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Canada

BARLEY-BASED FUNCTIONAL FOODS IN HEALTH AND NUTRITION

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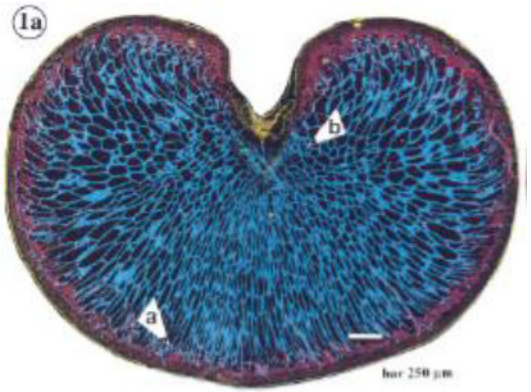
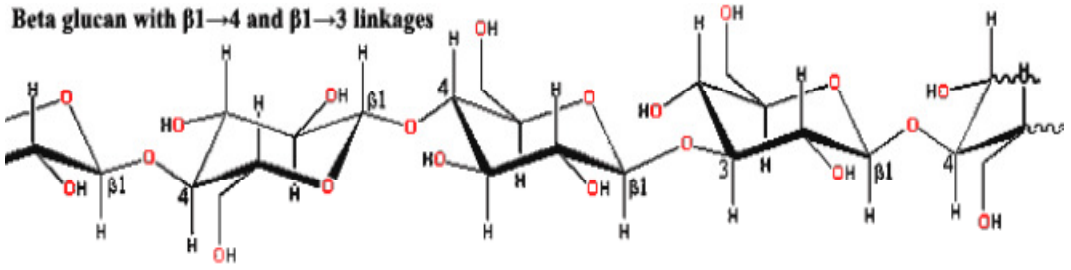
Outline

- ❖ Barley Functional Food
  - Barley characteristics
  - Barley health claim
  - Barley food status
- ❖ Health Benefits of Barley
  - Glycaemia
  - Satiety

BARLEY CHARACTERISTICS

- ✓ Rich source of β-glucan
- ✓ Low GI
- ✓ Rich source of antioxidants
- ✓ Long history of food use
- ✓ 5th major crop worldwide
- ✓ Now available in assorted forms and compositions





Barley Composition[a]

Component	%, dry weight
Starch	60-64
Amylose	2.9-30.9[b]
β-Glucans	3.6-6.1 (4.3-11.2)[b]
Arabinoxylans	4.4-7.8
Cellulose	1.4-5.0
Sugars	0.4-2.9
Oligosaccharides	0.2-1.8
Proteins	8-15
Lipids	2-3
Minerals	2.3
Vitamins	B-complex, E, etc.

[a]MacGregor 1993.
[b]Gray et al. 2009, Cereal Chem., 86, 669.

Dietary Fiber in Cereals

Cereal	%, dry weight
Rye	15.1
Triticale	14.6
Wheat	12.2
Dehulled oats	10.6
Dehulled barley	10.1
Canary seed	8.7
Millet	8.5
Corn	7.3
White sorghum	6.3
Brown rice	4.6

USDA 2010

BARLEY HEALTH CLAIM

Canada Health Claim

- **Linking barley grain products to a reduction of blood cholesterol**

- The claim is relevant and generally applicable to the Canadian population given that a high proportion of the population (approximately 40% of Canadian adults aged 20 to 79) has unhealthy total cholesterol levels (>5.2 mmol/L), putting them at an increased risk for heart disease.

USA - FDA Health Claim

- **Associating Consumption of Barley Products with Reduction of Risk of Coronary Heart Disease**

- The claim allows foods containing barley to claim that they reduce the risk of coronary heart disease (whole grain barley and dry milled barley products such as flakes, grits, flour, and pearled barley, which provide at least 0.75 grams of soluble fiber per serving)

European Food Safety Authority (EFSA)

- **Linking barley beta-glucans with lowering blood cholesterol, which may reduce the risk of (coronary) heart disease**

- The target population proposed by the applicant is adults with normal or mildly elevated blood cholesterol concentrations

