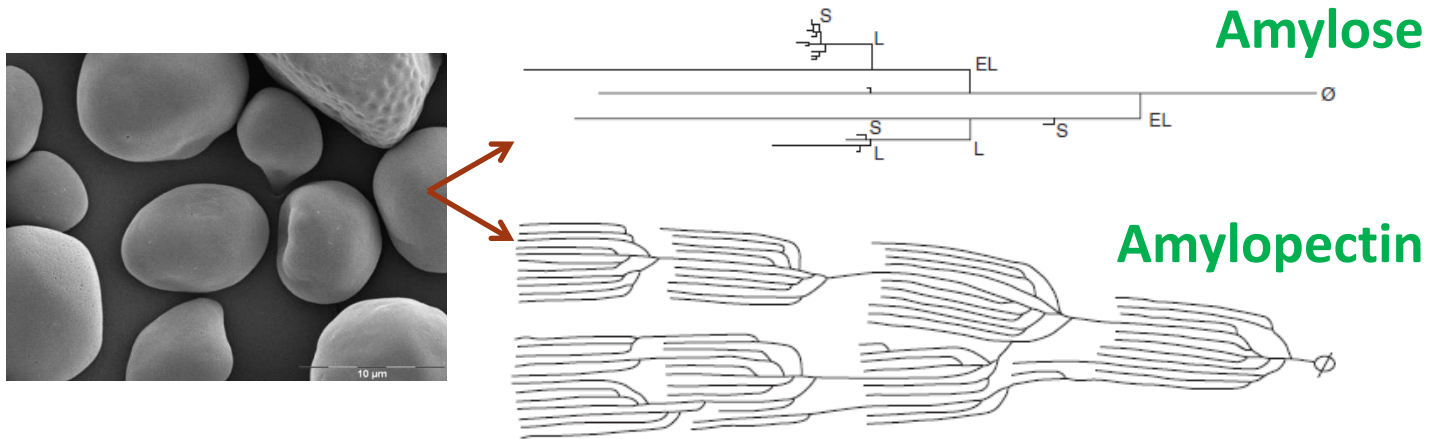


Dietary fibers



Starch

- Starch consists of amylose and amylopectin:

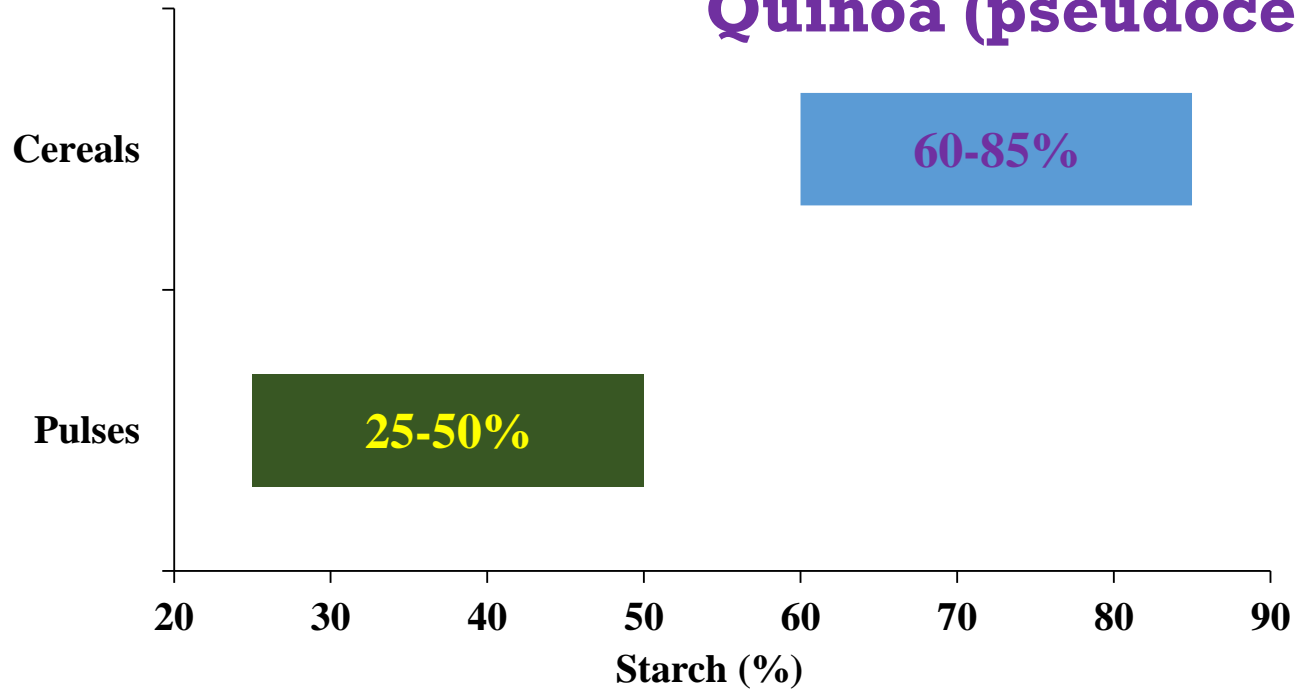


- Amylose content of starch ranges from 0% (waxy starch) to 85% (high-amylose starch).
- Amylose content affects thermal property, pasting property, gel formation, and enzymatic hydrolysis of starch.

Starch

Wheat, oats, barley, rye

Quinoa (pseudocereal)



Pea, lentil, faba bean, chickpea

Functional properties of starch and flour



DSC

Thermal property

Starch or
Flour

Heating



- Gelatinized starch
- Denatured protein



Heating

Pasting RVA

Food Hydrocolloids 94 (2019) 217–228

Retrospective



ELSEVIER

Contents lists available at [ScienceDirect](#)

Food Hydrocolloids

journal homepage: www.elsevier.com/locate/foodhyd

Behaviors of starches evaluated at high heating temperatures using a new model of Rapid Visco Analyzer – RVA 4800

Siyuan Liu^a, Tommy Z. Yuan^a, Xinya Wang^a, Michael Reimer^b, Carly Isaak^b, Yongfeng Ai^{a,*}

Functional properties of starch and flour



DSC

Thermal property

Starch or Flour

Heating



- Gelatinized starch
- Denatured protein



RVA

Pasting property

Heating & shearing



Starch/
Flour paste



Rheometer

Cooling



Starch/
Flour gel

Gelation property

Storage



Retrograded starch



Texture analyzer

Dietary fiber

- Dietary fiber is the edible parts of plants or analogous carbohydrates that are **resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine.**



