



UNIVERSITY OF SASKATCHEWAN

Corn in Feedlot Rations

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Barley vs. corn as major cereal grains

	Western Canada[2]		Upper Midwest US[3]
	Barley grain	Corn grain	Corn grain
DM, %	88.0 ± 6.62	84.1 ± 7.17	76.9 ± 10.1
OM, % DM	97.0 ± 0.75	98.3 ± 0.80	98.6 ± 0.39
CP, % DM	12.4 ± 1.56	9.2 ± 1.49	8.4 ± 1.04
Starch, % DM	59.9 ± 5.84	71.1 ± 7.82	73.2 ± 3.32
ADF, % DM	7.16 ± 2.64	5.7 ± 6.29	4.5 ± 1.45
NDF, % DM	17.8 ± 4.23	12.5 ± 9.66	10.6 ± 2.68
Fat, % DM	2.30 ± 0.50	3.7 ± 0.68	3.9 ± 0.61
TDN, % DM	80.4 ± 2.34	85.2 ± 4.72	86.0 ± 1.30
NE_m, Mcal/kg	1.96 ± 0.07	2.09 ± 0.15	2.12 ± 0.04
NE_g, Mcal/kg	1.30 ± 0.07	1.43 ± 0.13	1.46 ± 0.02

[1]Values reported from January 1, 2014 to January 1, 2019.

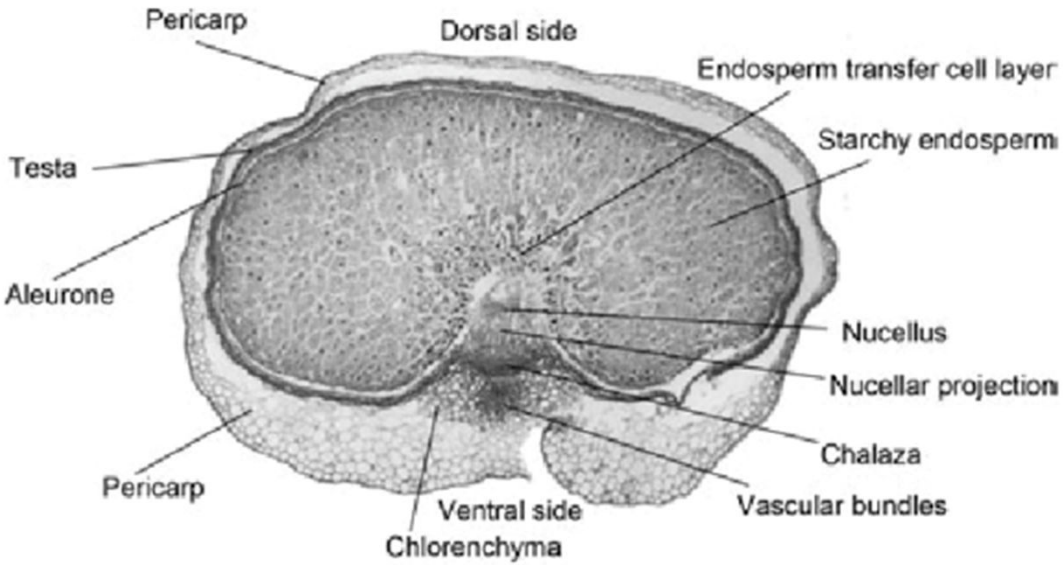
[2]For Canadian barley grain n ≥ 1,161; for corn grain n ≥ 564.

[3]For Upper Midwest US corn grain n ≥ 4,899.

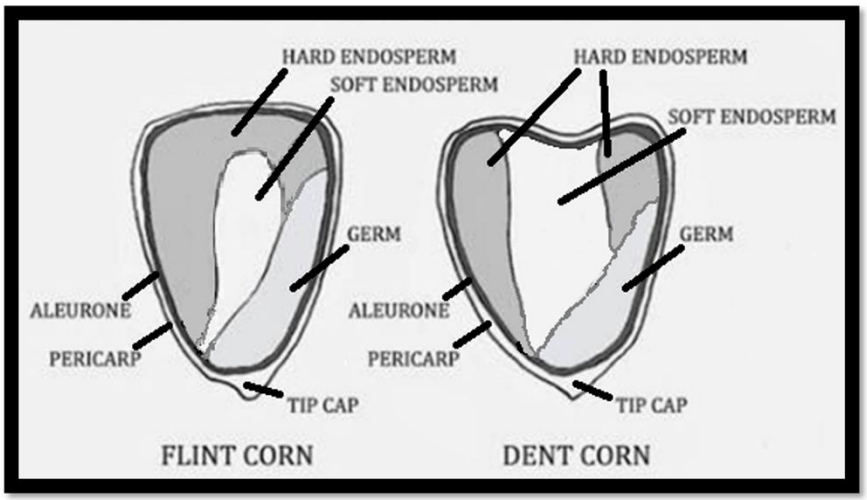
Corn has:

- **Greater starch & energy**
- **Lower CP and will have lower starch digestibility unless steam flaked or ensiled**

Barley and corn grain anatomy



Hull and pericarp



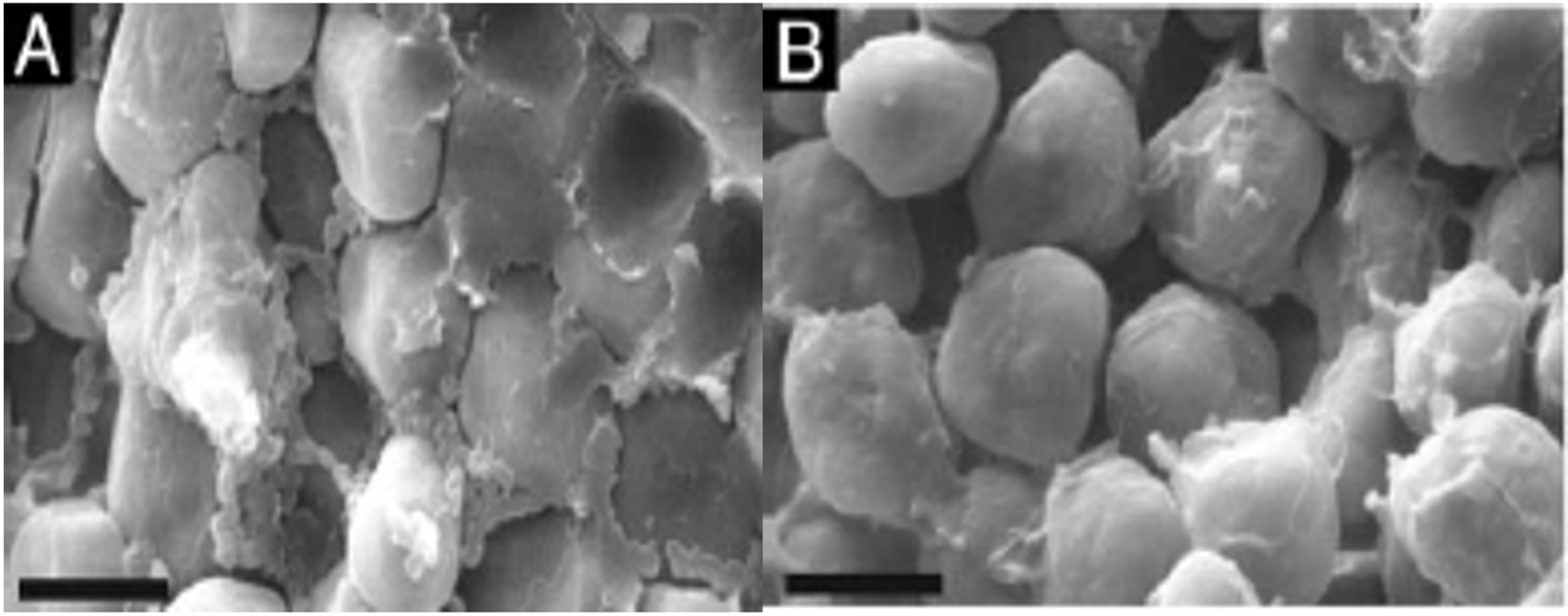
Pericarp + endosperm

Hard endosperm

Insoluble protein matrix

Gibbon et. al., 2003

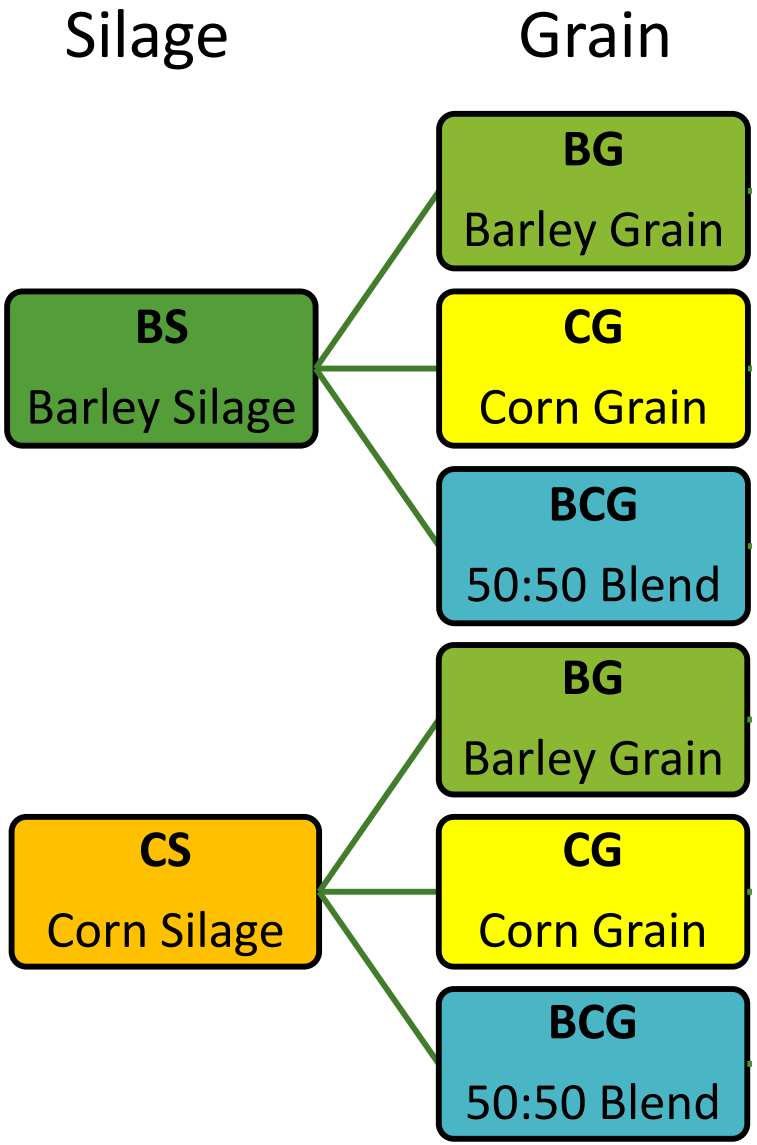
Starch in corn is imbedded in a protein matrix