STATUS OF BARLEY FOOD

Pot Barley

Pearl Barley

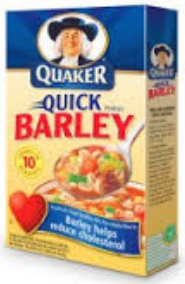
Barley Flour

Barley Flakes

Barley Grits

WG Barley

Breakfast Cereals



Baked Foods

Organic Foods

Mix Dishes & Soups

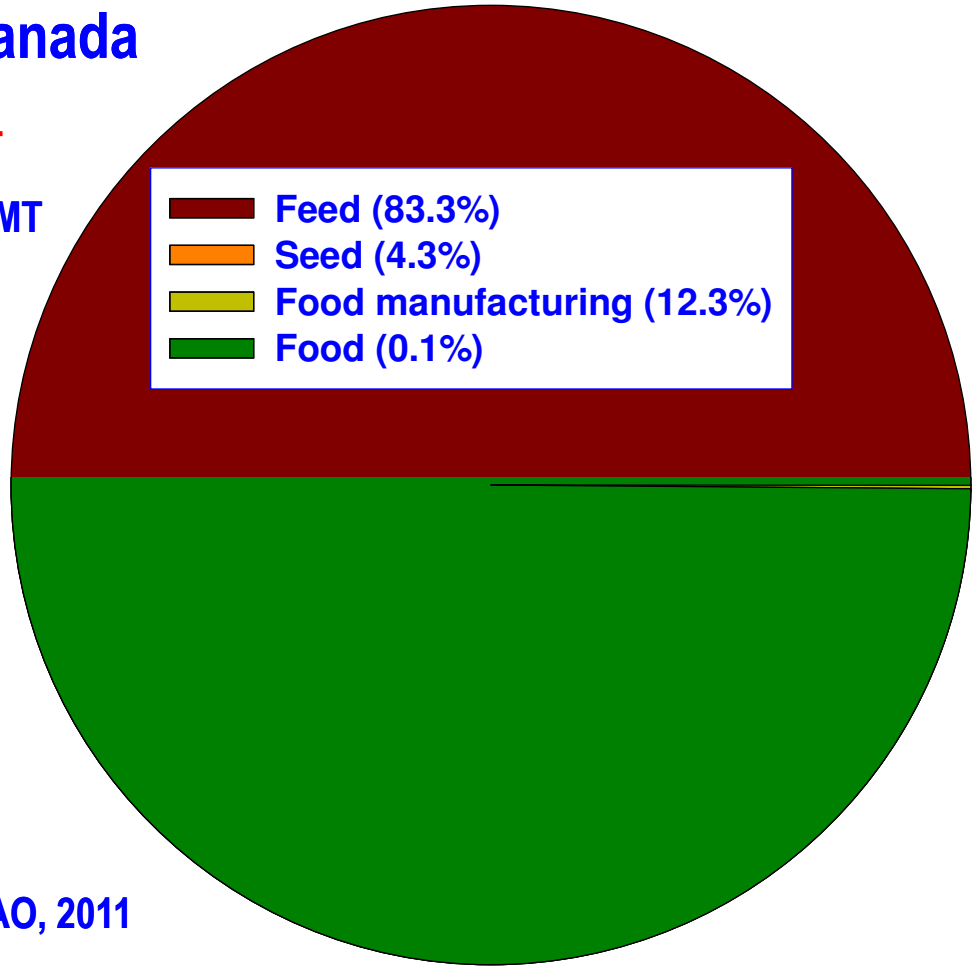
Supplements

Beverages

Barley Use in Canada

Total production: 7.8 MT

Total domestic use: 6.0 MT

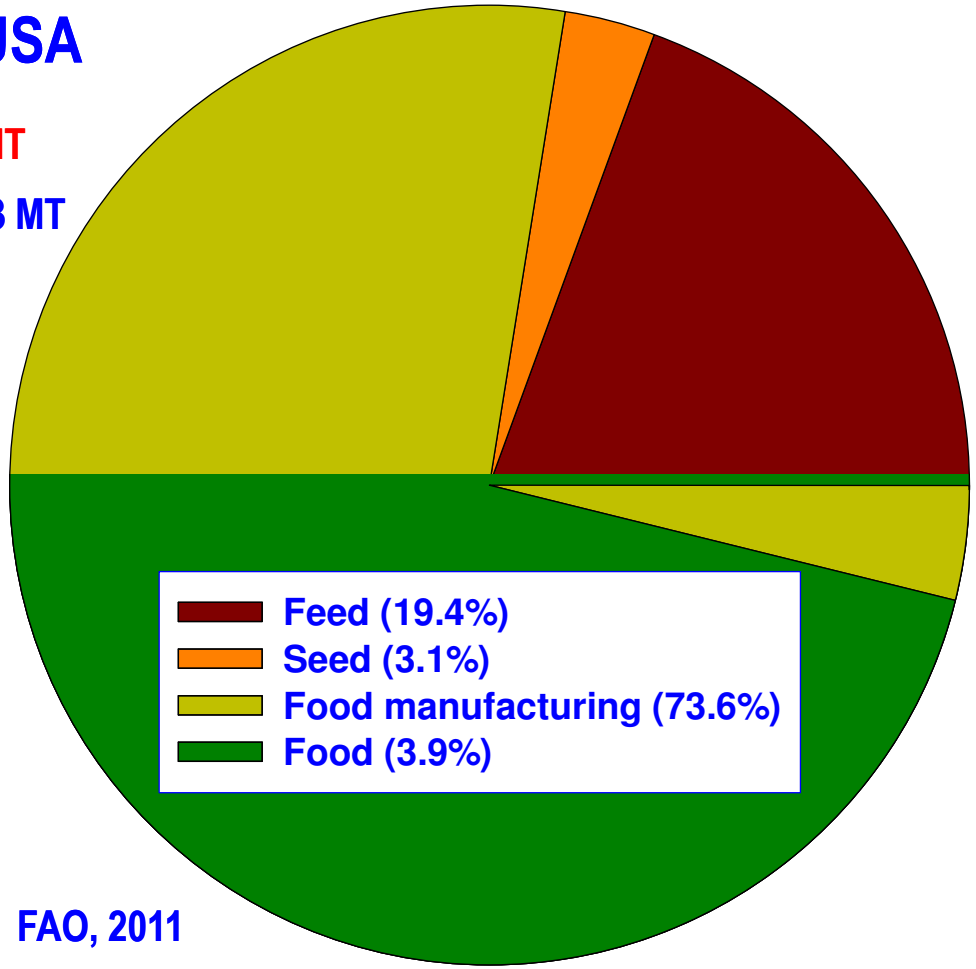


FAO, 2011

Barley Use in USA

Total production: 3.4 MT

Total domestic use: 4.3 MT

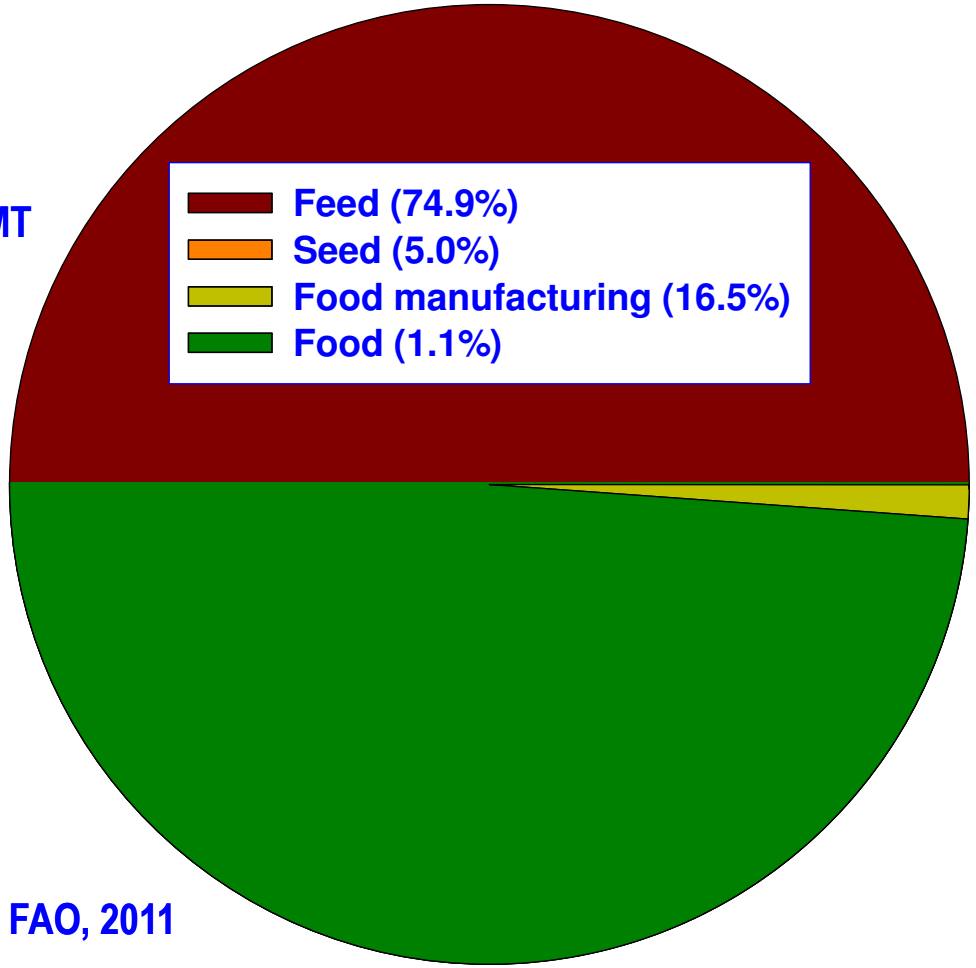


FAO, 2011

Barley Use in EU

Total production: 51.9 MT

Total domestic use: 49.3 MT

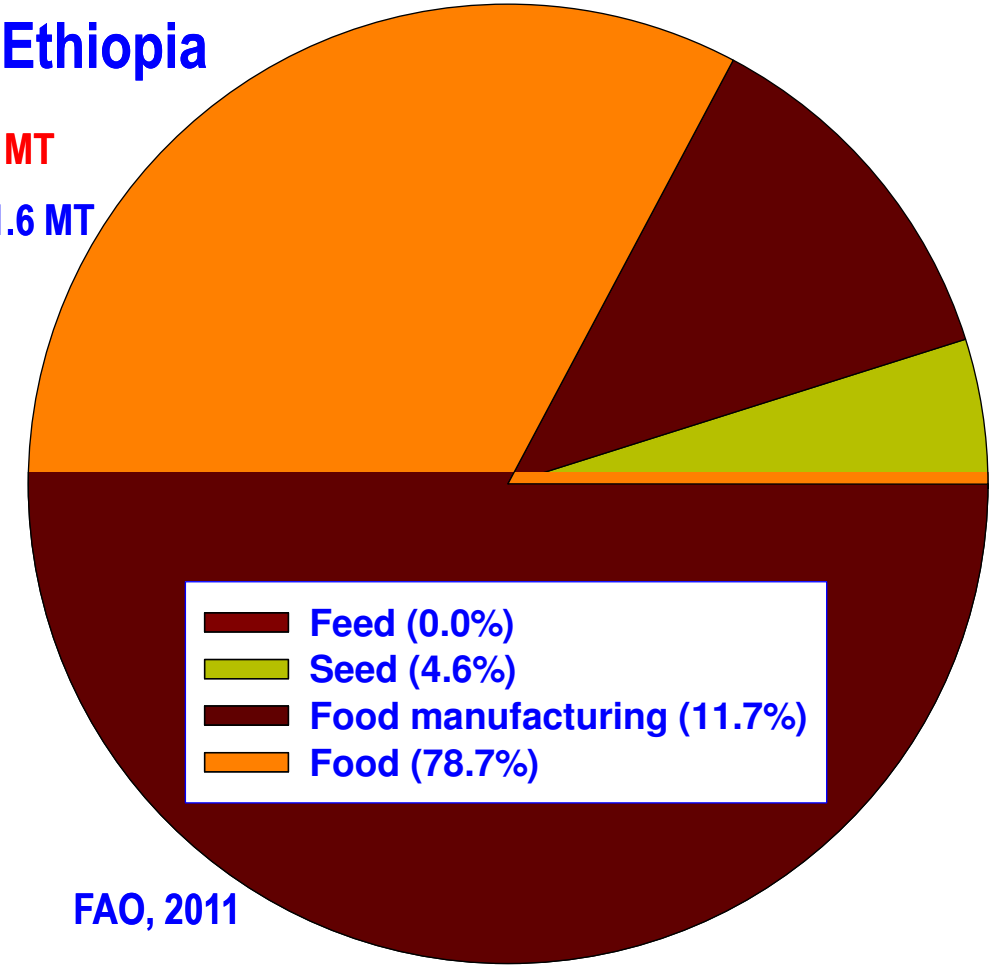


FAO, 2011

Barley Use in Ethiopia

Total production: 1.6 MT

Total domestic use: 1.6 MT

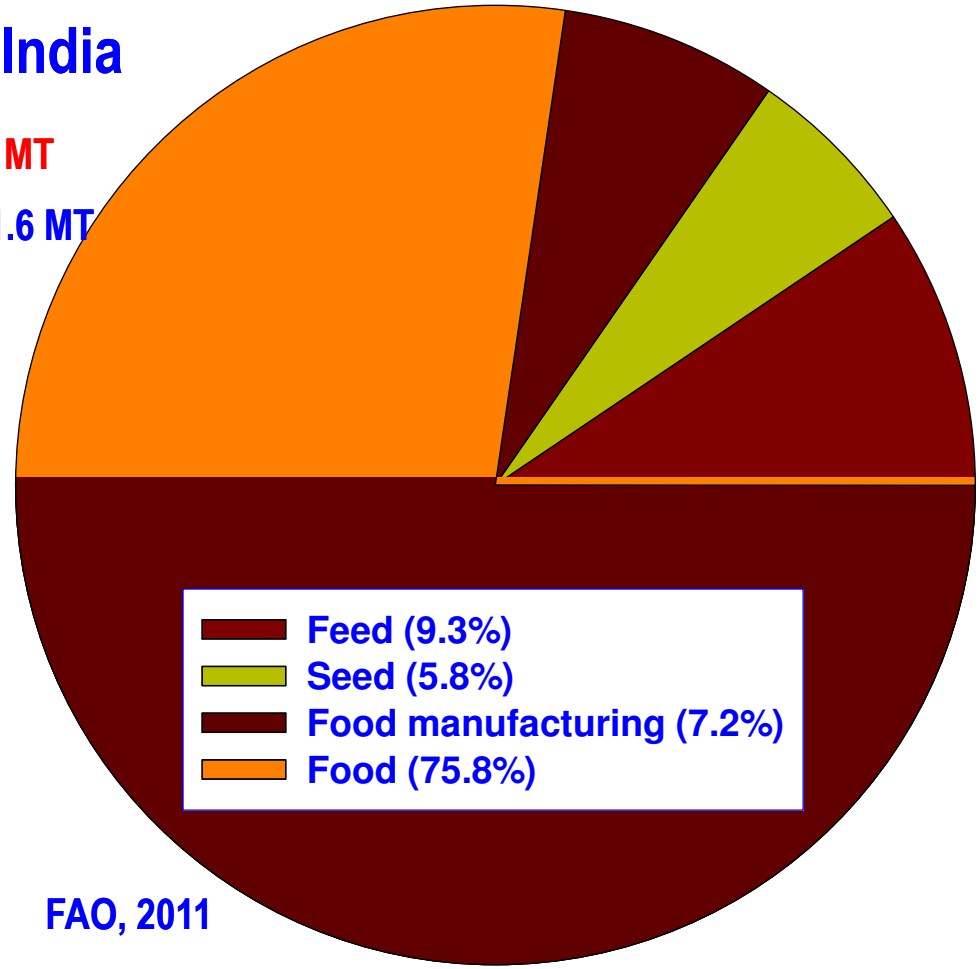


FAO, 2011

Barley Use in India

Total production: 1.7 MT

Total domestic use: 1.6 MT

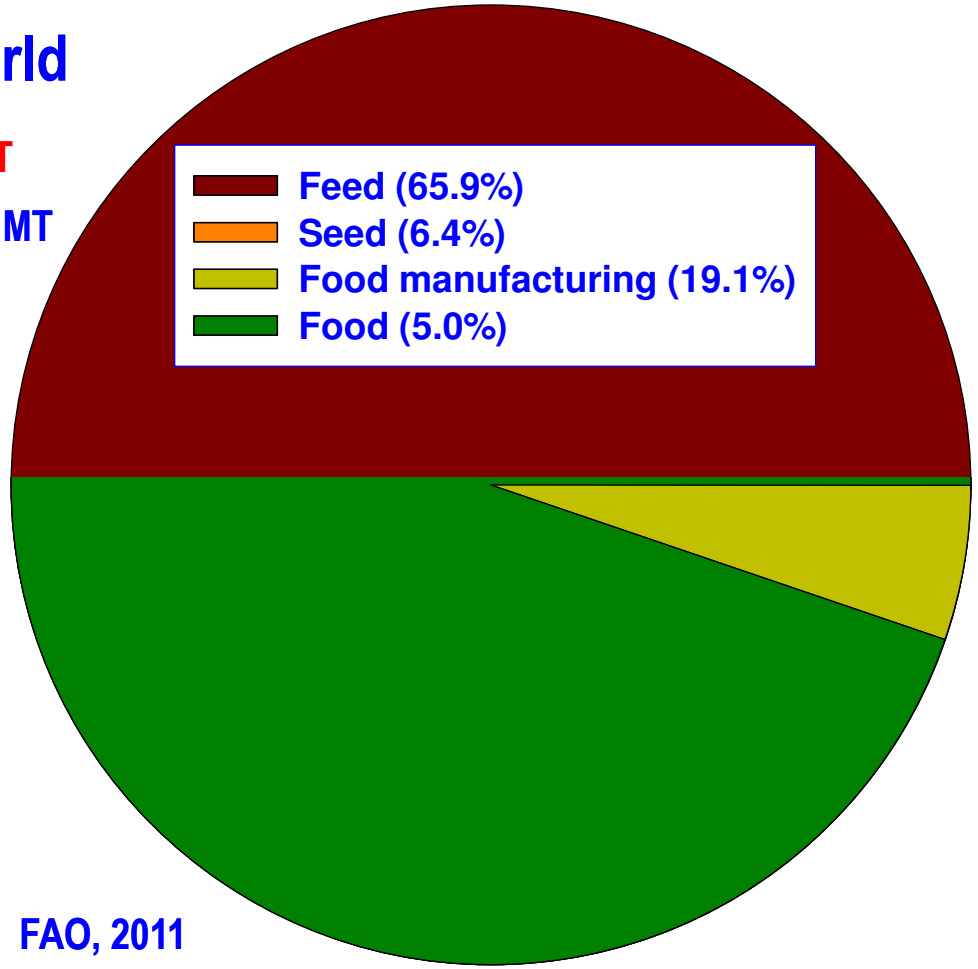


FAO, 2011

Barley Use in World

Total production: 132.9 MT

Total domestic use: 135.6 MT



FAO, 2011

Constraints to Barley Food Development

- Lack of international policies to encourage barley use for human food
- Lack of quality parameters
- Shortage of improved varieties for food barley
- Lack of quality research on food barley