**Wheat/barley/oat
bran**

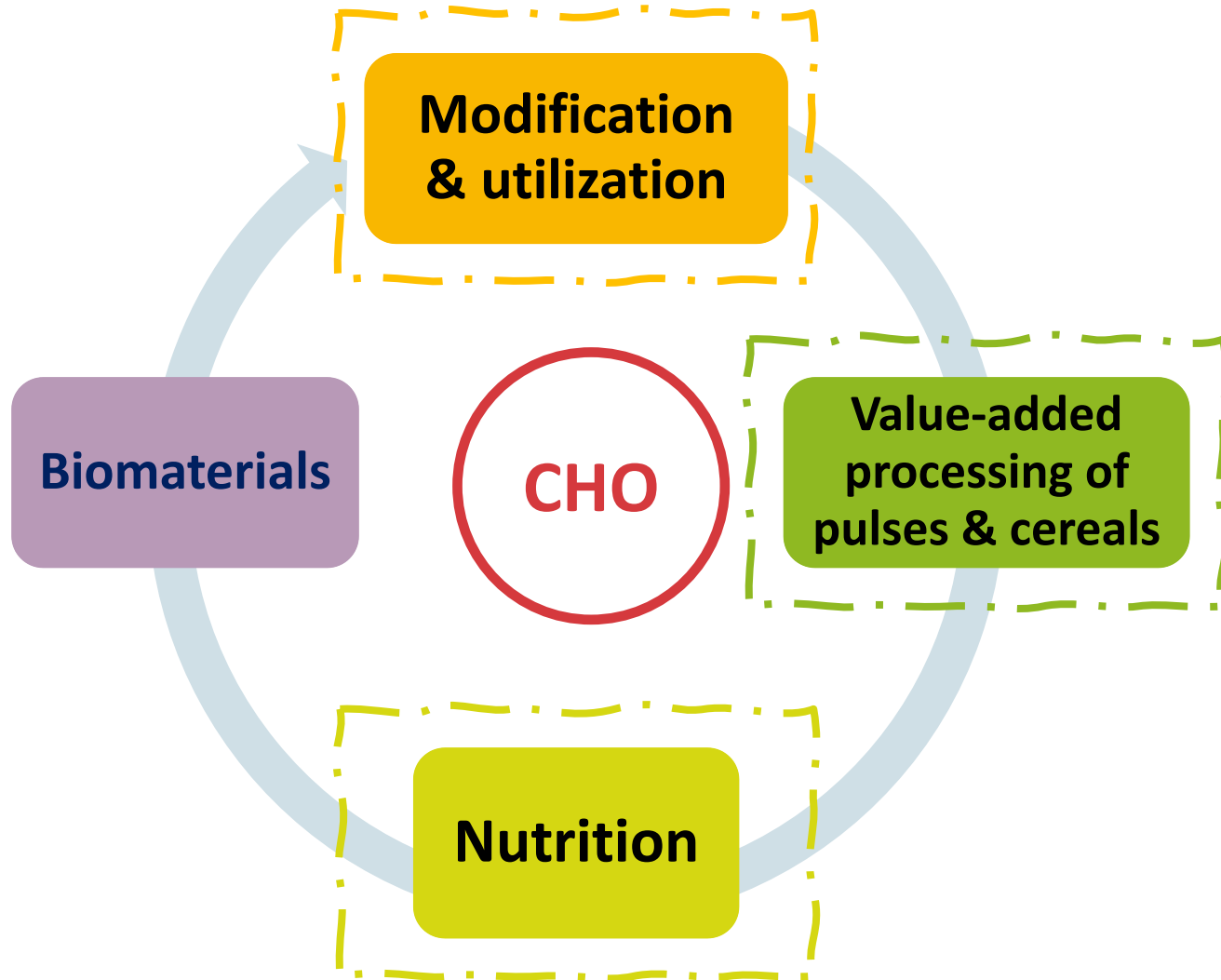


Pea hull fiber

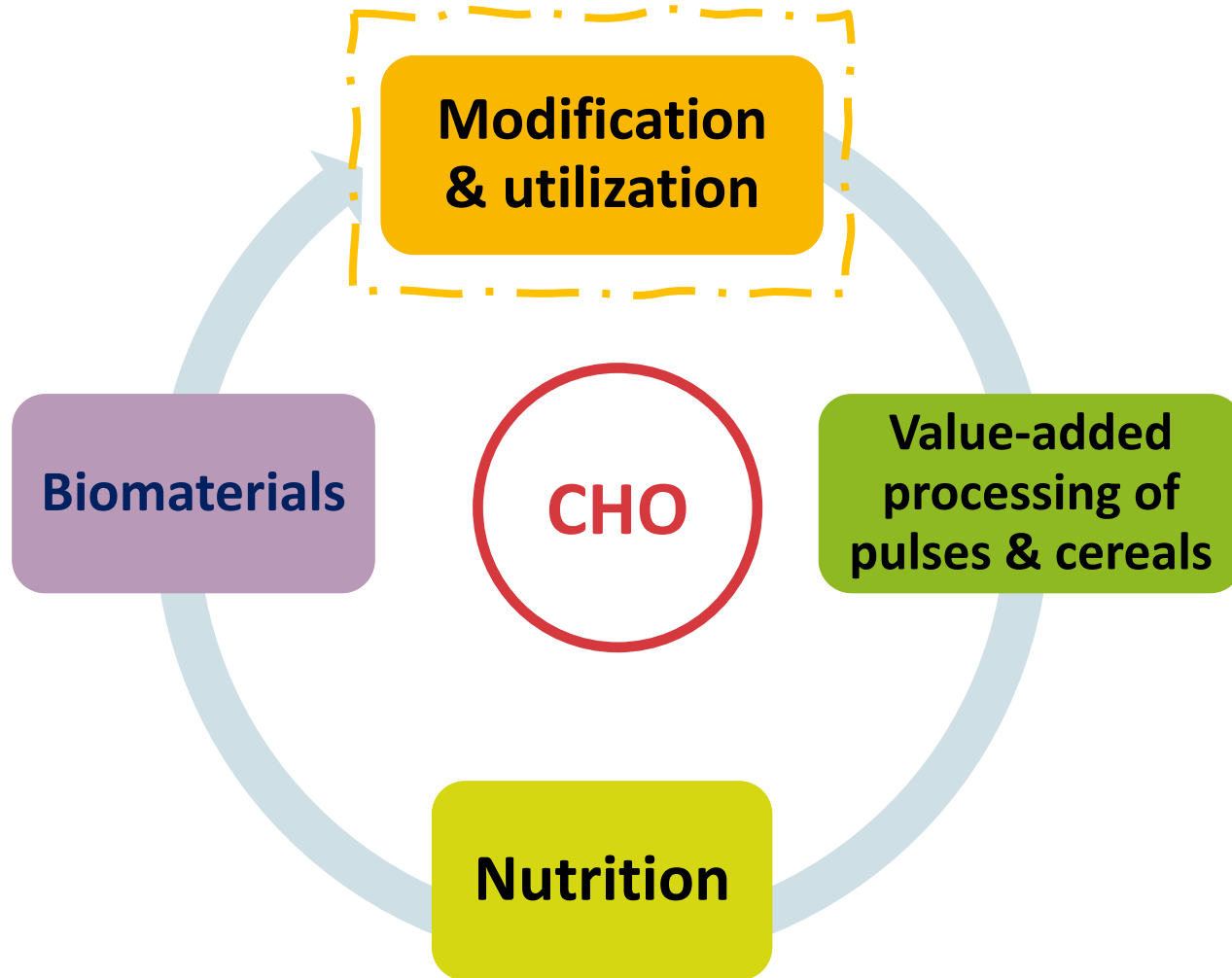


**Oat/barley
 β -glucan**

Research themes



Research themes



2020 Strategic Research Initiative Program (SRI; 2021-26)



**Dry
fractionation**



**Wet
fractionation**

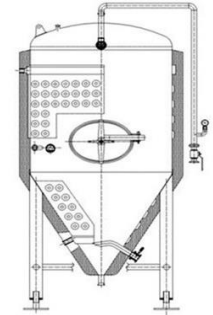
**Starch-rich
flour**



**Isolated
starch**



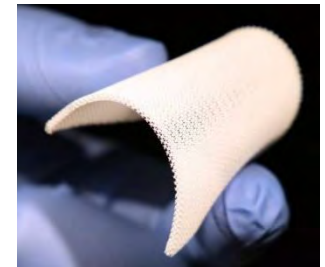
**Food
ingredients**



Bioconversion



Bioplastics



**Biomedical
materials**

Research team

- **9 research programs in the Prairie Provinces**
 - Tom Warkentin and Bunyamin Tar'an
 - Yongfeng Ai, Michael Nickerson, Darren Korber, Takuji Tanaka, Denise Beaulieu and Dan Columbus, Bishnu Acharya
 - Malcolm Xing (U of M)

2020 SRI – Pillar 1: Fractionation

- Dry, wet, and hybrid methods
- Both starch and protein
- New pulse varieties
 - Common and high-protein peas
 - Wrinkled pea
 - Faba bean
 - Lentil
- Pre-treatments of seeds



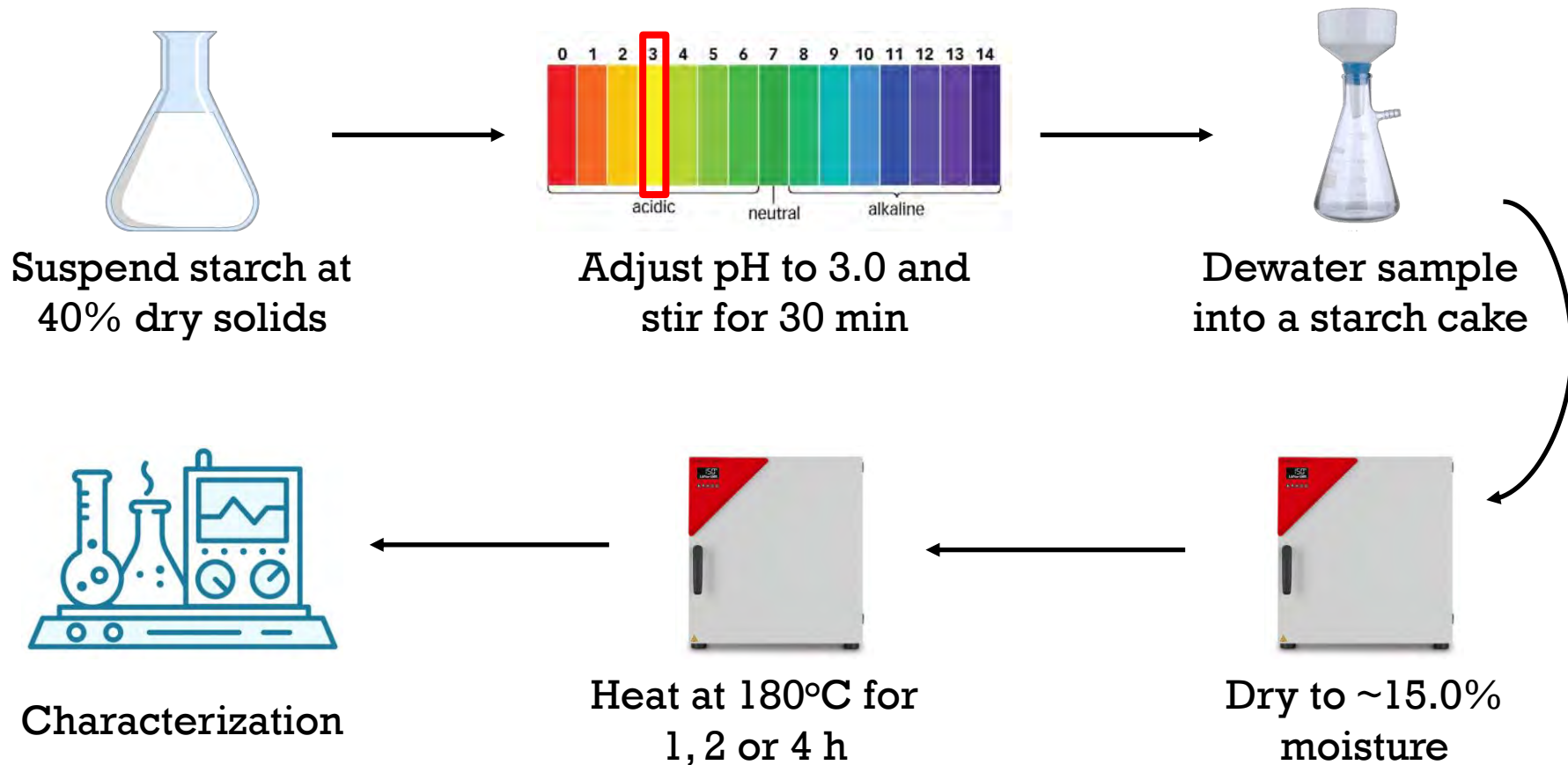
2020 SRI – Pillar 2: Food ingredient innovation

- Pyrodextrin and maltodextrin
- Resistant starch and dietary fiber
- Pregelatinized starch/flour
- Clean-label pulse starch
 - Physical modifications
 - Enzymatic modifications