Prolamin-protein matrix
e.g. hard endosperm

Soft endosperm

Evaluating dry processing of corn

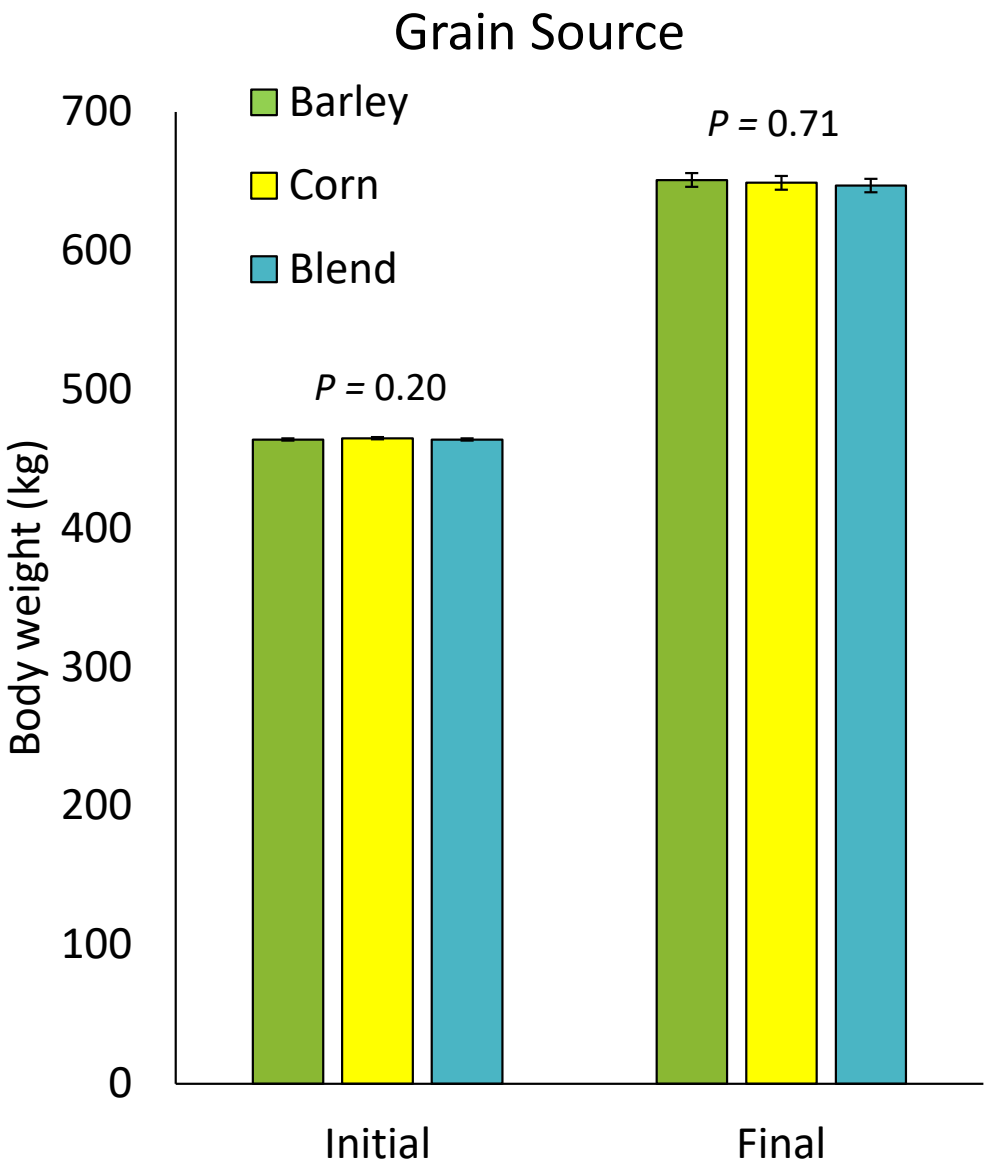


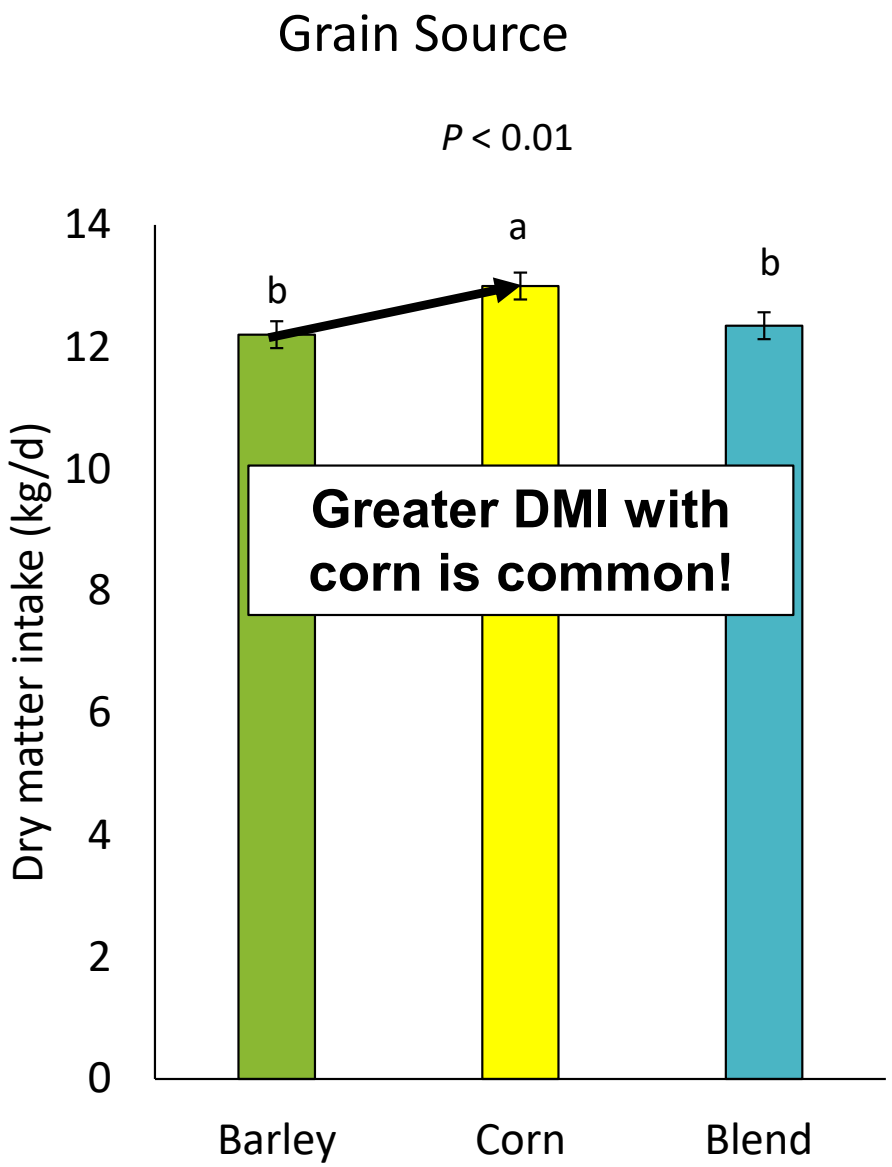
Evaluating dry processing of corn

- 288 steers stratified by BW and randomly assigned to one of 24 pens
  - 4 pens/treatment with 12 steers/pen
- Fecal samples were collected from the pen floor to estimate digestibility
  - Samples were subjected to NIR analysis to estimate fecal starch and digestibility of GE, DM, OM, CP, ADF and NDF as described by Jancewicz et al. (2016)
- Carcass data were obtained from the abattoir at slaughter (Cargill Meat Solutions, High River, AB)

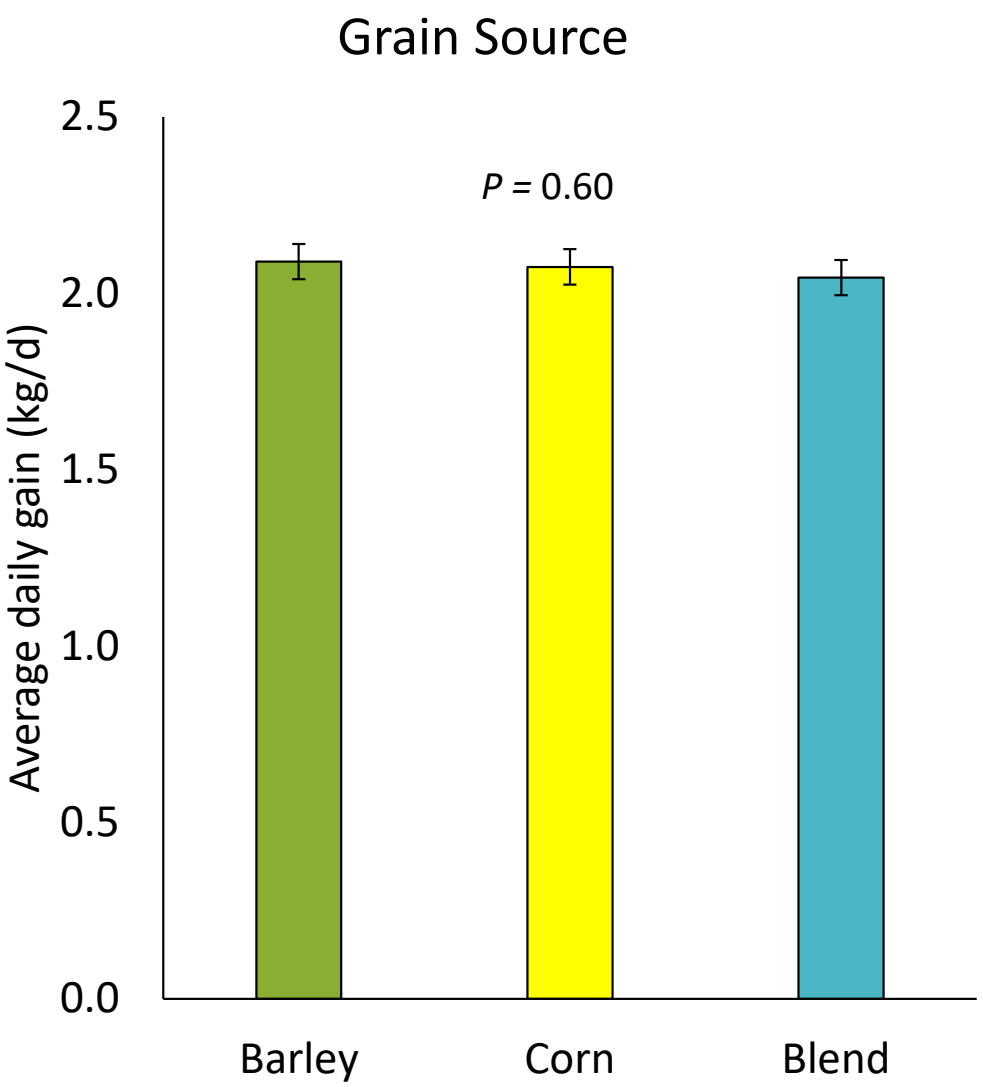
	Barley silage			Corn silage		
	Barley grain	Corn grain	Blend	Barley grain	Corn grain	Blend
Ingredient, % DM						
Barley silage	8.00	8.00	8.00	-	-	-
Corn silage	-	-	-	8.00	8.00	8.00
Barley grain	85.94	-	42.72	85.86	-	42.69
Corn grain	-	84.96	42.72	-	84.89	42.69
Urea	-	0.98	0.50	0.08	1.06	0.57
Mineral pellet[1]	5.56	5.56	5.56	5.56	5.56	5.56
Limestone	0.50	0.50	0.50	0.50	0.50	0.50
Chemical composition, % DM[2]						
DM, %	82.2 ± 1.07	81.7 ± 0.83	82.0 ± 0.81	80.0 ± 0.95	79.9 ± 1.65	80.1 ± 1.28
OM	95.6 ± 0.10	96.0 ± 0.16	95.8 ± 0.03	95.7 ± 0.14	96.1 ± 0.11	95.9 ± 0.02
CP	11.5 ± 0.17	11.3 ± 0.18	11.5 ± 0.14	11.6 ± 0.21	11.4 ± 0.20	11.5 ± 0.17
NDF	21.6 ± 1.57	13.5 ± 0.50	17.5 ± 0.53	21.4 ± 1.82	13.3 ± 0.26	17.3 ± 0.78
ADF	8.4 ± 0.44	5.9 ± 0.34	7.1 ± 0.31	8.3 ± 0.33	5.8 ± 0.24	7.0 ± 0.16
Starch	54.2 ± 1.43	64.5 ± 1.17	59.3 ± 0.27	54.7 ± 1.35	65.1 ± 1.23	59.9 ± 0.15
Ether extract	2.3 ± 0.08	4.0 ± 0.35	3.2 ± 0.22	2.3 ± 0.09	4.0 ± 0.36	3.2 ± 0.23
Ca	0.86 ± 0.03	0.83 ± 0.03	0.84 ± 0.03	0.86 ± 0.03	0.82 ± 0.02	0.84 ± 0.03
P	0.35 ± 0.02	0.32 ± 0.02	0.34 ± 0.01	0.35 ± 0.02	0.32 ± 0.02	0.34 ± 0.01
NE_m, Mcal/kg[3]	1.85	2.00	1.93	1.86	2.00	1.93
NE_g, Mcal/kg[3]	1.23	1.35	1.29	1.23	1.36	1.30