EFFECTS OF BARLEY ON GLYCAEMIA AND SATIETY

CLINICAL STUDIES

1st study

- Effect of pearling on glycemic response and GI,
- 3 barley foods, 2 barley fractions (wholegrain, white pearl)
- 10 healthy participants, BMI 27.6

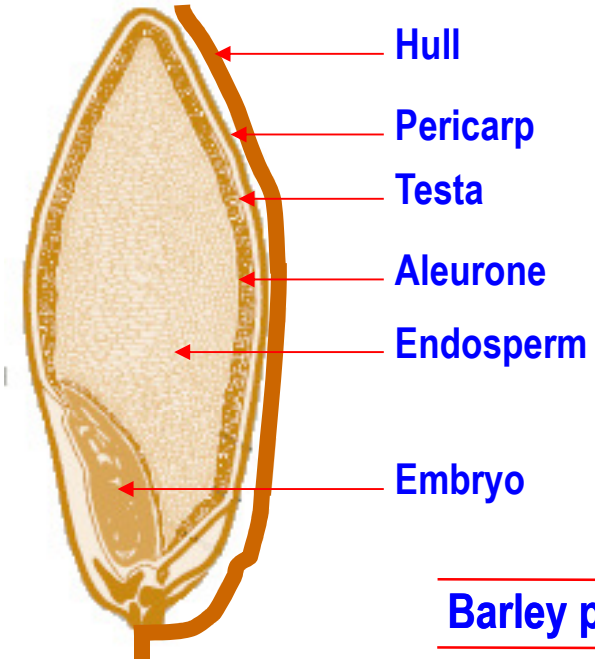
2nd study:

- Effect of barley cultivar and composition,
- 7 wholegrain foods, 1 commercial, pot and pearl food
- 10 healthy participants, BMI 26.4

3rd study

- Effect of pasta processing,
- 2 barley pastas, semolina pasta as control
- 10 healthy participants, BMI 28.3

BARLEY PEARLING



Pearling process: Sequential removal of kernel outer layers and germ

Barley product	Time (min)	% Removal
Whole grain	0.9-1.0	11-12
Commercial	2.0-2.3	17-18
Pot	3.0-3.3	22-24
White pearl	4.5-5.8	31-34

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Barley Cultivars

Cultivar	Type
AC Parkhill	2 row, hulled, normal
Chief	2 row, hulled, normal
GB992027	2 row, hulled, normal
AC Klink	6 row, hulled, normal
Celebrity	6 row, hulled, normal
OAC Kawartha	6 row, hulled, normal
AC Alberta	2 row, hulless, normal
CDC Fibar	2 row, hulless, waxy
CDC Rattan	2 row, hulless, waxy

Composition of Barley Foods

Component	%, dry weight
Starch	52.4-66.6
Amylose	2.9-30.9
β-Glucan	4.3-11.2