2020 SRI – Pillar 2: Food ingredient innovation

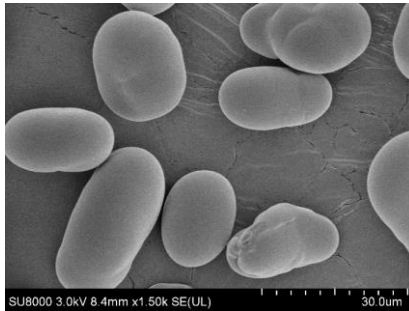
■ Preparation of pyrodextrin



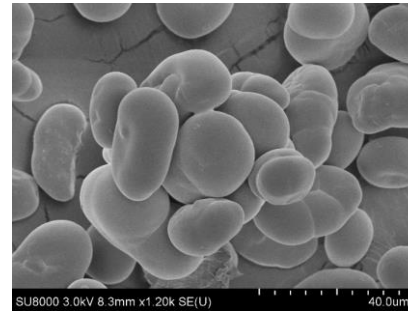
2020 SRI – Pillar 2: Food ingredient innovation

■ Starch *versus* pyrodextrin

Native pea starch



Pea pyrodextrin (4-h)



%Amylose

35.1%

1.1%

**Water
solubility**

1.1%

94.1%

Retrogradation

66.9%

Not detectable

**%Resistant
starch**

0.7%

31.8%

2020 SRI – Pillar 3: Bioconversion

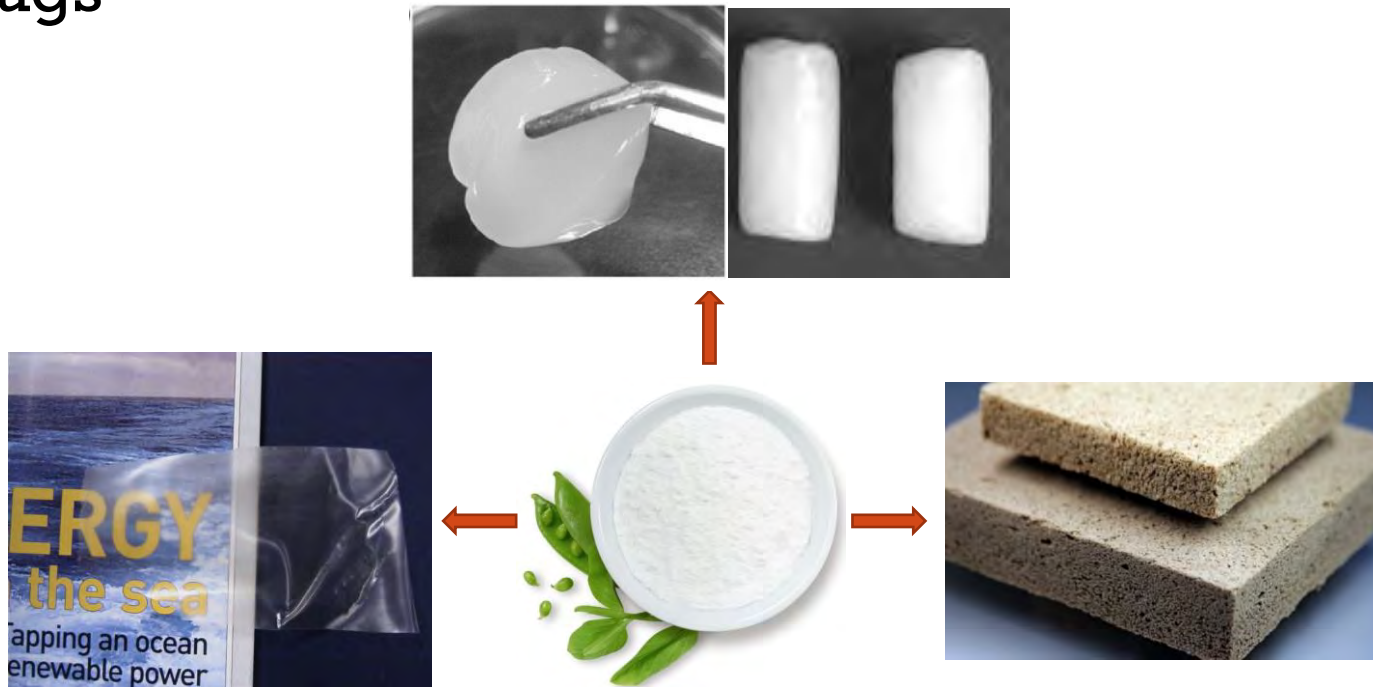
- Fermentative protein: 45-55% protein
- A “synbiotic” composition rich in both prebiotic & probiotic



Starch-rich flour
(60-80% starch)

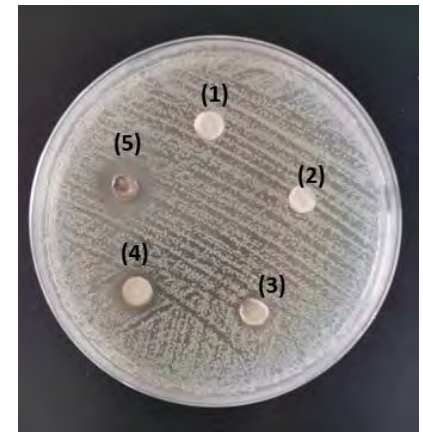
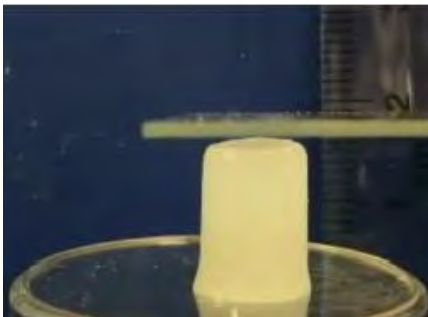
2020 SRI – Pillar 4: Biomaterials

- Biofilms for packaging materials
- Biofoams
- Biogels for encapsulating bioactive compounds and drugs



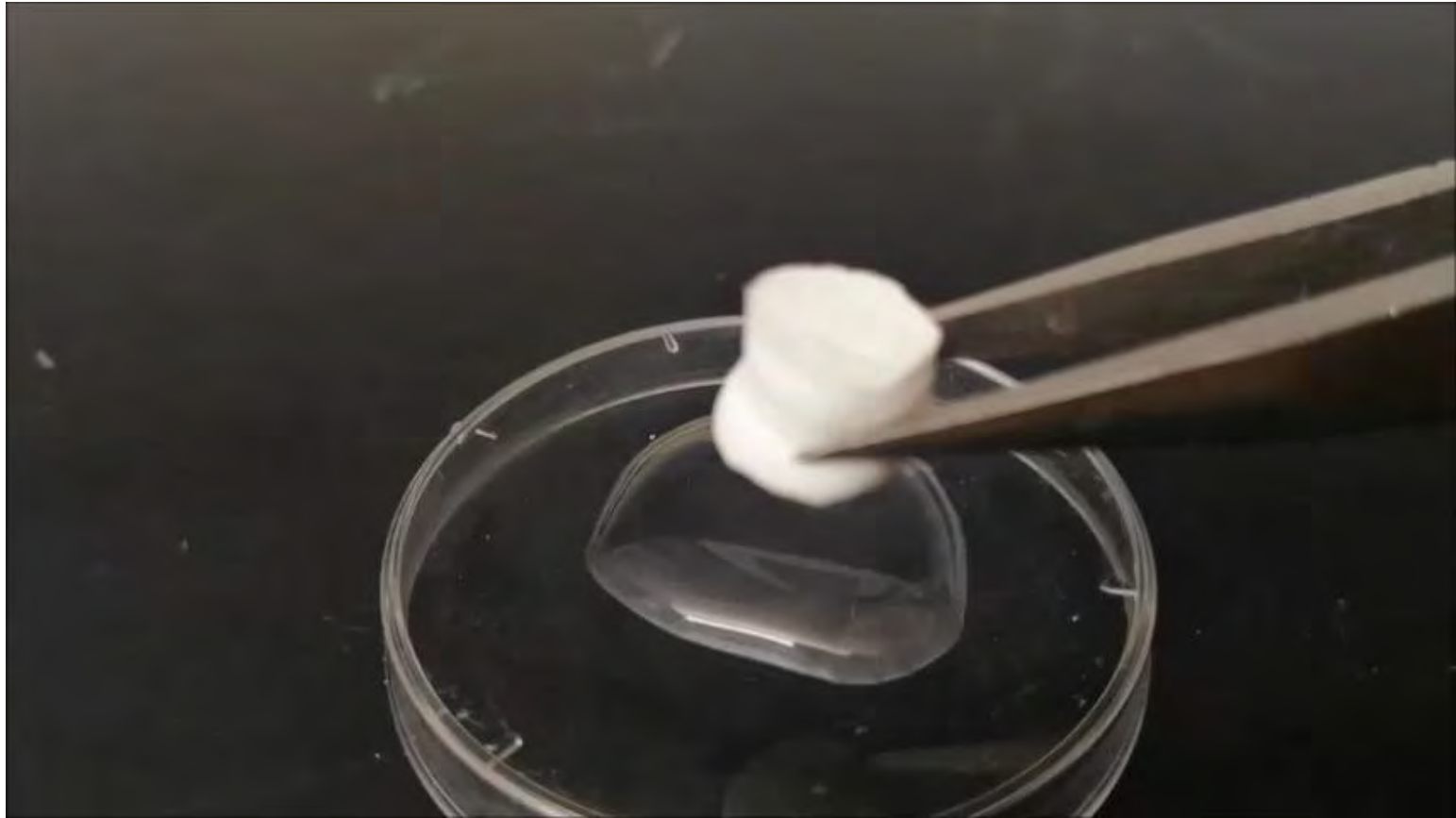
2020 SRI – Pillar 5: Biomedical materials

- Dr. Malcolm Xing (U of M)
 - Hemostasis materials
 - Bandages
 - Wound dressing and skin graft