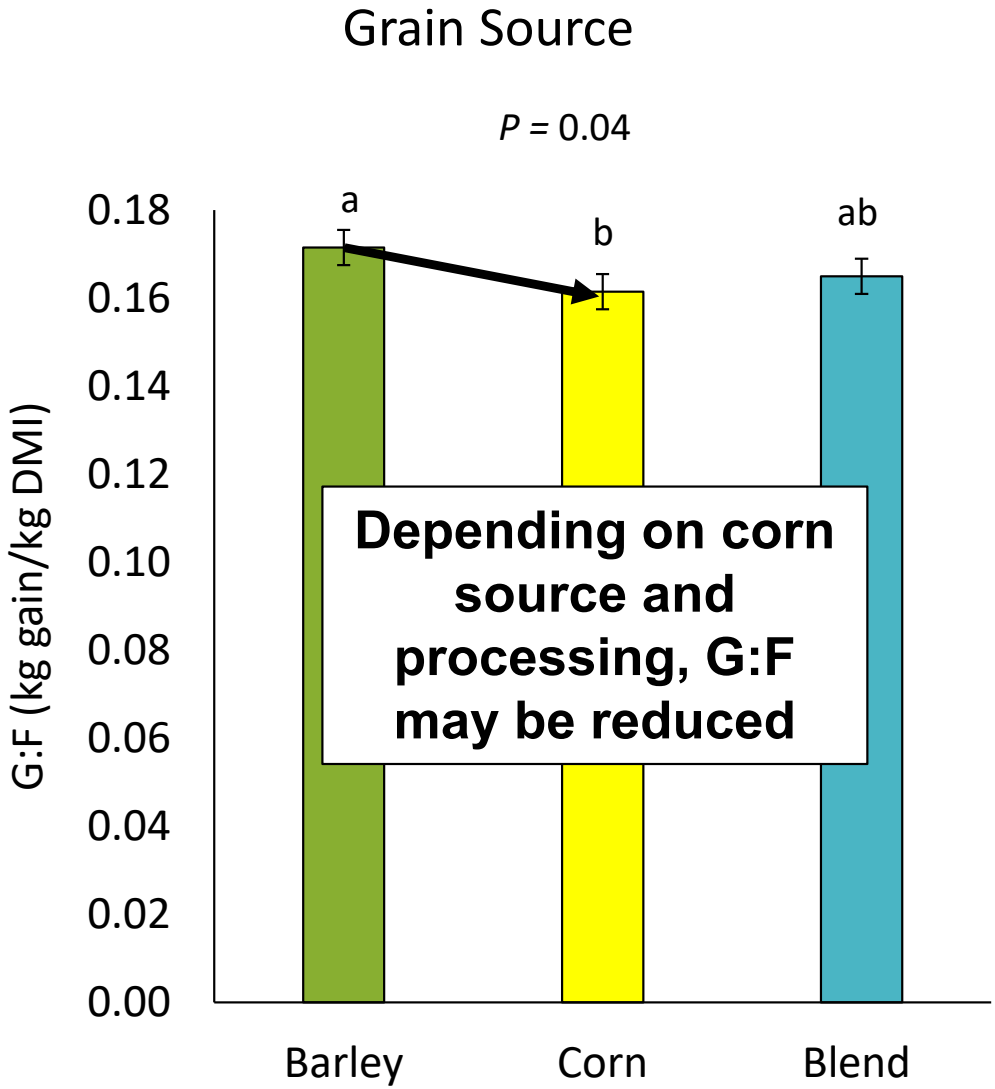
Grain source effects on BW and DMI





Grain source effects on ADG and G:F



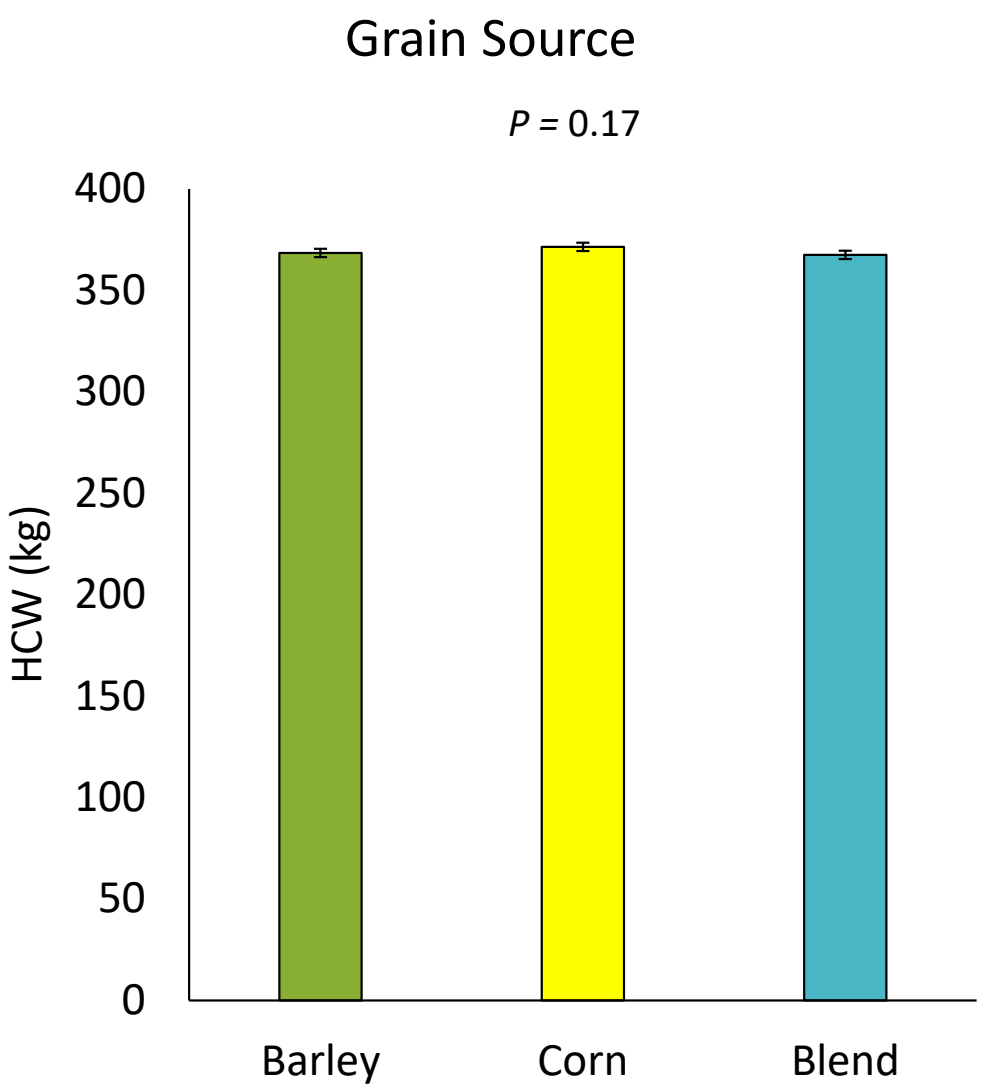


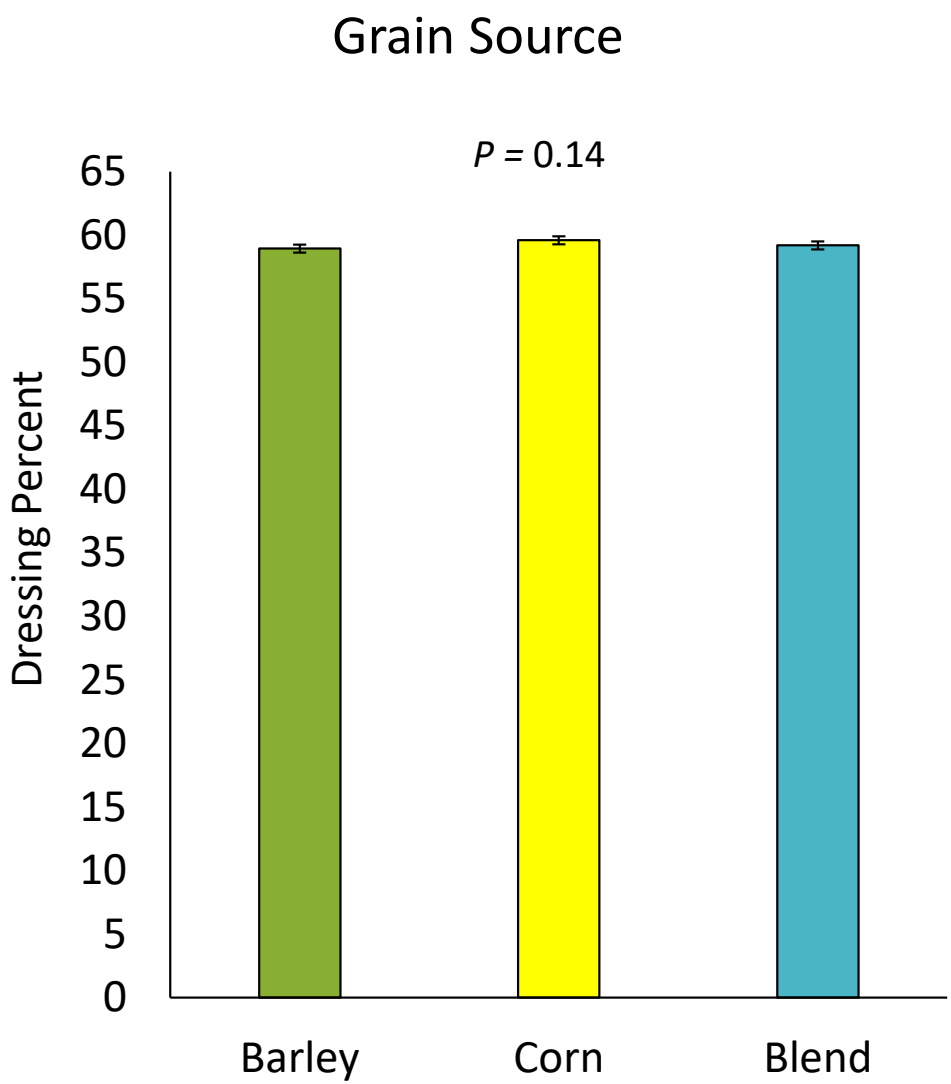
Comparing dry-rolled corn and barley on starch digestibility

	Dry-rolled corn	Dry-rolled barley
Digestion:		
Ruminal	**71**	**76**
Rumen escape	**29**	**24**
Post ruminal	**64**	**81**
Total tract	**90**	**95**