Soluble dietary fiber	2.2-7.9
Insoluble dietary fiber	7.4-17.7

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Barley Food Forms

Food cooking/processing
Food form
Starch characteristics
Fiber content
β-glucan content

Glycemic response
Glycemic index
Satiety index
Viscosity
β-glucan MW
β-glucan Solubility

BARLEY GLYCAEMIA

TABLE 1 The iAUC and GI of 3 barley cultivars processed (pearled) in 2 different ways: Expt. 1[1]

	iAUC			GI		
	Fraction			Fraction		
Barley cultivar	WG	WP	Mean	WG	WP	Mean
	mmol × *min/L*					
Celebrity	71 ± 20	88 ± 14	79 ± 16[a,b]	25 ± 4	33 ± 3	29 ± 3[a,b]
AC Parkhill	85 ± 21	109 ± 19	97 ± 19[a]	30 ± 5	41 ± 5	35 ± 4[a]
CDC Fibar	61 ± 16	78 ± 11	69 ± 13[b]	22 ± 4	30 ± 3	26 ± 3[b]
Mean of cultivars	72 ± 18	91 ± 14*	—	26 ± 4	35 ± 3*	—
White bread	—	—	189 ± 22[§]	—	—	71[§]

[1] Values are means ± SEM for $n = 10$ participants. There was a significant main effect of cultivar. Means without a common superscript letter differ, $P < 0.05$. *Significant main effect of pearling level, $P < 0.05$. [§]White bread differed from all barley test meals, $P < 0.05$. There was no significant cultivar × pearling interaction for iAUC or GI. GI, glycemic index; iAUC, incremental AUC; WG, whole-grain; WP, white pearled.