2020 SRI – Pillar 5: Biomedical materials

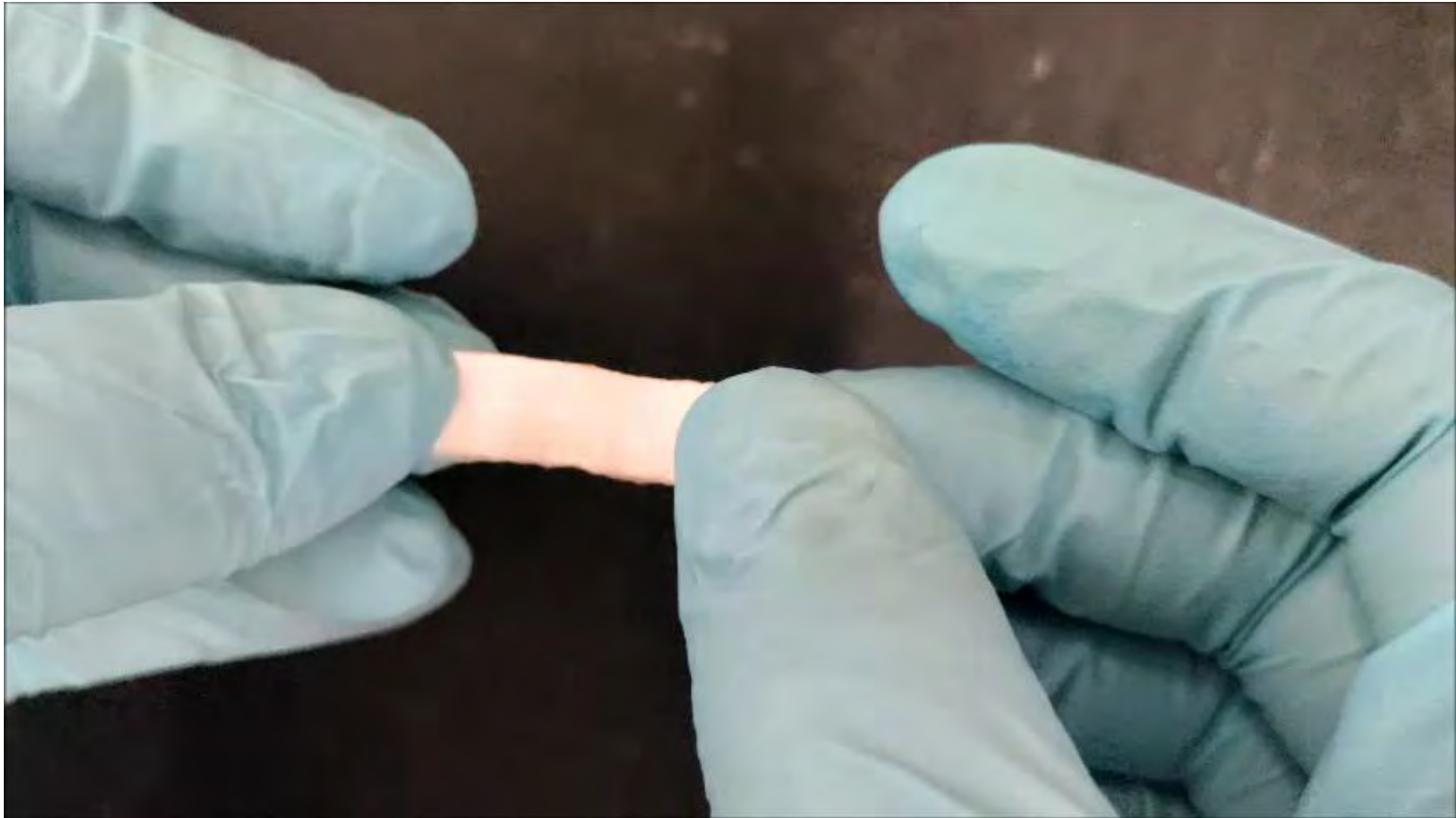
Pea-starch-based sponge recovers shape after absorbing water



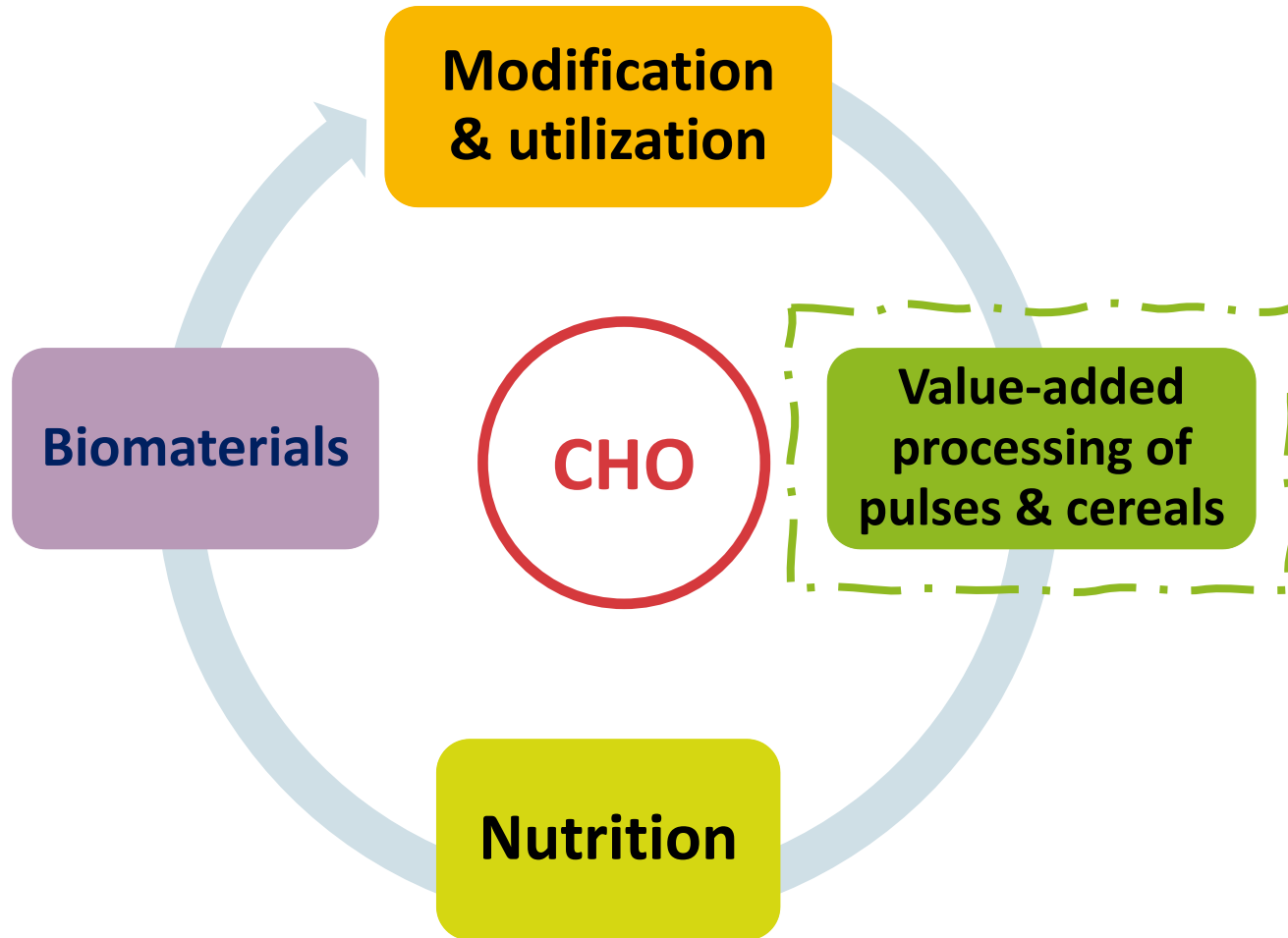
(Courtesy of Drs. Malcolm Xing and Yuqing Liu at UofM)

2020 SRI – Pillar 5: Biomedical materials

Pea-starch-based sponge strip shows excellent flexibility



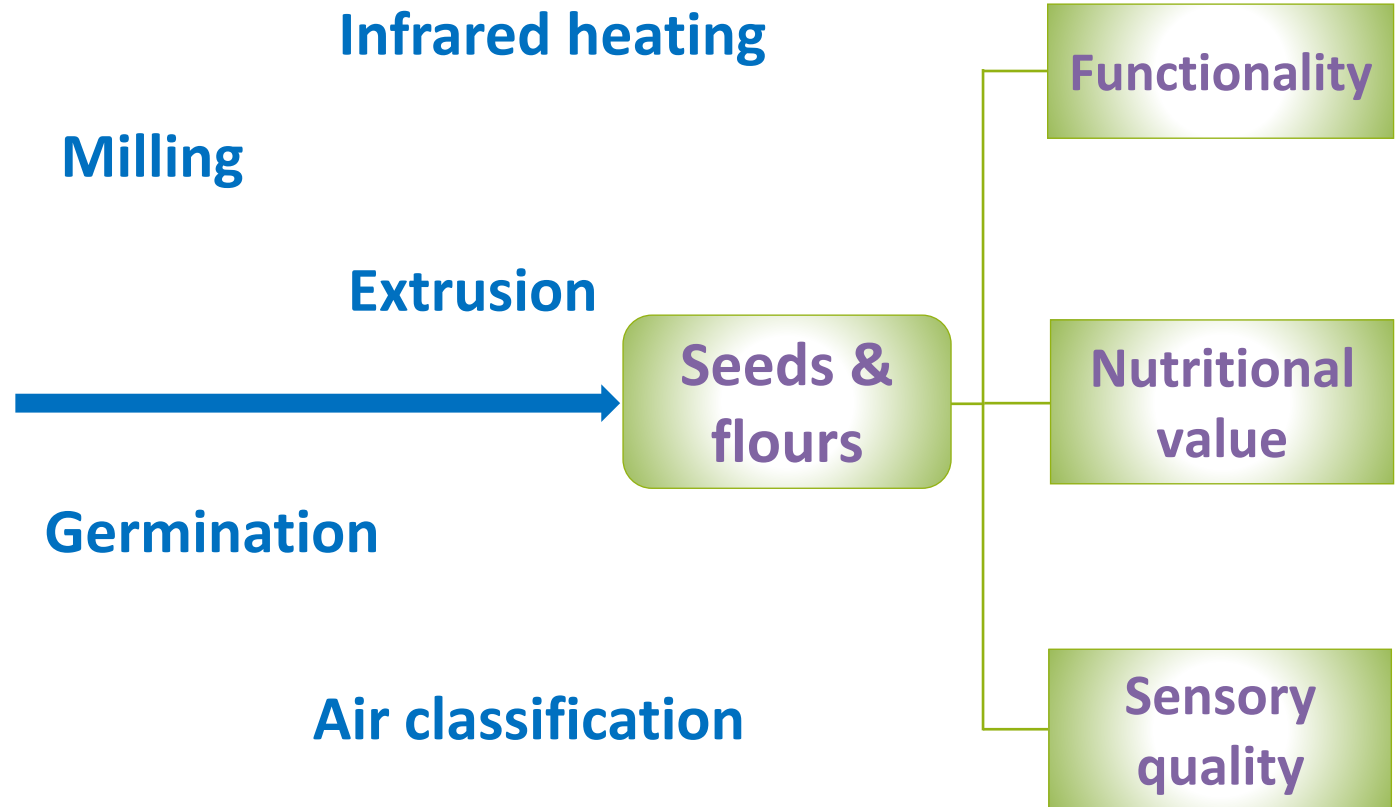
Research themes



Theme 2: Value-added processing of pulses and cereals

- Pea
- Lentil
- Faba bean
- Chickpea

- ❖ Quinoa
- ❖ Oats
- ❖ Barley
- ❖ Wheat



Infrared heating to modify pulse flours

Food Research International 136 (2020) 109568



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Contents lists available at [ScienceDirect](#)