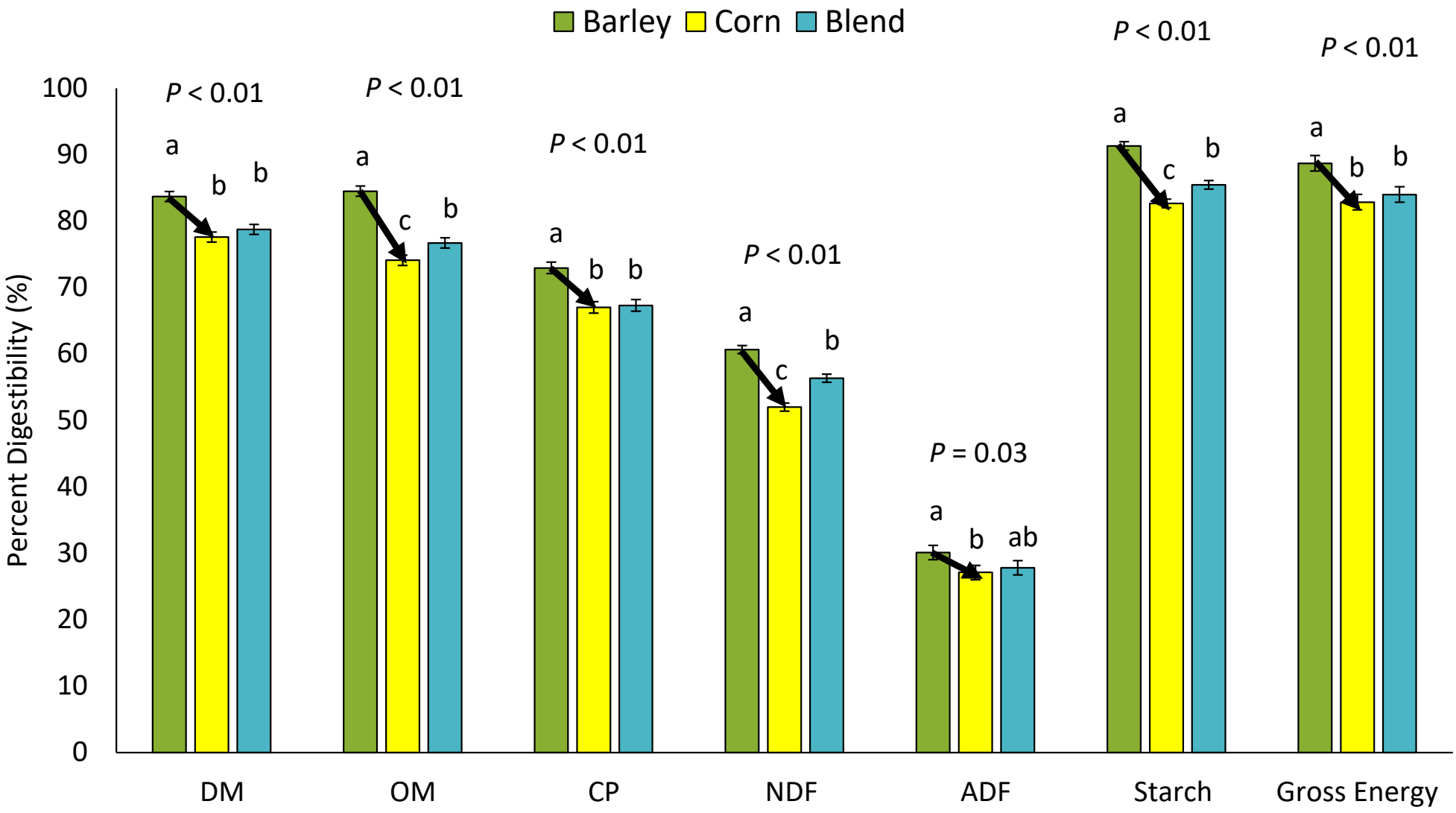
Adapted from Zinn (1997) and Zinn (1996)

Grain source effects on the carcass





Grain source and predicted digestibility



Johnson et al., 2019; Transl. Anim. Sci.

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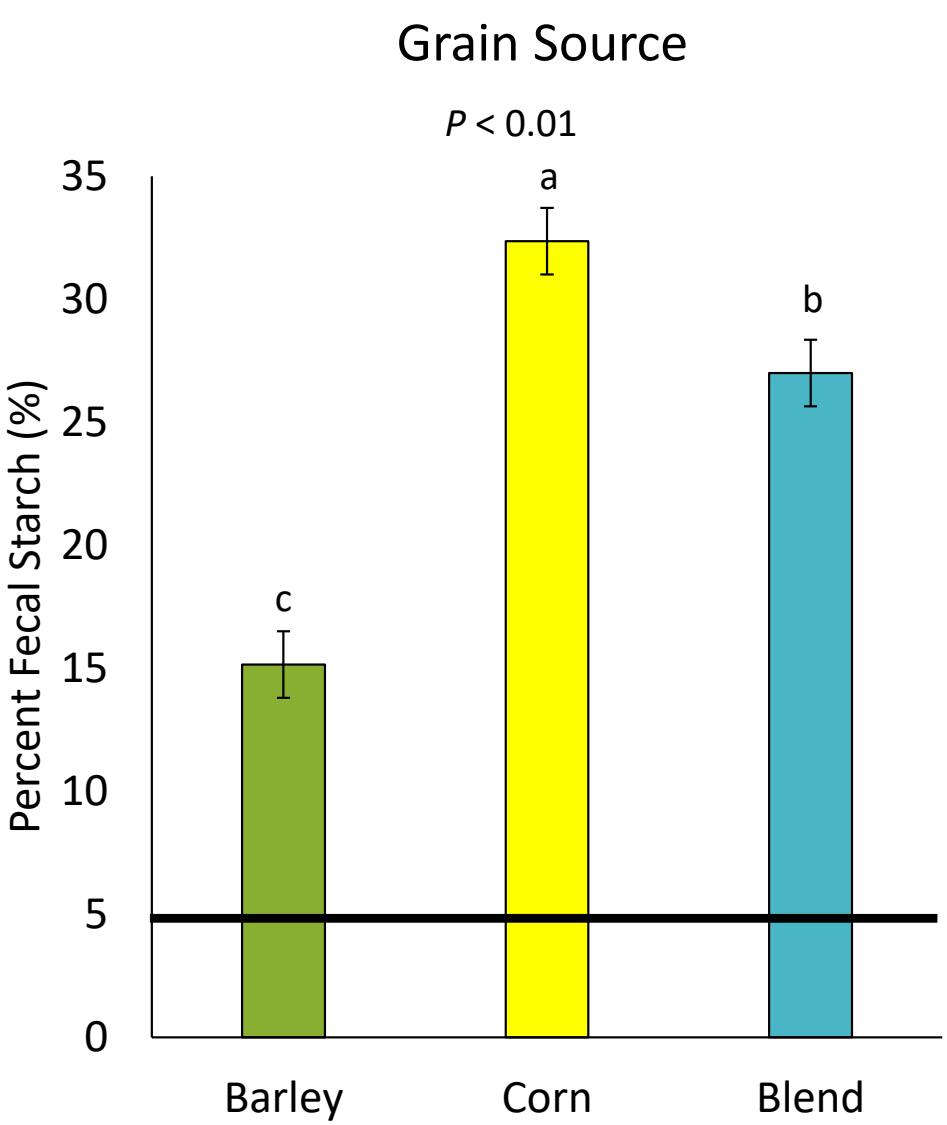
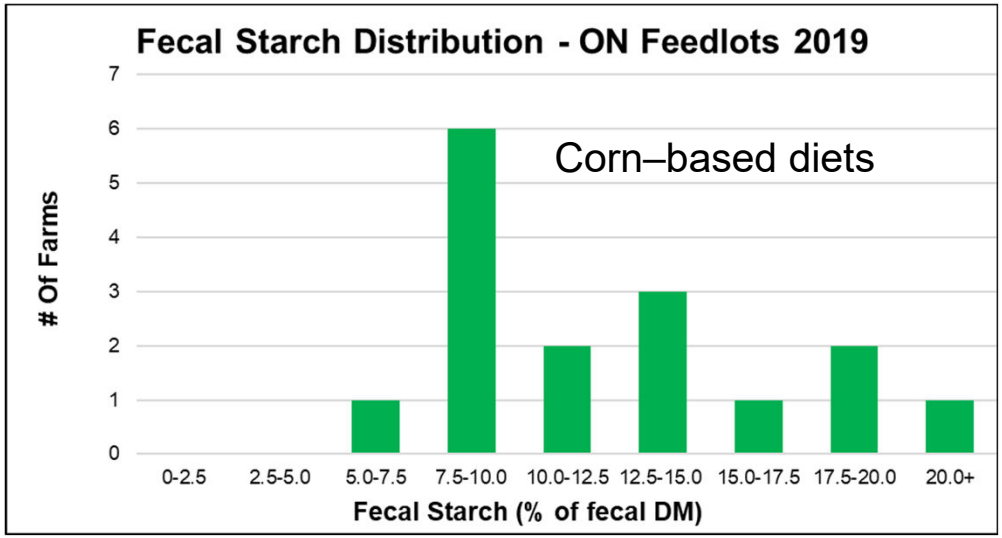
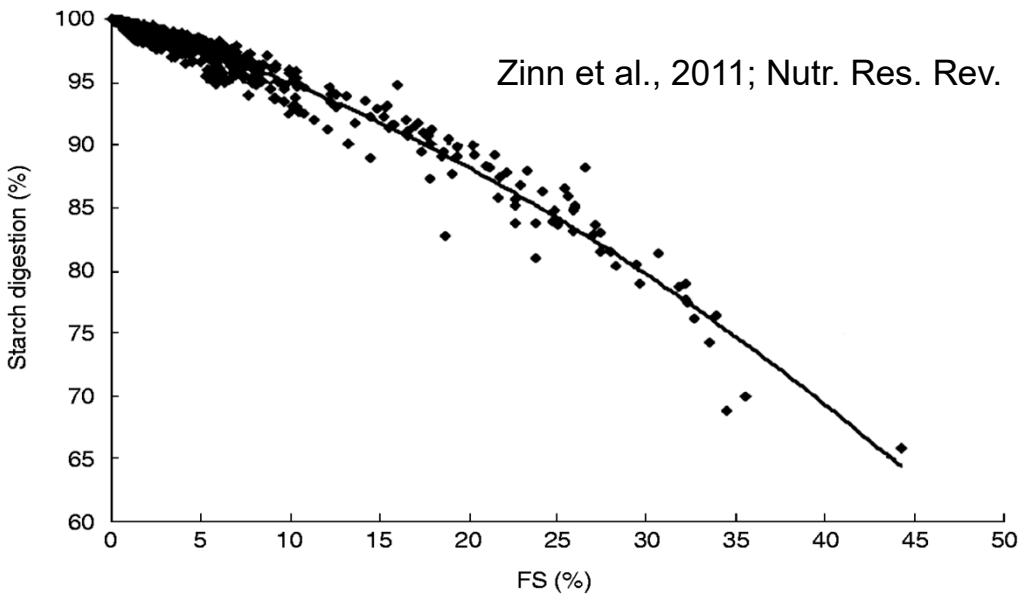
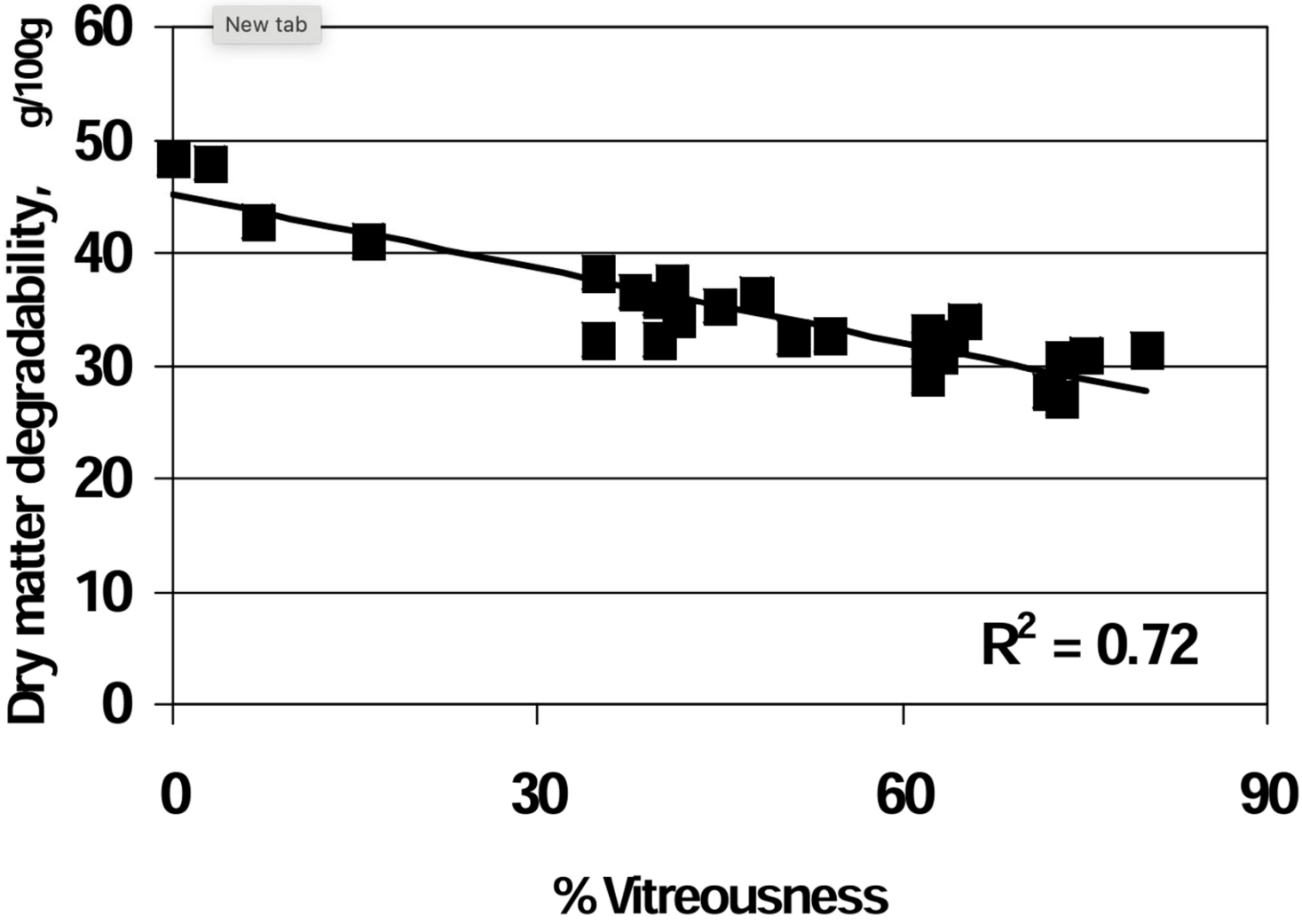
Grain source effects