TABLE 2 The iAUC and GI of 7 barley cultivars: Expt. 2[1]

Barley cultivar[2]	iAUC	GI
	mmol × min/L	
Celebrity	48 ± 9[b]	21 ± 4[b]
Chief	65 ± 11[b]	29 ± 4[b]
Rattan	58 ± 12[b]	26 ± 6[b]
AC Klinck	71 ± 12[b]	36 ± 8[b]
Kawartha	61 ± 10[b]	28 ± 4[b]
AC Alberta	63 ± 13[b]	29 ± 7[b]
GB	52 ± 10[b]	24 ± 5[b]
White bread	163 ± 15[a]	71[a]

[1] Values are means ± SEM for n = 10 participants. Means without a common superscript letter differ, $P < 0.05$. GI, glycemic index; iAUC, incremental AUC.
[2] Cultivars were processed to remove the husk only (whole-grain).

TABLE 3 The iAUC and GI of 2 fractions of pearled barley pasta and semolina pasta: Expt. 3[1]

	iAUC			GI		
	Fraction			Fraction		
Barley cultivar	WG	WP	Mean	WG	WP	Mean
	mmol × min/L					
Celebrity pasta	137 ± 17	115 ± 17	126 ± 14	71 ± 6	58 ± 4	64 ± 4
AC Parkhill pasta	141 ± 17	127 ± 12	133 ± 13	73 ± 7	64 ± 4	69 ± 3
Mean of cultivars	139 ± 14	121 ± 13*	—	72 ± 4	61 ± 3*	—
Semolina pasta	—	—	151 ± 20	—	—	78 ± 8
White bread	—	—	142 ± 16	—	—	71

[1] Values are means ± SEM, n = 10 participants. Pasta was made from 2 barley cultivars pearled in 2 different ways with semolina pasta as a control. *Significant main effect of pearling level, $P < 0.05$. There was no significant main effect of cultivar and no significant cultivar × pearling interaction for iAUC or GI. GI, glycemic index; iAUC, incremental AUC; WG, whole-grain; WP, white pearled.

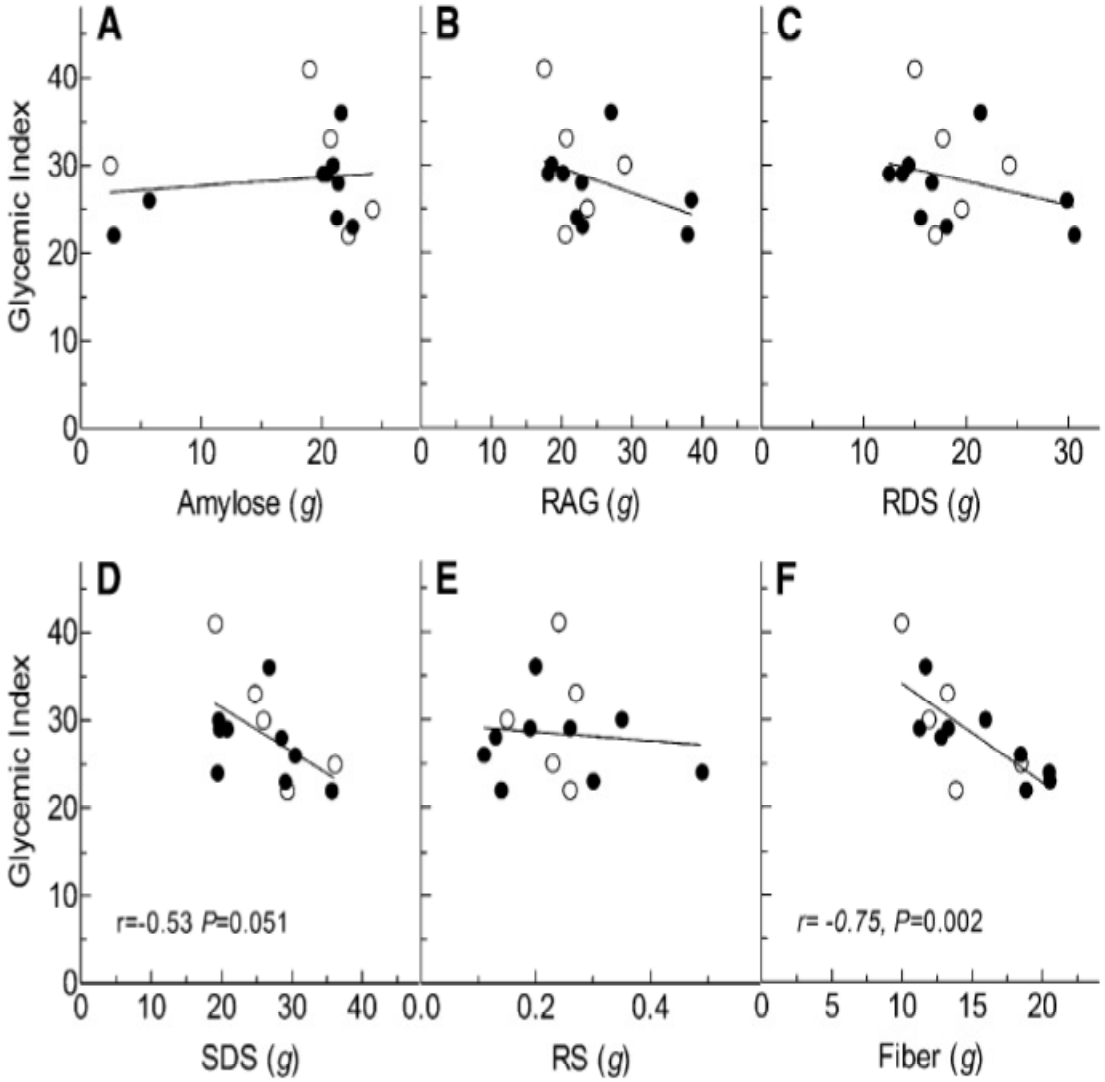

FIGURE 1 Correlations between the GI and amounts of amylose (*A*), RAG (*B*), RDS (*C*), SDS (*D*), RS (*E*), and total fiber (*F*) in whole-grain and pearled barley consumed by $n = 6$ (Expt. 1) or $n = 2$ (Expt. 2) healthy participants. *Filled circles*, whole-grain barley; *open circles*, pearled barley. GI, glycemic index; RAG, rapidly available glucose; RDS, rapidly digested starch; RS, resistant starch; SDS, slowly digested starch.