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Influence of infrared heating on the functional properties of processed lentil flours: A study focusing on tempering period and seed size

Siyuan Liu^a, Hanyue Yin^a, Mark Pickard^b, Yongfeng Ai^{a,*}

Food Chemistry 396 (2022) 133649



ELSEVIER

Contents lists available at [ScienceDirect](#)

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Improvement of the nutritional quality of lentil flours by infrared heating of seeds varying in size

Siyuan Liu^{a,b}, Yikai Ren^a, Hanyue Yin^a, Michael Nickerson^a, Mark Pickard^c, Yongfeng Ai^{a,*}

Infrared heating to modify pulse flours



Infrared heating



Milling



Modified pulse flours

- **Gelatinized starch**
- **Denatured protein**
- **Solubilized fiber**

Extrusion



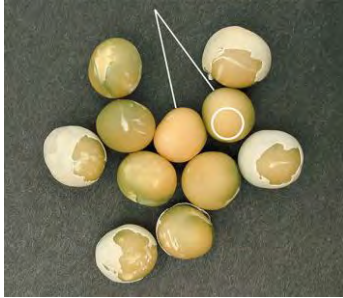
Gluten-free pasta



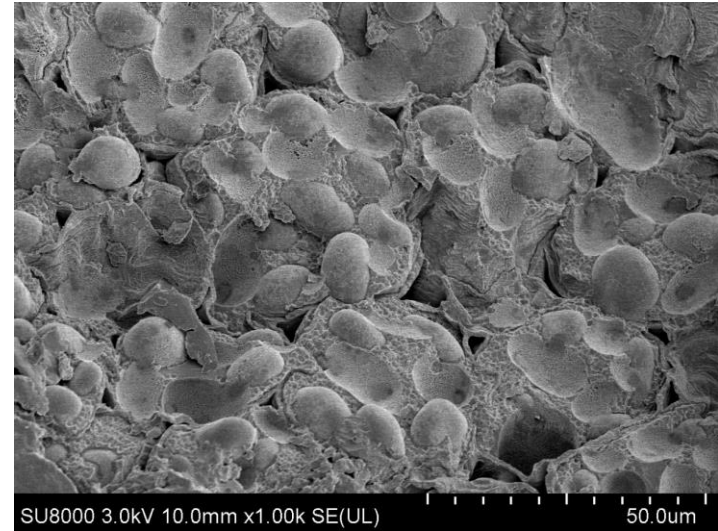
Extruded snacks

Microscopic structure of pulse cotyledons

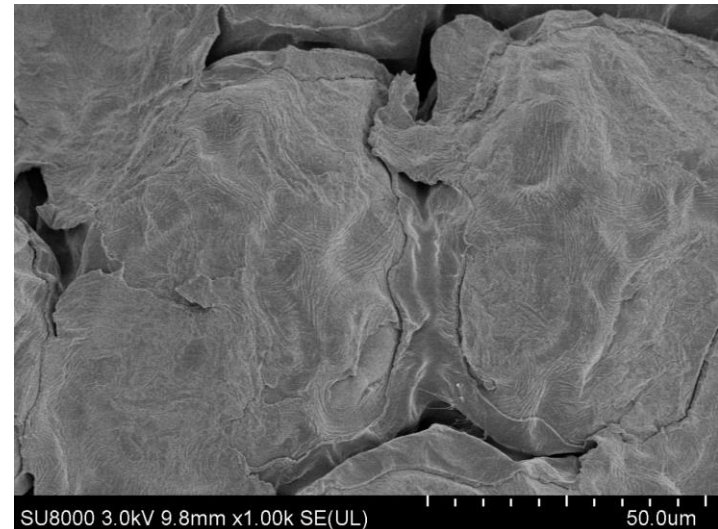
Pea



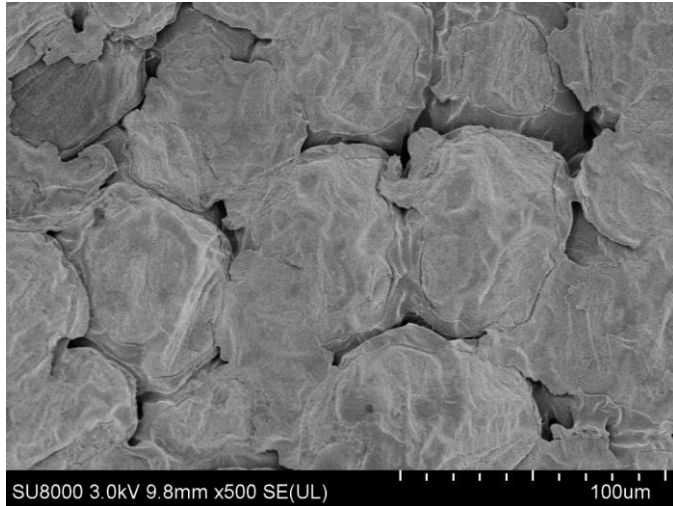
1,000 ×



Faba bean

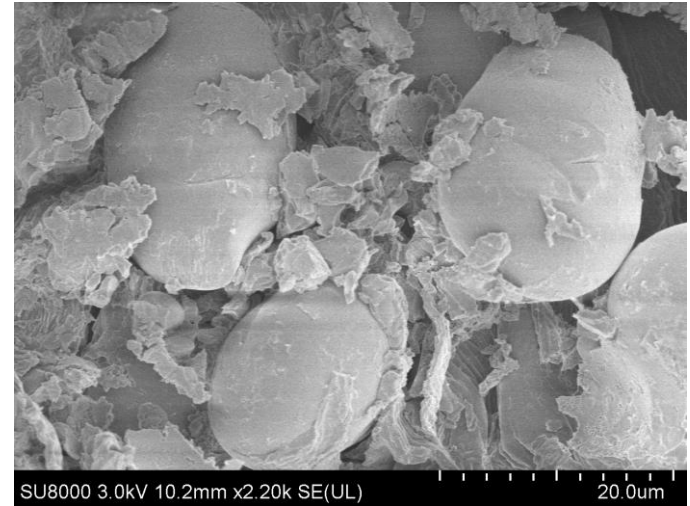


Seed pre-treatments on air classification of pulses



Pulse cotyledon

Trt.



Pre-treated



Air classification ?