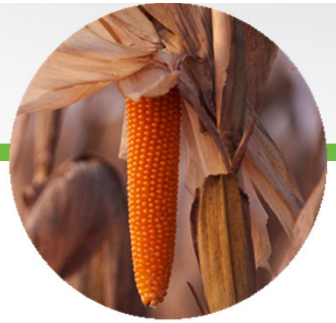


Unlikely to overcome effects with dry processing



Comparing dry rolled barley and corn

- Feeding dry-rolled corn grain decreased growth performance relative to barley
  - Increased DMI & reduced G:F
  - Lower digestibility for corn
    - Clearly seen with elevated fecal starch
  - Similar responses in growing and finishing diets
  - Responses confirmed with metabolic studies (Johnson et al., 2020; Sutherland et al., 2021)
- Dry rolled corn likely has a value that is ~98% that of barley grain when considering cost of CP and energy (Gibb and McAllister, ND)

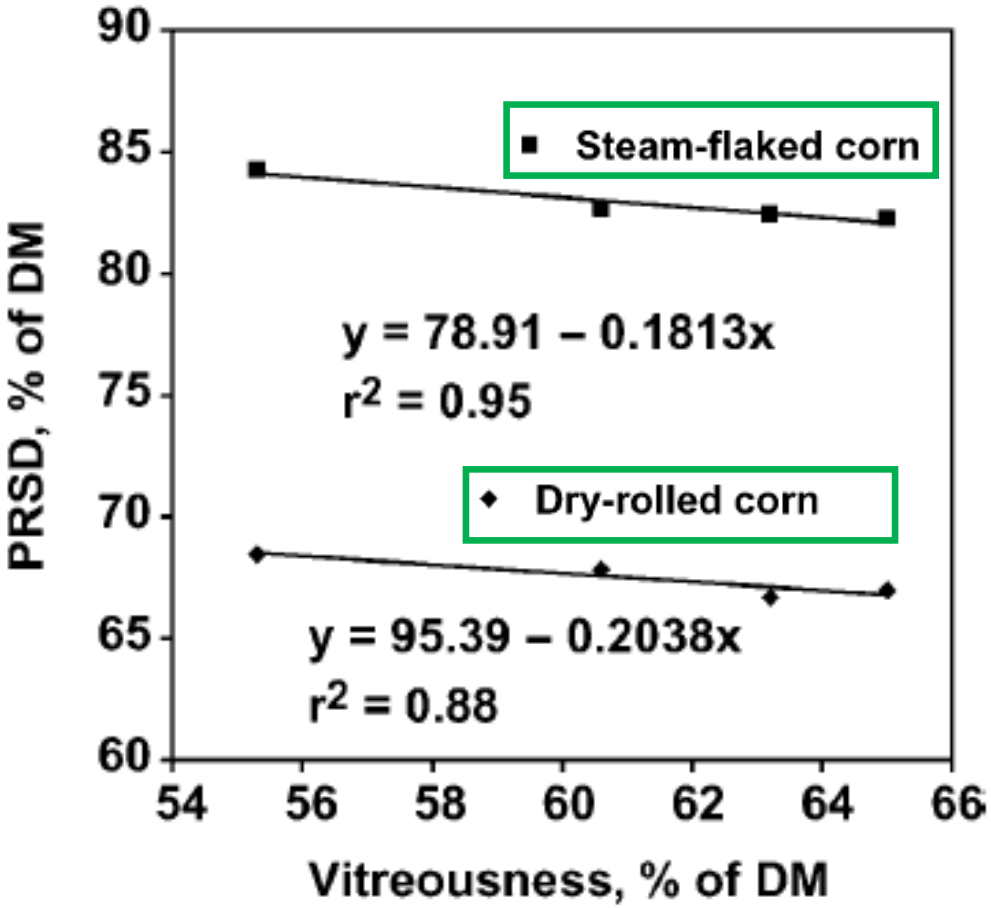



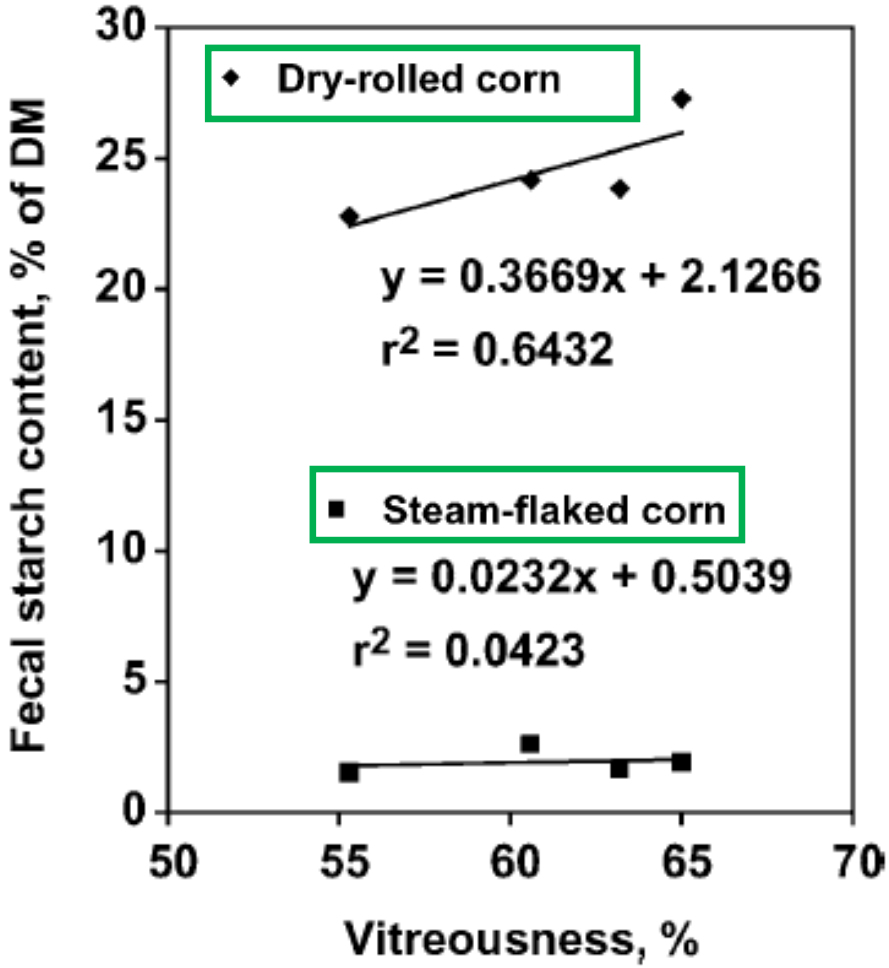
Corn

- 5 classes of corn
  - Flint – high proportion of vitreous endosperm
  - Flour – high proportion of floury endosperm
  - **Dent (most common) – blend of flint and flour**
  - Sweet – floury endosperm with high sugar content
  - Popcorn – hard pericarp and hard endosperm with floury higher-moisture endosperm

Does vitreousness matter?

Corona et al., 2006; JAS





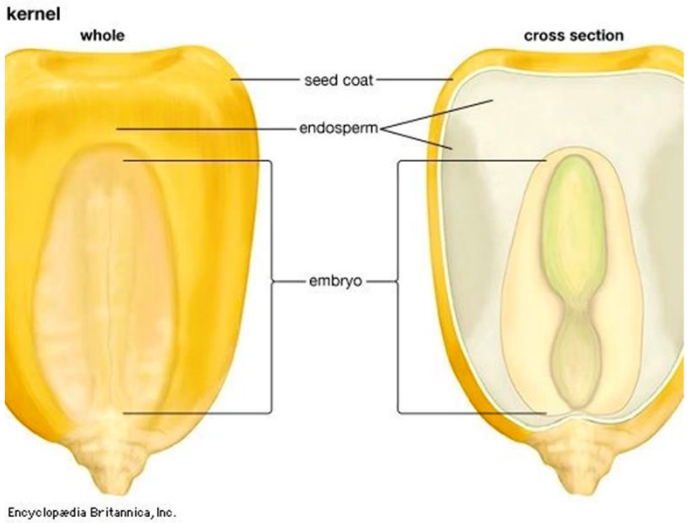
PRSD = predicted ruminal starch digestibility

Processing strategies to improve utilization of corn

- Options
  - Whole corn
  - Ground corn
  - Rolled corn
  - Tempered corn
  - High moisture corn
  - Steam flaked corn

↓ particle size to ↑ starch access

Alter starch/protein structure to improve starch availability



Effect of tempering

Zinn et al., 1998; JAS

- Tempering (adding 4 to 8% moisture; total concentration of 18-20% moisture) reduces:
  - Energy cost for rolling
  - Reduce proportion of fine particles
  - May increase ADG and carcass weight while reducing F:G relative to dry rolled corn
  - But, no major changes in digestibility are expected (not different than DR, lower than flaked)

Summary of processing on digestion

Zinn et al., 2011; Nutr. Res. Rev.