Conclusions for Glycaemia

- Cultivars exhibited significant differences in GR (30%) and GI (10 units)
- Pearling significantly increased GR (20%) and GI (10 units)
- Milling and extruding the barley grains into wet pasta increased GI (186%)
- Starch digestion fractions did not appear to have a significant impact on the GI, only total dietary fiber appears to have an impact on GI

BARLEY SATIETY

Table 2. Incremental areas under the satiety curve (iAUC) and satiety Index (SI) of cooked barley cultivars and white bread, Expt. 1[1]

Barley Cultivar	Satiety iAUC mm	Satiety Index score (SI)	iAUC Blood Glucose (mmol×min/L)	GI
Celebrity WG*	6105 ± 1074^{ac}	133 ± 19.8^{ac}	48±9^{a}	21 ± 4^{a}
Celebrity CP*	6234 ± 640^{ac}	153 ± 37.5^{ac}	55±6^{a}	25 ± 3^{a}
Celebrity PP*	6342 ± 865^{ac}	135 ± 18.3^{ac}	47±5^{a}	22 ± 3^{a}
Celebrity WP*	6078 ± 1074^{ac}	134 ± 23.5^{ac}	68±11^{a}	32 ± 6^{a}
Alberta	5768 ± 805^{ac}	120 ± 19.8^{ac}	63±13^{a}	29 ± 4^{a}
Chief	7004 ± 1054^{ac}	165 ± 35.3^{ac}	65±11^{a}	26 ± 6^{a}
CDC Rattan	6812 ± 1161^{ab}	133 ± 19.3^{ab}	58±12^{a}	36 ± 8^{a}
AC Klinck	6075 ± 1183^{ac}	133 ± 24.3^{ac}	71±12^{a}	28 ± 4^{a}
Kawartha	7518 ± 563^{ab}	175 ± 27.9^{ab}	61±10^{a}	29 ± 7^{a}
GB	6445 ± 653^{ac}	137 ± 6.7^{ac}	52±10^{a}	24 ± 5^{a}
White bread	4774 ± 478^{c}	100^{c}	163±15^{b}	71^{b}

[1] Values are means ± SEM for *n* =10. Means with different superscript letters differ significantly (Repeated measures of analysis, post hoc Tukey test, $P < 0.05$.) * Celebrity Cultivar has been pearled into 4 levels of pearling; WG: Whole grain, CP: Commercial pearl, PP: Pot pearled, WP: White pearled.

Table 3. Incremental areas under the satiety curve (iAUC), Satiety index (SI), iAUC of the glycemic response and the GI of two barley pastas and their fractions, semolina pasta and white bread, Expt. 2[1, §]

	Satiety iAUC mm			**Satiety Index Score (SI)**			**iAUC Blood Glucose (mmol×min/L)**			**GI**		
	Fraction[€]		Mean	Fraction		Mean	Fraction		Mean	Fraction		Mean
	WG	WP		WG	WP		WG	WP		WG	WP	
Celebrity	7118±835	7365±945	7241±890[ac]	140±20.9	151±27.0	145±23.5[a]	137±17	115±17	126±14	71±6	58±4	64±4
AC-Parkhill	6574±1166	6239±898	6406±103[ab]	121±13.4	118±12.7	119±13.1[a]	141±17	127±12	133±13	73±7	64±4	69±3
Mean	6846±1000	6802±921		130±17.5	134±19.8		139±14	121±13[*]		72±4	61±3[*]	
Semolina			8379±706[c]			178±26.7[a]			151±20			78±8
White Bread			5011± 875[b]			100[a]			142±16			71

[1] Values are means ± SEM for *n* = 10.

[abc] Means with different superscript letters differ significantly (Repeated measures of analysis, post hoc Tukey test, $P < 0.05$.)

[€] WG: wholegrain; WP: white pearled.

[§] Pasta made from 2 barley cultivars pearled in 2 different ways and semolina pasta as a control

[*] Significant main effect of pearling level, $P < 0.05$.