Seed pre-treatments on air classification of pulses



Germination

Salt soaking

**Pin
milling**

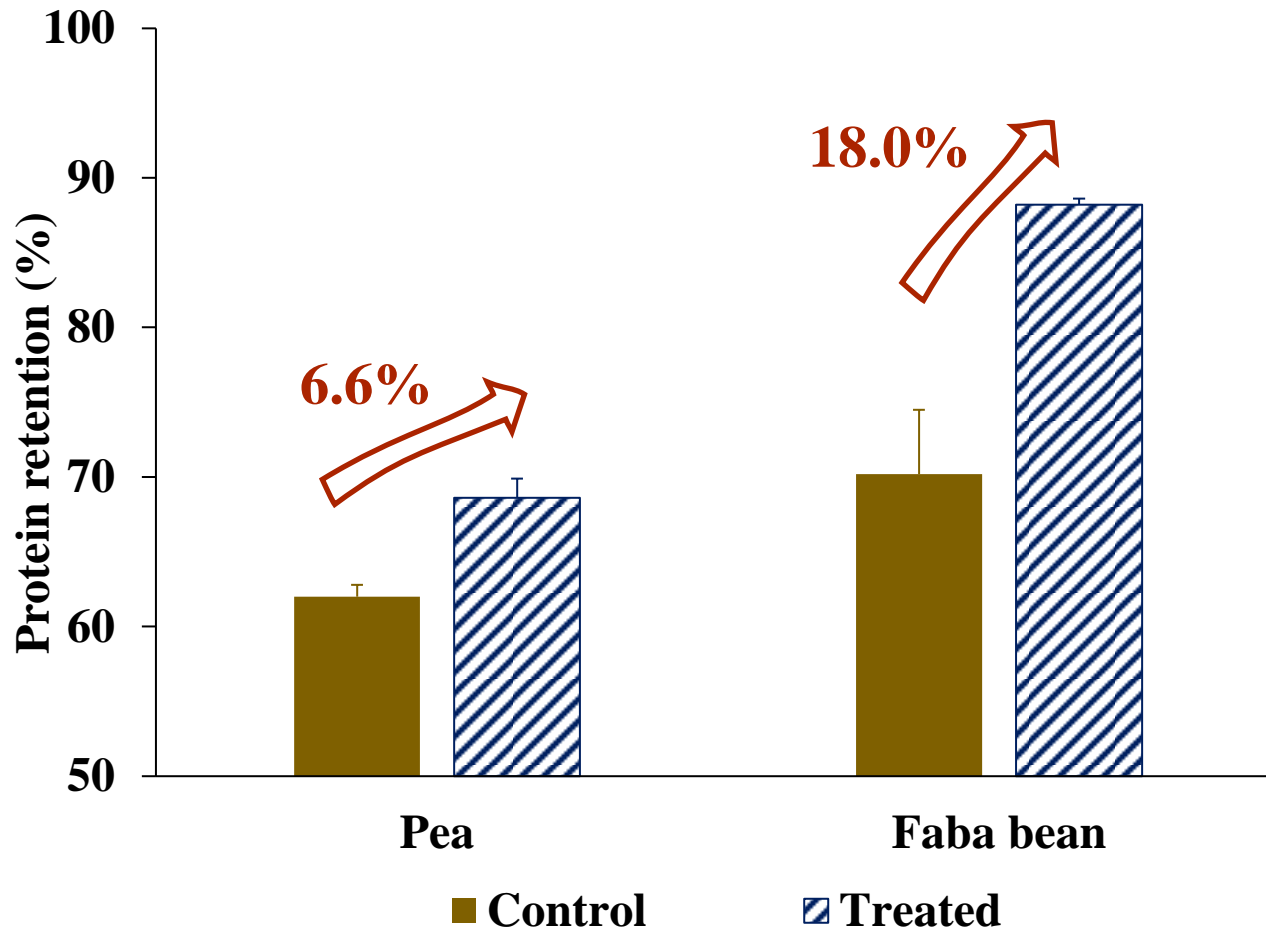
**Air
classification**

**Protein-rich
stream**

**Starch-rich
stream**

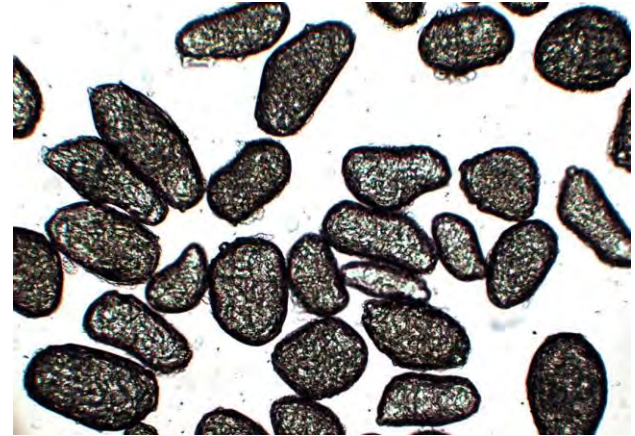
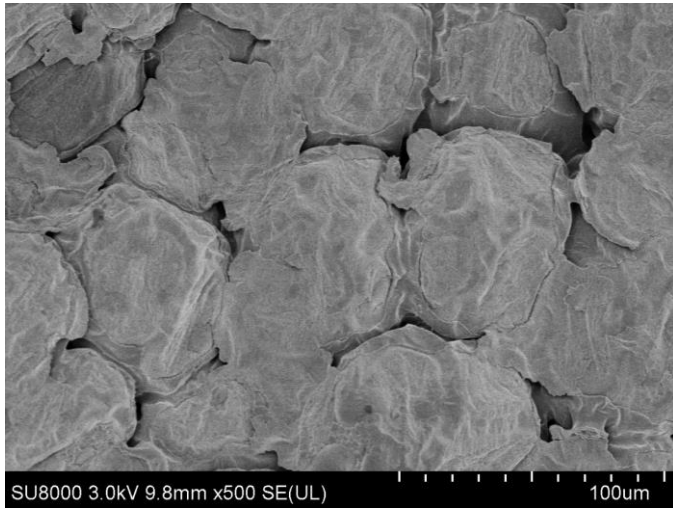


Seed pre-treatments on air classification of pulses

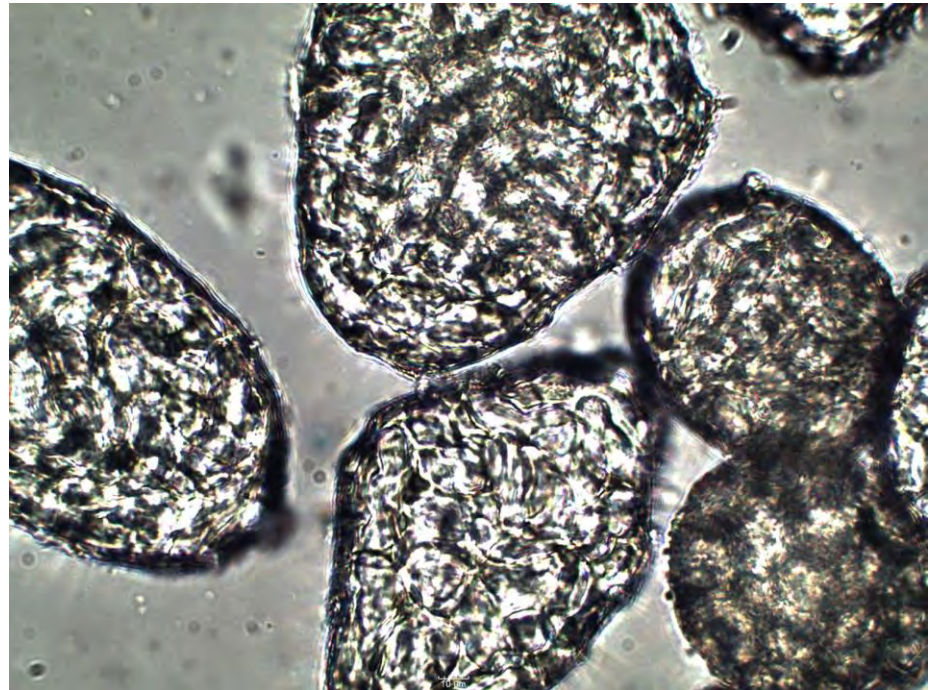


%Protein retention in protein-rich stream during air classification of control and pre-treated pea and faba bean

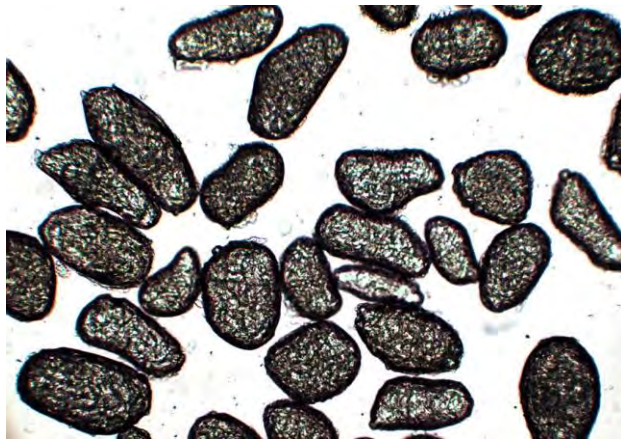
Generating “whole-cell” pulse flours



Pulse cotyledon

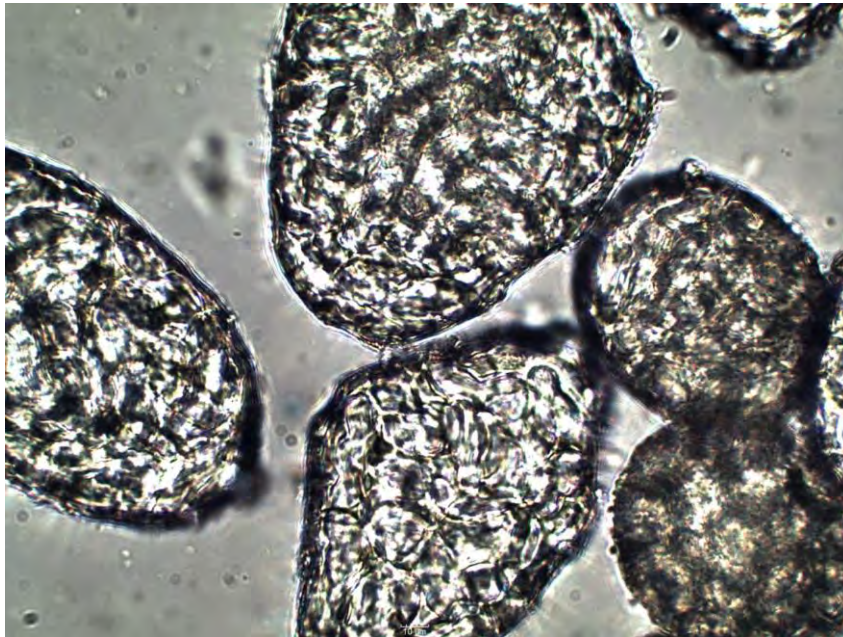


Generating “whole-cell” pulse flours

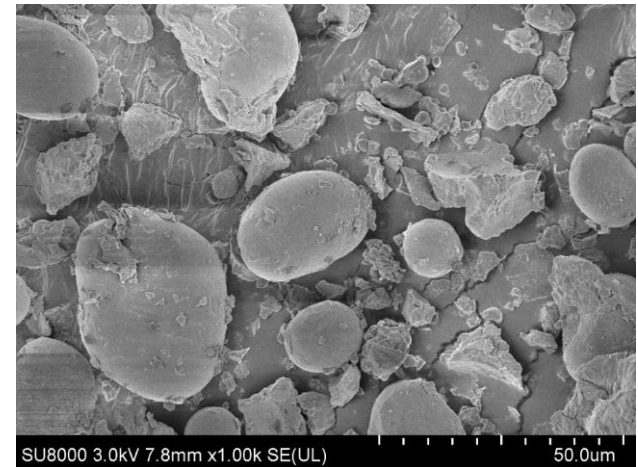


Type 1 resistant starch (RS1)