Item	Dry whole	Dry rolled	Dry finely processed	Tempered cold rolled	High moisture	Steam flaked
Diet observations (*n*)	5	26	1	3	7	93
Starch digestion (%)						
Ruminal		60·6		47·5	91·0	84·2
Postruminal						
Total tract	90	89.3	92	89.8	99.2	99.1
Fraction disappearing in rumen (%)						

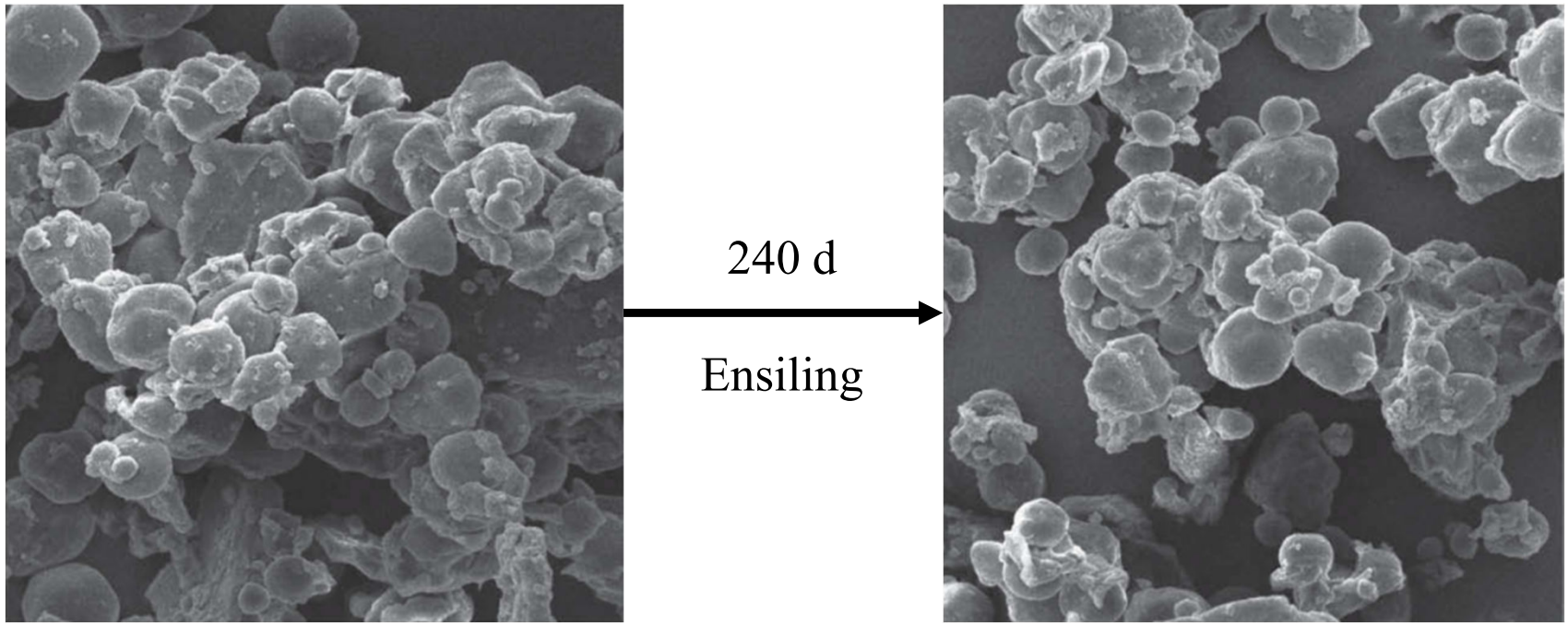
Similar digestion characteristics – only small improvements with rolling and fine processing

High-moisture corn

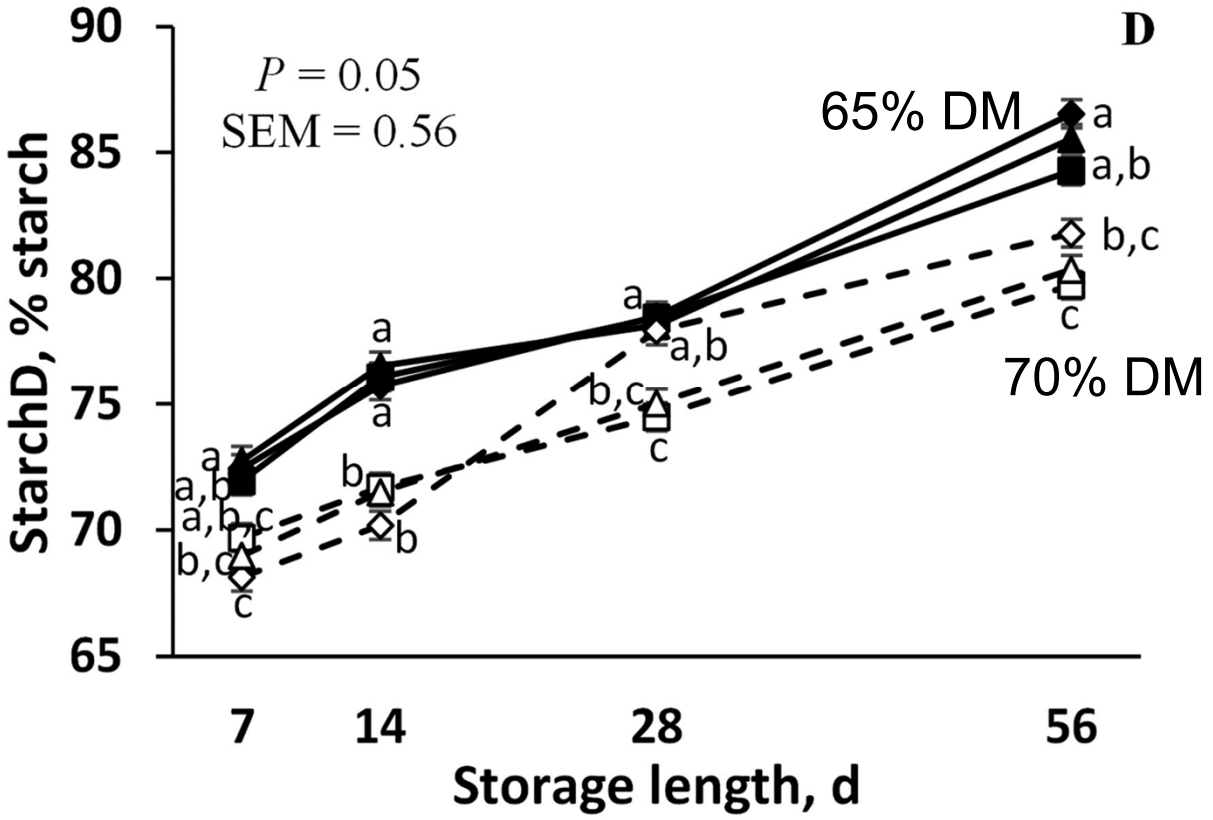
- 2 approaches for production
  - Harvest with adequate moisture (35% moisture)
    - Roll or grind
    - Pack and ensile
  - Roll or grind
  - Reconstitute to 60-65% DM (35-40% moisture)
  - Pack and ensile

Ensiling alters the structure of corn starch

Hoffman et al. 2011

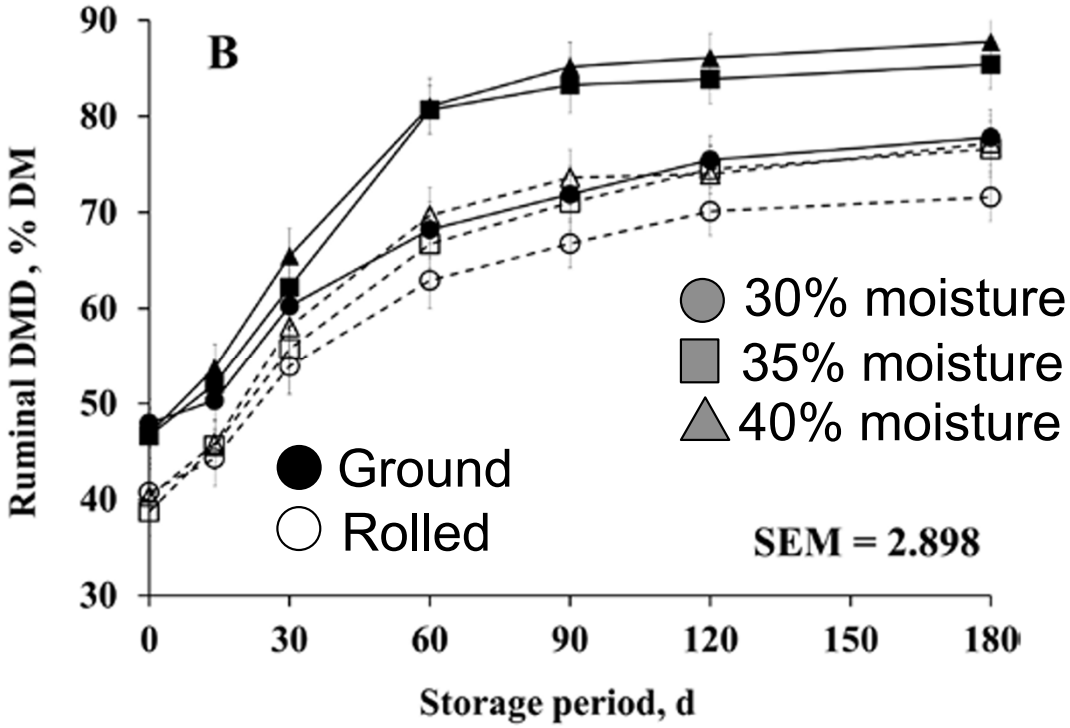


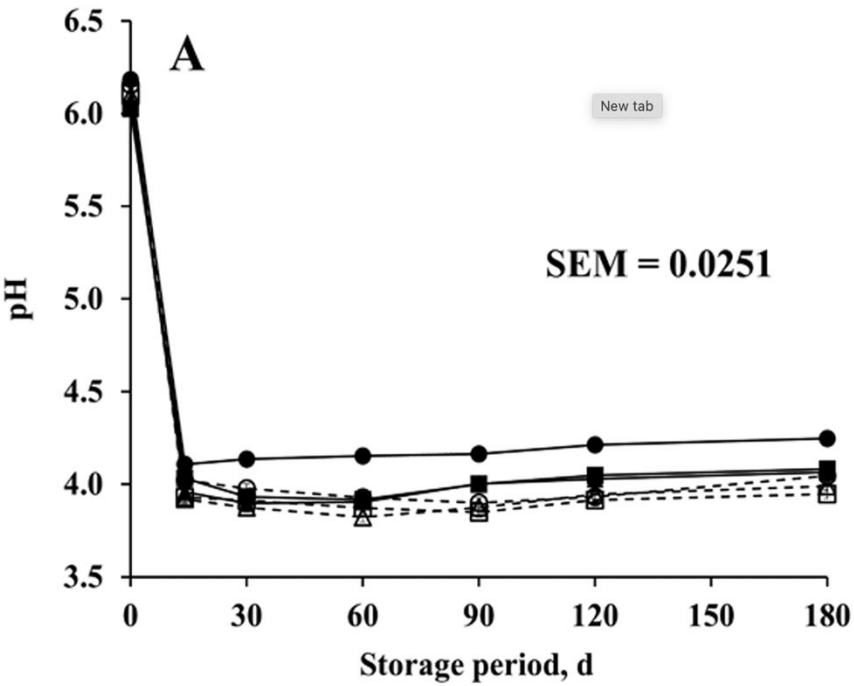
Storage time and moisture affect starch digestibility



- Starch availability increases over time
- Common to add grain with a slower rate of digestion
  - 2/3 – 3/4 : 1/3-1/4 HMC:dry rolled
- What grain to use in western Canada?