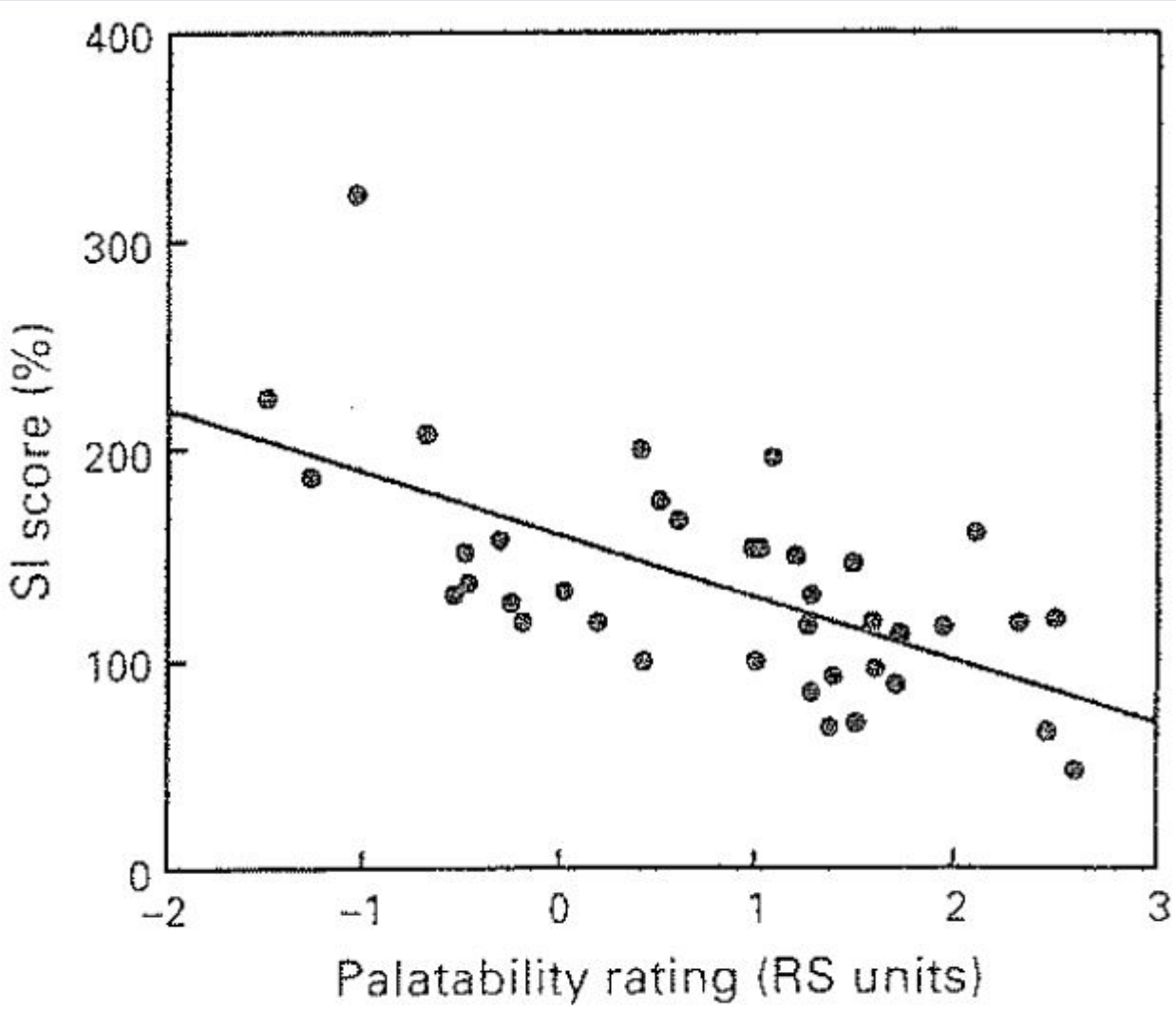

Figure 6 The relationship between the mean palatability ratings and SI scores of the test foods. $r = -0.64$, $P < 0.001$, $n = 38$.

Conclusions for Satiety

- Boiled barley grains appears to have a limited effect on subjective satiety
- Pearling has no effect on satiety
- Food form appears to have an effect on satiety

PHYSICOCHEMICAL PROPERTIES OF BARLEY AND HEALTH EFFECTS

Table 2. Physico-chemical Characteristics of Cooked Barley Kernels [e£]

n = 3

Cultivar	Fraction[ψ]	Food Form	β-glucan content *(% db)*[*]	MW of β-glucan (g/mol×10^3)[§]	% Soluble β-glucan	Viscosity of β-glucan slurry (mPa•sec)[€]	Viscosity of β-glucan extract (mPa•sec)[ᵡ]	% Viscosity of β-glucan
Celebrity	WG	Boiled Kernel	5.9 ± 0.14[a]	2310 ± 600	36.99 ± 2.9[a]	2467 ± 46[ab]	1460.33 ± 30[ab]	59%
Celebrity	WP	Boiled Kernel	6.1 ± 0.13[a]	1870 ± 200	40.33 ± 0.5[a]	2331 ± 184[ab]	393.00 ± 14[ab]	17%
AC-Parkhill	WG	Boiled Kernel	4.2 ± 0.04[a]	1460± 320	47.00 ± 0.7[a]	826 ± 83[a]	55.10 ± 2.0[a]	7%
AC-Parkhill	WP	Boiled Kernel	4.4 ± 0.13[a]	1640 ± 656	42.88 ± 0.7[a]	2954 ± 410[a]	1662.67 ± 43[a]	56%
CDC Fibar	WG	Boiled Kernel	9.5 ± 1.6[b]	2290 ± 105	78.21 ± 1.8[b]	1960 ± 92[b]	882.00 ± 105[b]	45%
CDC Fibar	WP	Boiled Kernel	11.1 ± 0.4[b]	1960 ± 140	81.01 ± 0.8[b]	3906 ± 102[b]	1748.67 ± 239[b]	45%

[£] Significant main effect of cultivar, $P < 0.05$, means with different superscripts are significantly different. There was no significant main effect of pearling.

[ψ] WG: Whole grain, WP: White Pearled

[e] Mean ± SD

[*] Percent dry basis

[§] MW = Molecular weight

[€] Viscosity as measured by Rapid Visco Analyzer (RVA)

[ᵡ] Measured by flow-injection analysis (FIA)

Table 3. Physico-chemical Characteristics of Cooked Barley Pasta[e]

Cultivar	Fraction[ψ]	Food Form	β-glucan content *(% db)*[*]	MW of β-glucan (g/mol×10^3)[§]	% Soluble β-glucan	Viscosity of β-glucan slurry (mPa•sec)[€]	Viscosity of β-glucan extract (mPa•sec)[ɤ]	% Extract Viscosity of β-glucan
Celebrity	WG	Pasta	6.1 ± 0.2[a]	1130 ± 331[ab]	34.47 ± 0.1[a]	840 ± 80[ab]	34.70 ± 5.0[a]	4%
Celebrity	WP	Pasta	6.2 ± 0.5[a]	810 ± 865[ab]	46.77 ± 0.6[a]	230 ± 18[ab]	26.13 ± 4.0[a]	11%
AC-Parkhill	WG	Pasta	4.0 ± 0.01[a]	250 ± 280[a]	45.86 ± 0.9[ab]	372 ± 45[a]	23.63 ± 3.0[a]	6%
AC-Parkhill	WP	Pasta	4.2 ± 0.2[a]	490 ± 101[a]	54.60 ± 0.5[ab]	223 ± 35[a]	21.73 ± 1.0[a]	10%
CDC Fibar	WG	Pasta	11.30 ± 0.89[b]	1240 ± 131[b]	58.74 ± 0.3[b]	947 ± 19[b]	476.3 ±3 14[b]	50%
CDC Fibar	WP	Pasta	11.07 ± 0.5[b]	1100 ± 250[b]	63.50 ± 0.9[b]	470 ± 198[b]	114.00 ±5.0[b]	24%

$n = 3$

[£] Significant main effect of cultivar, $P < 0.05$, means with different superscripts are significantly different. There was no significant main effect of pearling.

[φ] WG: Whole grain, WP: White Pearled

[e] Mean ± SD

[*] Percent dry basis

[§] MW = Molecular weight

[€] Viscosity as measured by Rapid Visco Analyze

[ɤ] Measured by flow-injection analysis (FIA)