- Low-glycemic benefit
- High dietary fiber level

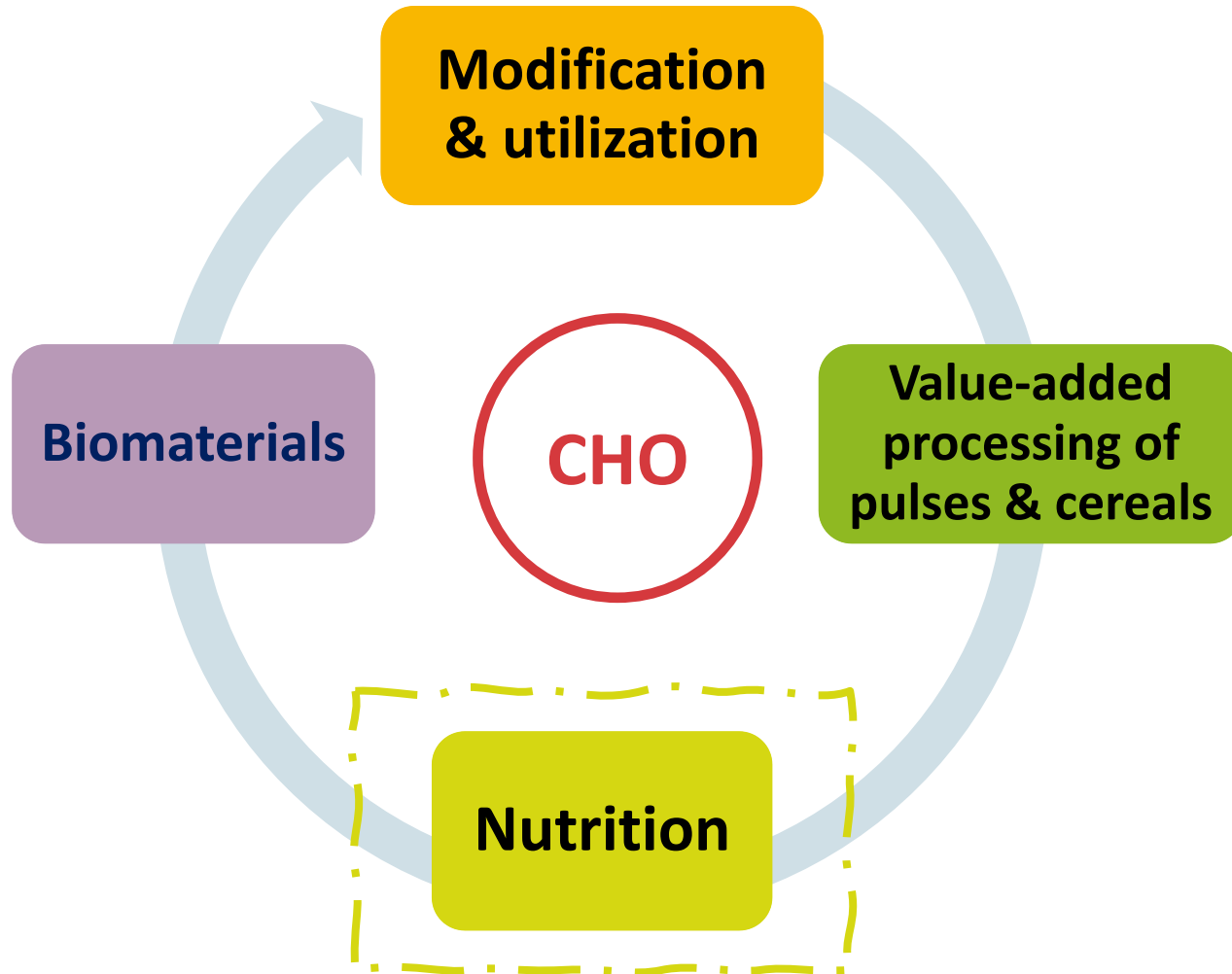


VS.



Dry-milled pulse flour

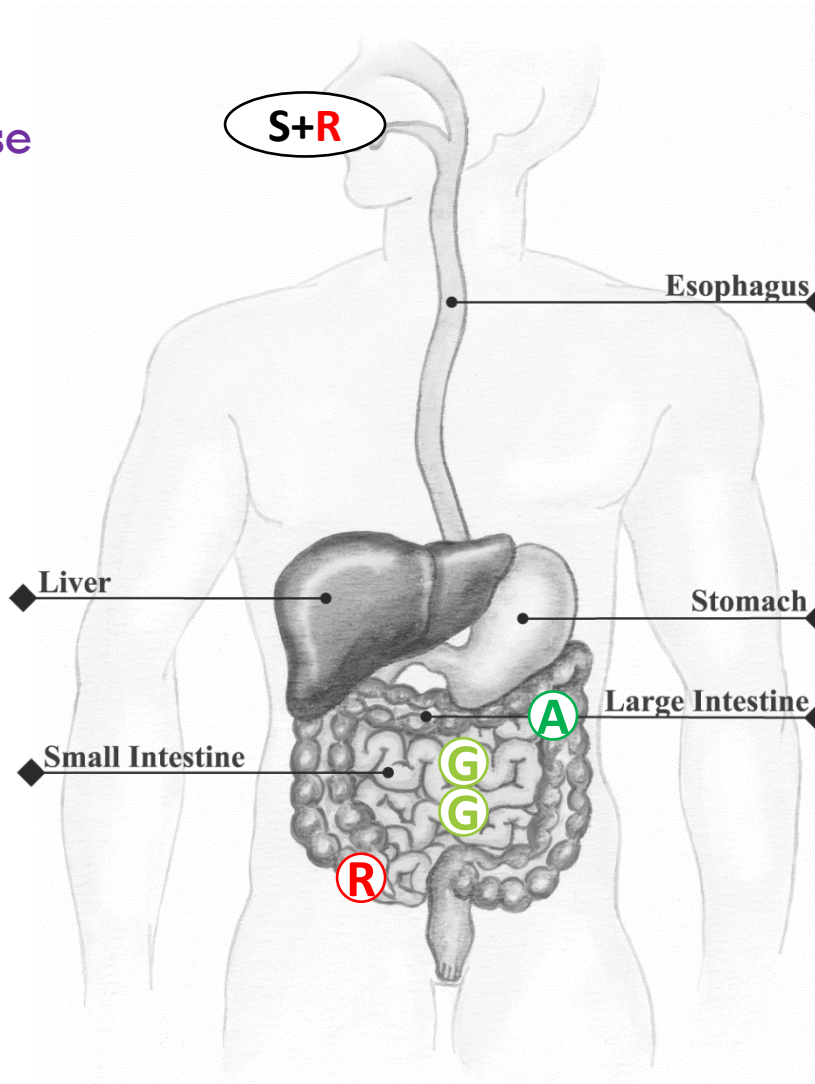
Research themes



Digestion of starch

Salivary α -amylase

Pancreatic α -amylase
Glucoamylase
Maltase
Sucrase
Isomaltase



Ⓢ Starch

ⓖ Glucose

Ⓡ Resistant starch

ⓐ Short-chain fatty acids

Factors influencing starch digestibility

- Amylose content
- Presence of protein & dietary fiber
- Starch entanglement
- Interaction with lipids
- Chemical derivatives
- ...

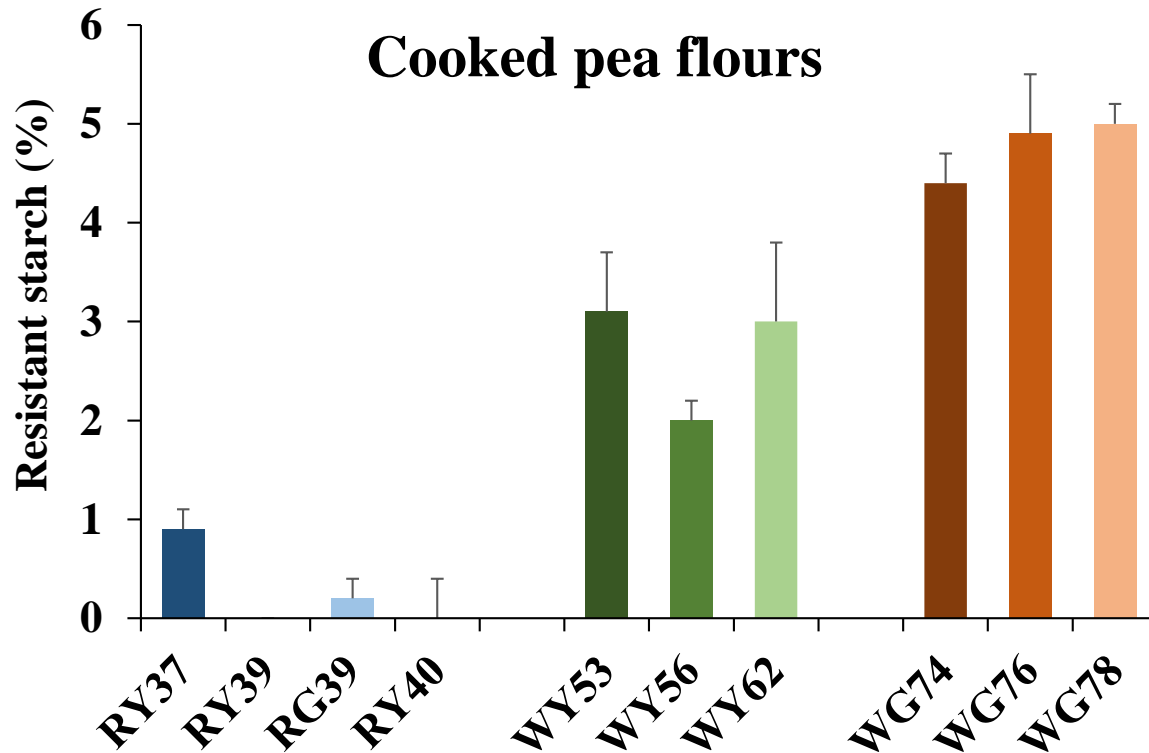
Factors influencing starch digestibility

- Amylose content
- Presence of protein & dietary fiber
- Starch entanglement
- Interaction with lipids
- Chemical derivatives
- ...