Starch digest. increases with reconstituted HMC





Gomes et al., 2020; JAS

Source: Rachel Carey

High-moisture corn products

Carey et al., 2023; CJAS

Comparing barley to HMC products

Ingredients, % DM)	Barley grain		HMC		SNAP	
Project	FL-1	FL-2	FL-1	FL-2	FL-1	FL-2
Dry-rolled barley grain	88.0	88.0	44.0	44.0	77.5	77.0
Barley silage	9.7	10.1	9.8	10.0	0.0	0.0
High-moisture shelled corn	0.0	0.0	44.0	44.0	0.0	0.0
Snaplage	0.0	0.0	0.0	0.0	20.0	20.7
Limestone	1.50	1.50	1.50	1.50	1.50	1.50
Urea	0.59	0.20	0.46	0.27	0.79	0.55
Salt	0.20	0.20	0.20	0.20	0.20	0.20
Mineral-vitamin supplement	0.025	0.025	0.025	0.025	0.025	0.025

Carey et al., 2023; CJAS

Comparing barley to HMC products

Composition, % DM	Barley grain		HC		SN	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
DM, %	86.2	84.1 ± 0.22	80.8	81.0 ± 0.69	88.2	85.0 ± 0.52
OM	93.9	95.1 ± 0.08	94.5	95.3 ± 0.05	94.2	95.4 ± 0.05
CP	14.0	14.0 ± 0.76	14.1	13.8 ± 0.34	14.0	13.9 ± 0.60
EE	2.5	3.5 ± 0.25	2.4	3.6 ± 0.07	2.3	3.2 ± 0.22
NDF	21.4	21.7 ± 0.53	18.1	18.8 ± 0.40	23.2	22.1 ± 0.40
Starch	53.0	51.0 ± 0.64	57.2	55.4 ± 0.67	52.8	52.7 ± 0.59
NE_m, Mcal/kg	1.98	2.12 ± 0.003	2.08	2.19 ± 0.013	2.00	2.14 ± 0.005
NE_g, Mcal/kg	1.34	1.45 ± 0.010	1.42	1.51 ± 0.005	1.36	1.47 ± 0.014

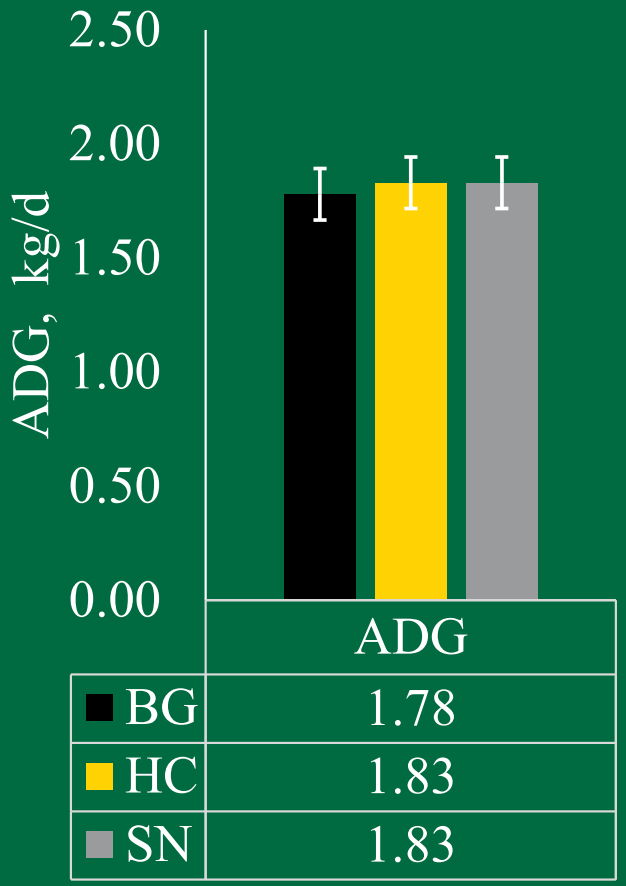
University of Saskatchewan

Slides from R.E. Carey

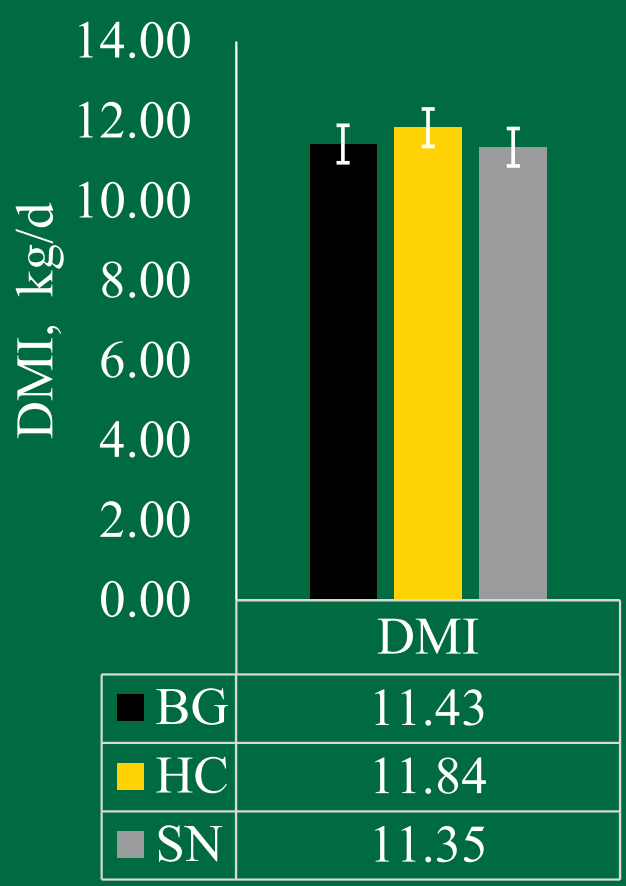
Carey et al., 2023; CJAS

Steer performance was not affected

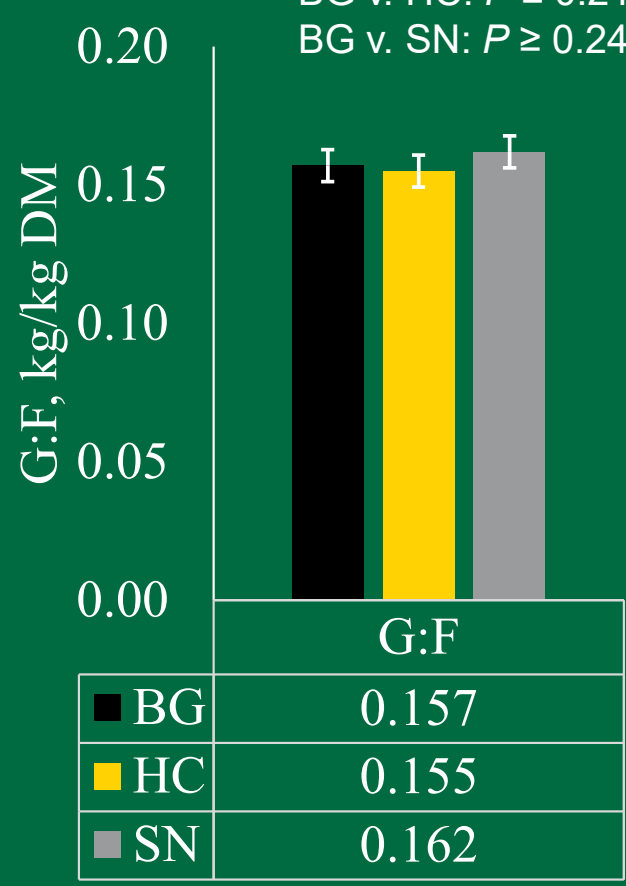
BG v. HC: $P \geq 0.21$
BG v. SN: $P \geq 0.24$