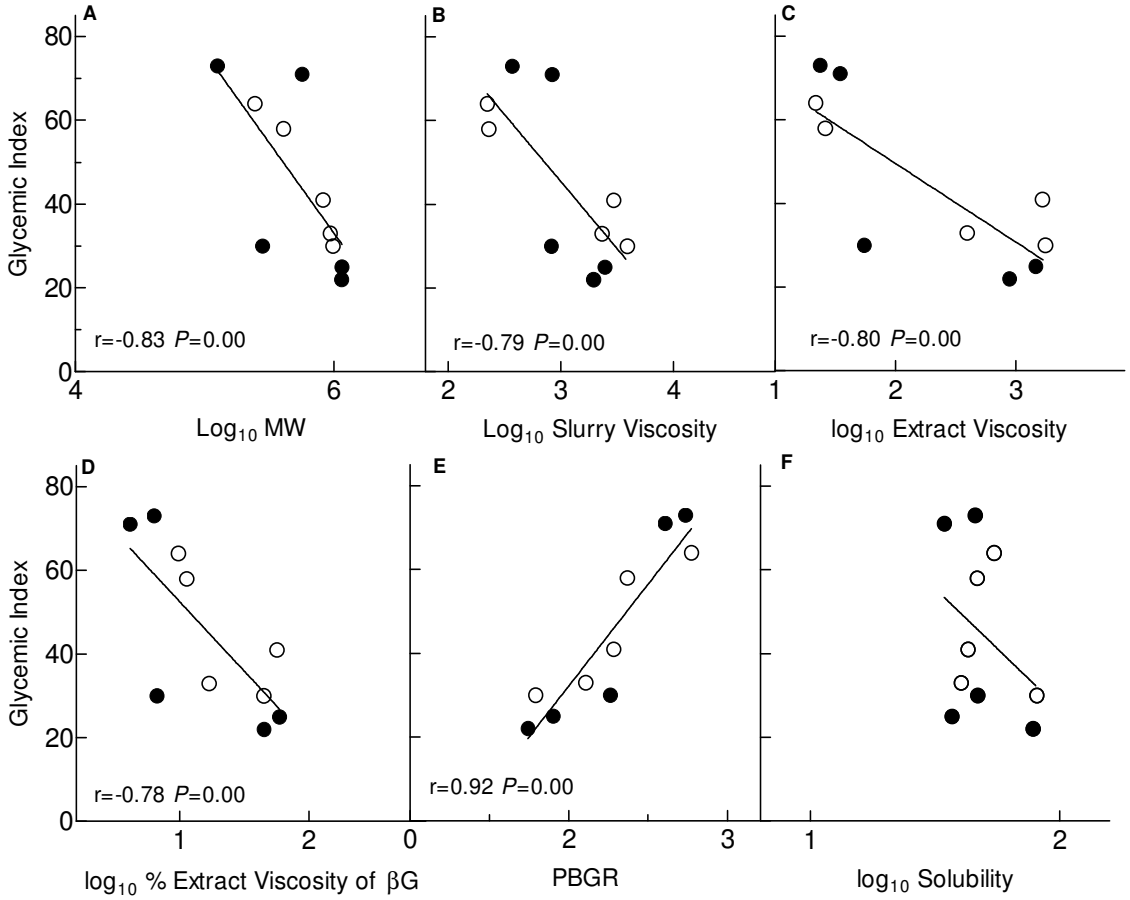

Figure 1. Correlation between the glycemic index (GI) and $\log_{10}$ MW (A), $\log_{10}$ Viscosity (B), $\log_{10}$ Extract Viscosity (C), $\log_{10}$ % β-glucan contribution (D), Peak blood glucose rise (PBGR) (E) and $\log_{10}$ solubility (F) for barley products. Values are means ± SD, n = 10. Viscosity = slurry viscosity of starch and β-glucan,; Extract viscosity = only β-glucan viscosity. *Filled circles*, whole-grain barley; *open circles*, pearled barley

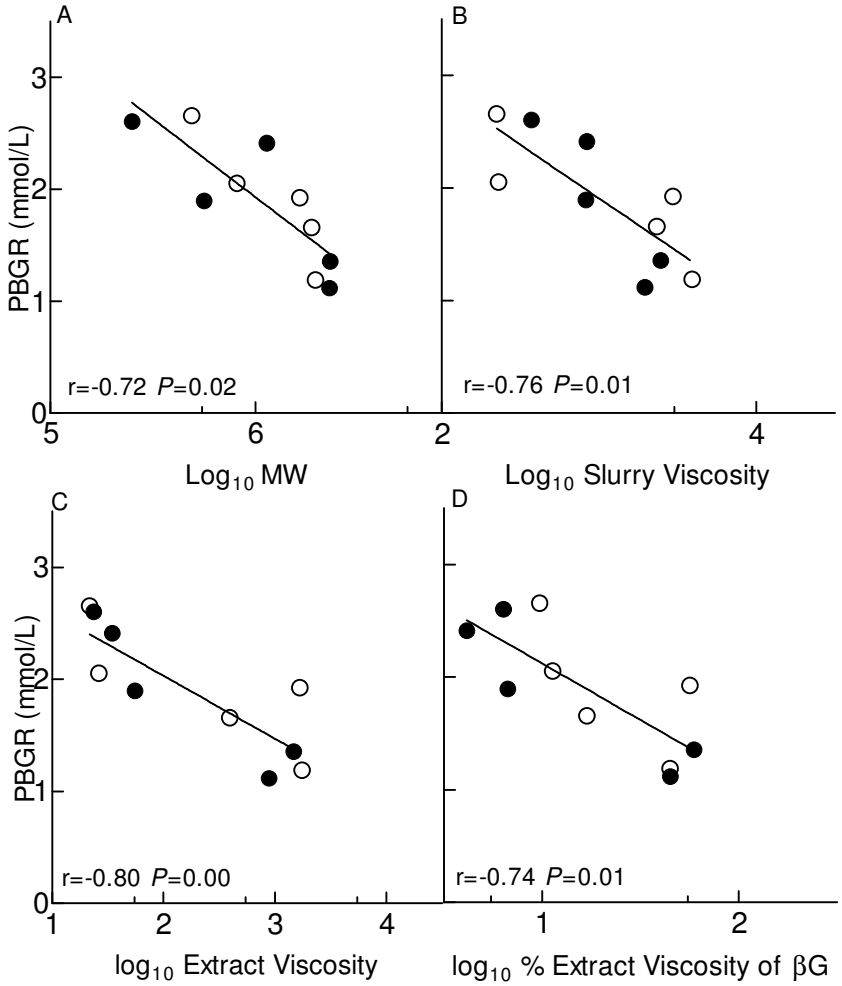

Figure 2. Correlation between the Peak blood glucose rise (PBGR) and $\log_{10}$ MW (A), $\log_{10}$ Viscosity (B), $\log_{10}$ Extract Viscosity (C) and $\log_{10}$ % β-glucan contribution (D), for barley products. Values are means ± SD, n = 10. Viscosity = slurry viscosity of starch and β-glucan; Extract viscosity = only β-glucan viscosity. *Filled circles*, whole-grain barley; *open circles*, pearled barley

Conclusions for Physicochemical Properties

- Barley cultivars differed in their physicochemical properties (e.g. viscosity, MW, solubility, etc.)
- Pearling had a little effect on physicochemical properties
- Food form significantly affected physicochemical properties and thus its glycemic response and glycemic index

Take Home Messages

- Barley holds potential as a functional food and source of dietary supplement (e.g. β-glucan)
- Barely is a low GI food that can be used in the management of diabetes and obesity
- Barley food form is crucial in delivering anticipated health effects of barley
- More global efforts are needed to promote barley as a healthy food

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Canada

THANK YOU

Questions

AAFC Vision: Driving innovation and ingenuity to build a world leading agricultural and food economy for the benefit of all Canadians

AAFC Mission: to provide leadership in the growth and development of a competitive, innovative and sustainable Canadian agriculture and agri-food sector