Factors influencing starch digestibility

■ Amylose content

%Resistant starch, dry flour basis



%Amylose

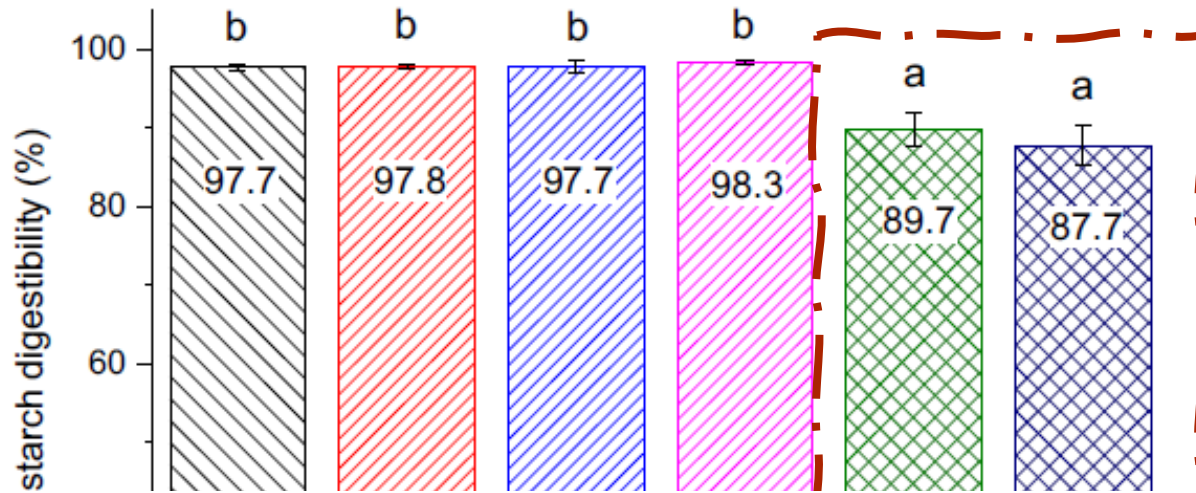
37-40%

53-62%

74-78%

Pearson correlation: $r = 0.952$, $p < 0.001$

Total tract apparent starch digestibility of diets formulated with rice, normal pulse, and high-amylose wrinkled pea flours in beagles



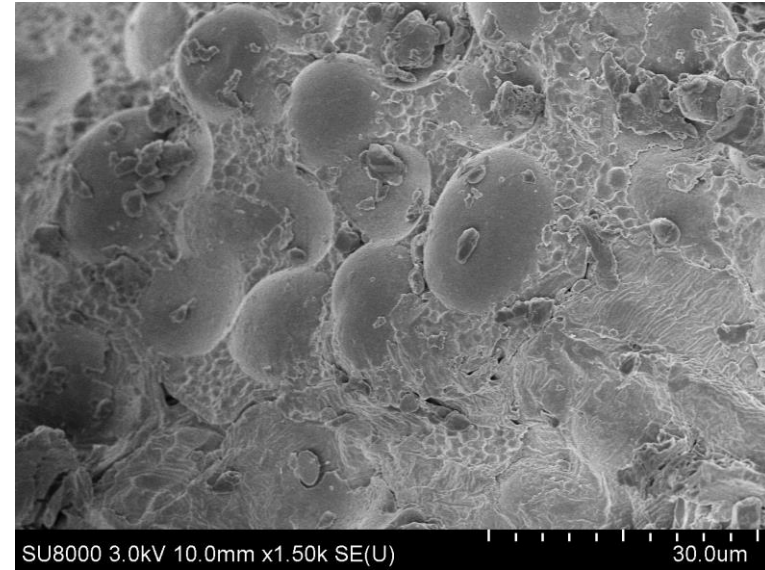
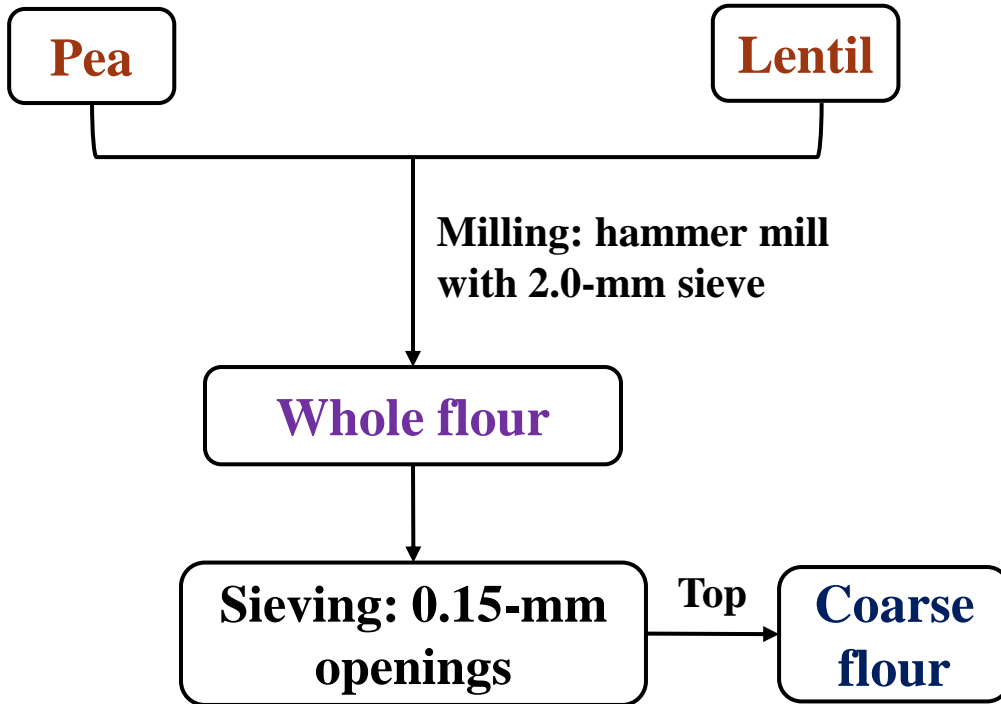
Pearson correlation: $r = -0.966$, $p < 0.01$



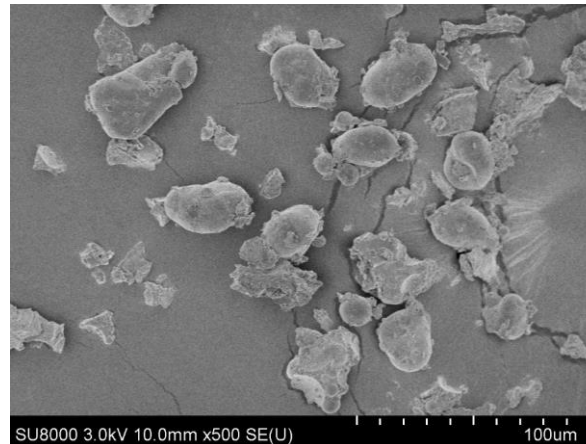
* Values with the same letter are not significantly different at $p < 0.05$.

Factors influencing starch digestibility

- Presence of protein & dietary fiber



10.0-14.3% RS



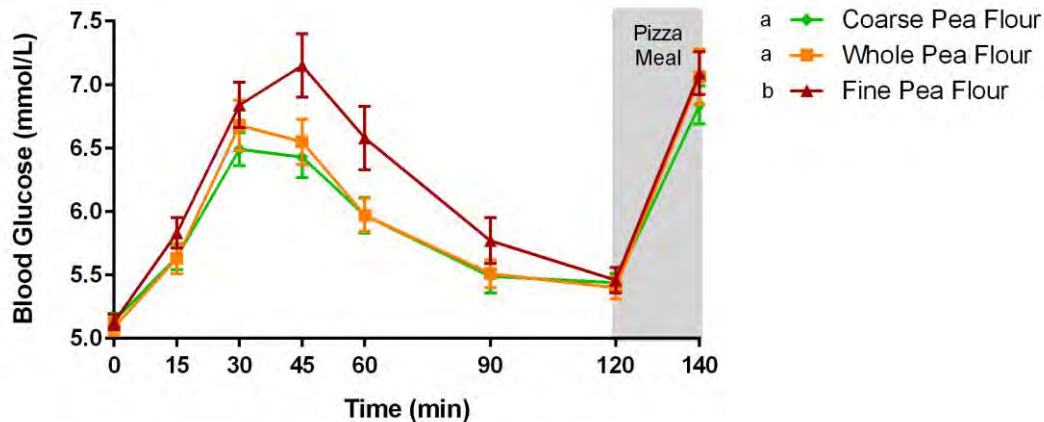
3.6-5.6% RS

(Cheng et al., *Food Chemistry*.
Under review)

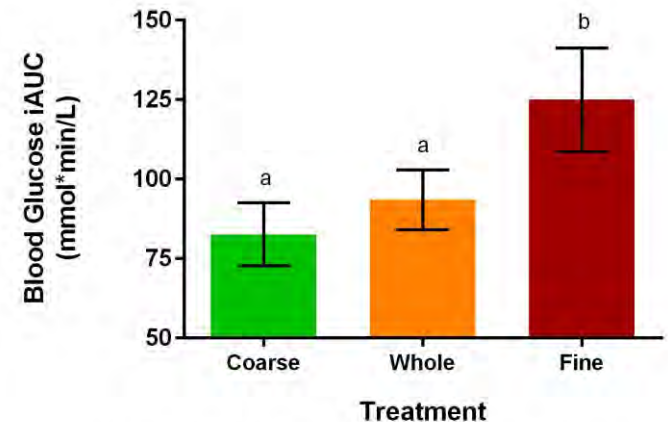
Factors influencing starch digestibility

■ Presence of protein & dietary fiber

- Adding coarse and whole pea flours to crackers at 20% inclusion level reduced glycemic response



Values are mean \pm SEM; n=20. Means with different letters are significantly different. Two-way ANCOVA (treatment, $p < 0.002$; time, $p < 0.0001$; treatment*time, NS).



Values are mean \pm SEM; n=20. Means with different letters are significantly different. One-way ANOVA (treatment, $p < 0.002$).

Take-away messages

- **Structure-function-nutrition approach** is the most effective for us to identify new opportunities to utilize carbohydrates in SK crops with significant value addition.
- To elucidate **interactions among starch, protein, dietary fiber, and lipids** is important to maximize the functional and nutritional value of the different components.
- **Collaborations with academic and industrial researchers** will allow us to expand our research scope and explore more promising directions.

- Financial support:





Email: yongfeng.ai@usask.ca