	ADG
BG	1.78
HC	1.83
SN	1.83



	DMI
BG	11.43
HC	11.84
SN	11.35



	G:F
BG	0.157
HC	0.155
SN	0.162

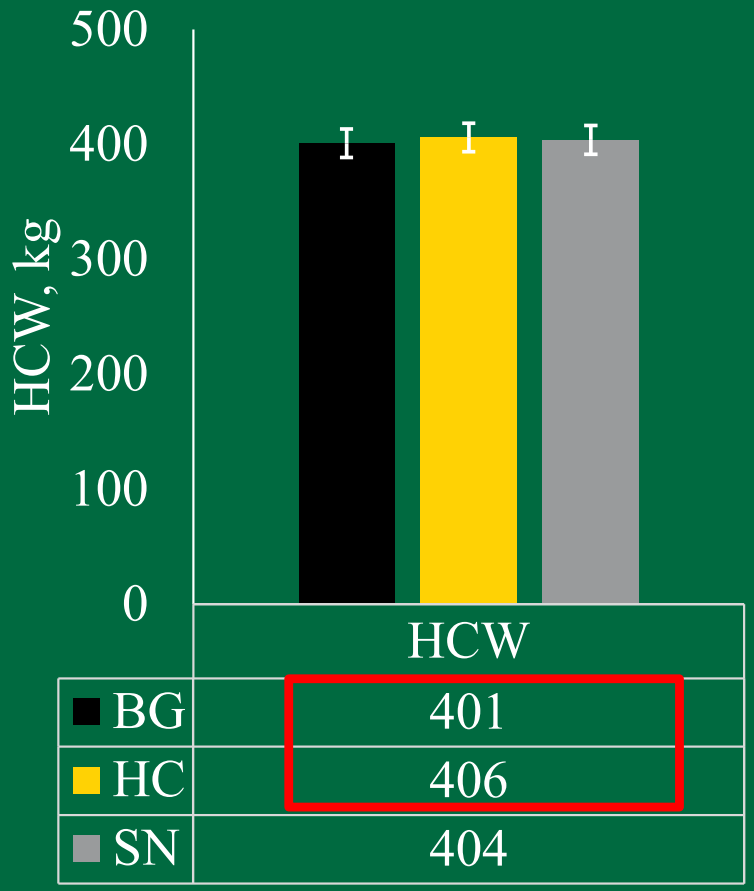
Fecal starch values all < 3% of DM

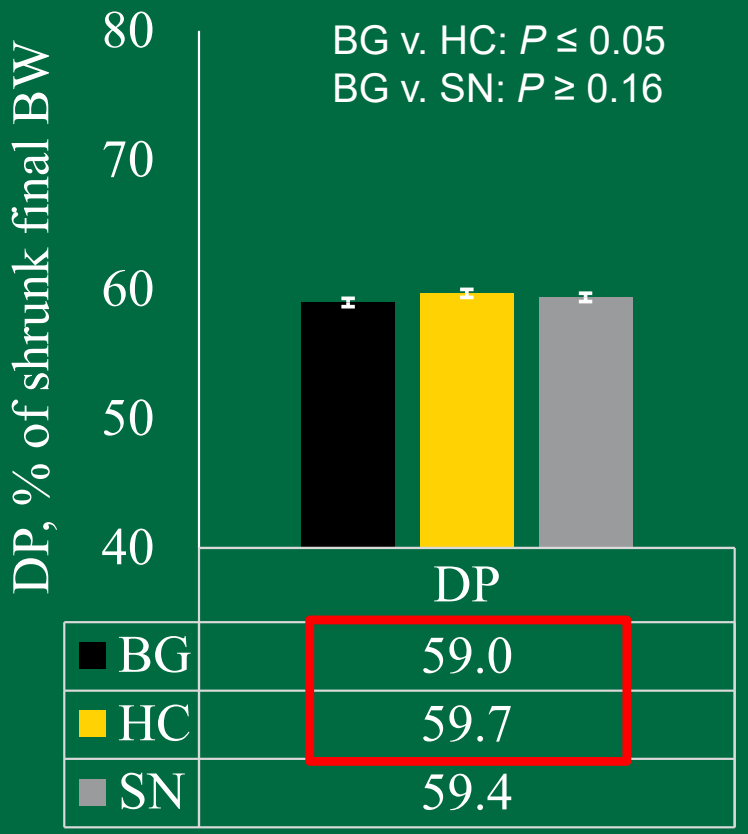
BE WHAT THE WORLD NEEDS

Slides from R.E. Carey

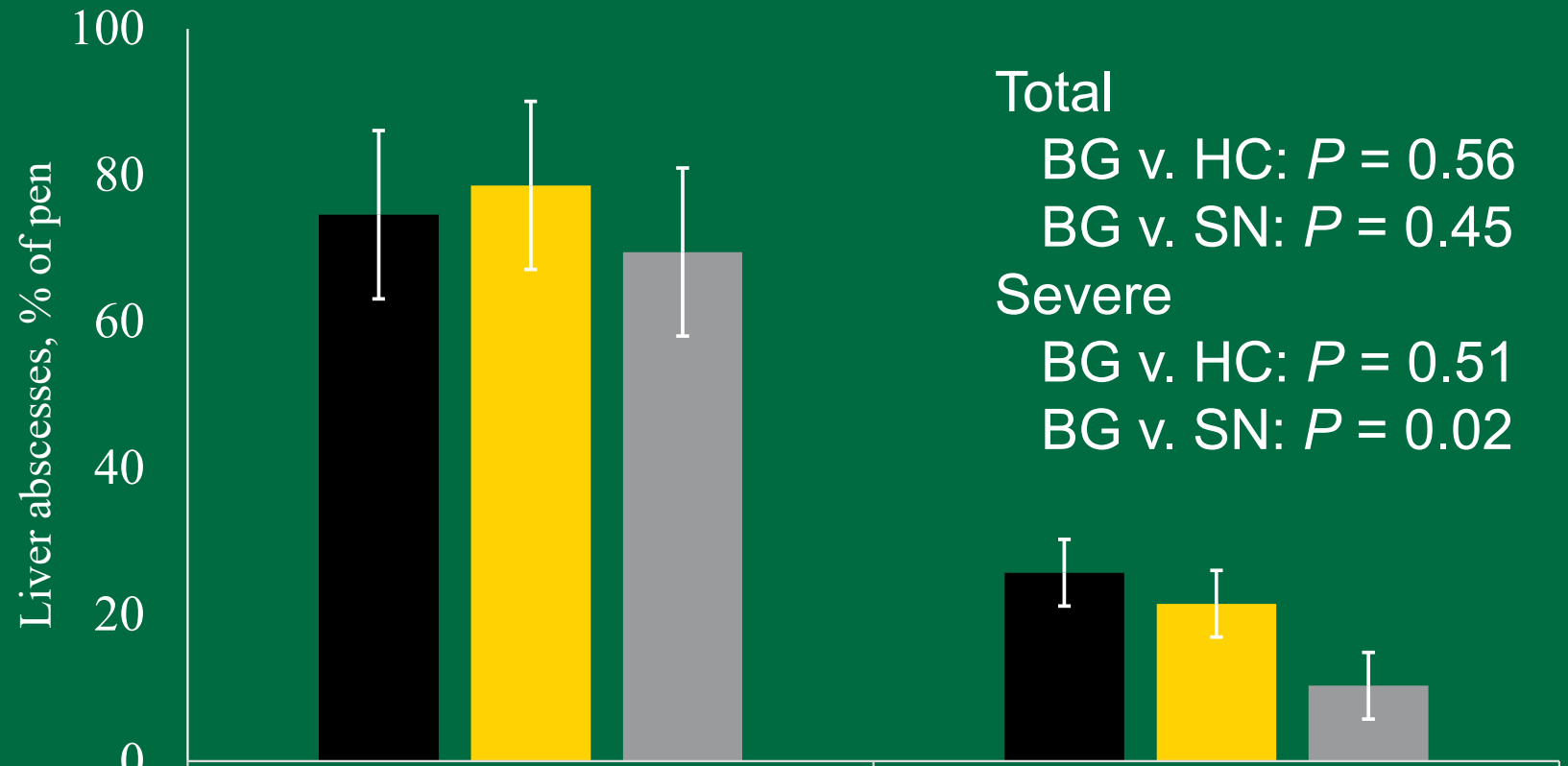
Carey et al., 2023; CJAS

High moisture corn increased HCW and DP





SNAP reduced severe liver abscesses



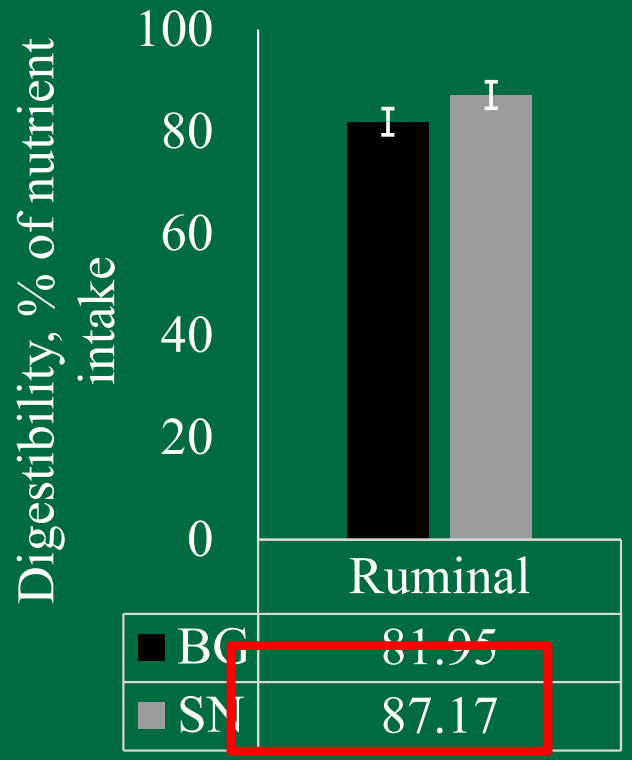
	Total	Severe
BG	74.6	25.7
HC	78.6	21.5
SN	69.5	10.3

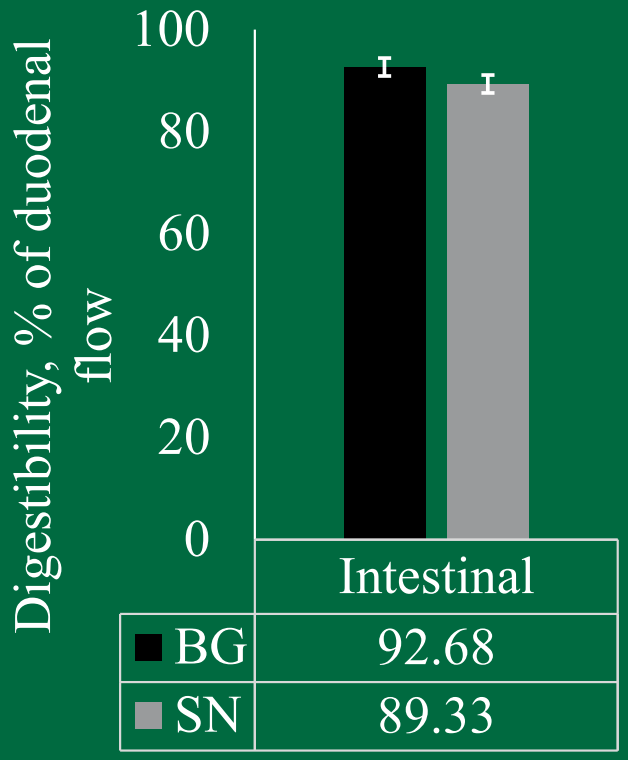
Year to year snaplage variability

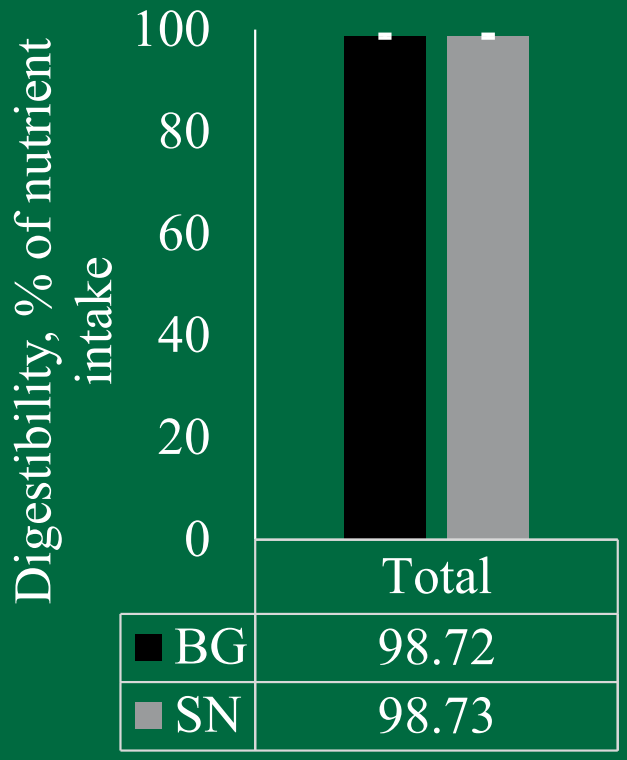
Nutrient concentration, % of DM	Digestibility (2019)	Feedlot (2020)
DM, %	59.0 ± 2.69	72.2 ± 8.15
OM	97.1 ± 0.39	97.1 ± 0.43
CP	10.5 ± 0.15	11.1 ± 0.65
NDF	28.9 ± 1.51	37.1 ± 2.75
ADF	13.5 ± 0.92	17.9 ± 1.29
Starch	51.6 ± 0.95	40.4 ± 3.28

Starch digestibility – metabolism study

Ruminal: $P = 0.02$
Intestinal: $P = 0.10$
Total: $P = 0.96$







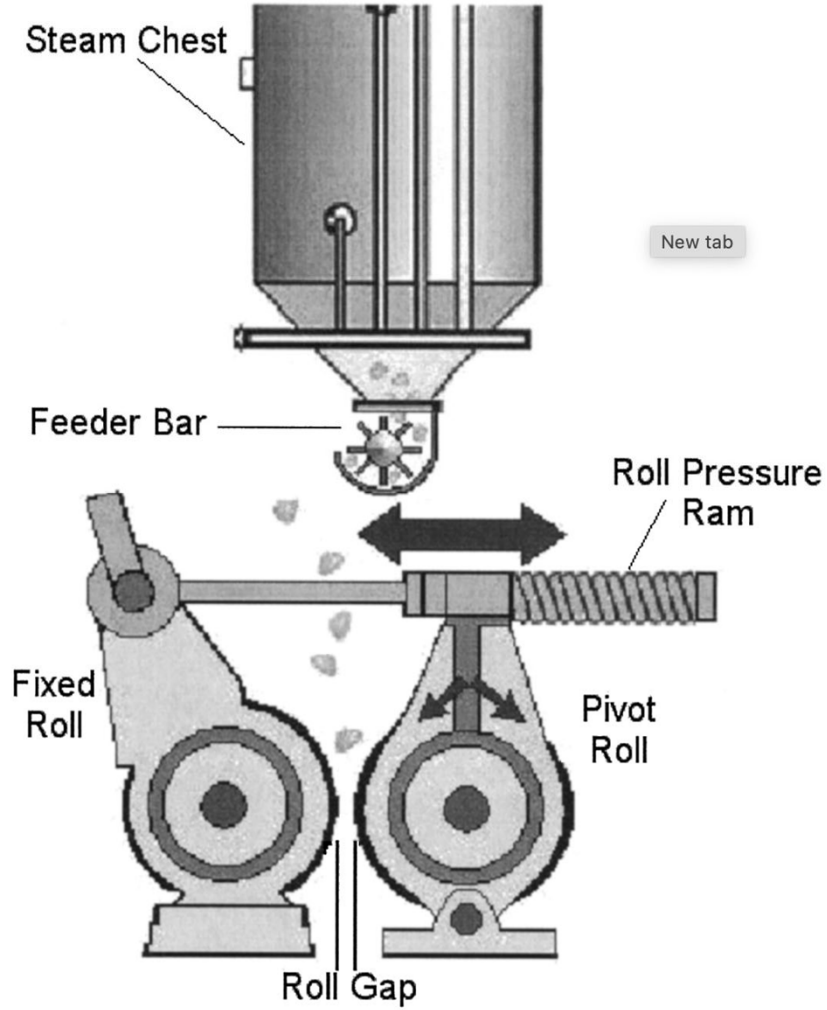
Summary of HMC products

- Feeding high-moisture corn with barley yielded similar DMI, but greater carcass weight
- Snaplage did not affect performance but can replace all the silage in the diet and a portion of the grain
- Reconstitution could be considered in western Canada

Zinn et al., 2002; JAS

Steam flaking corn

- Limited flaking capacity in western Canada
  - Regulation
  - Energy cost
  - Corn cost
- Increase NEg of yellow corn (vitreous) by 18%



- 20-30 min steam conditioning + flaking density of 0.31 g/L

Why steam flake corn?

- Disrupt the starch protein matrix

	Grain Processing Method		
Site of Digestion	**Dry Rolled**	**Coarse Flake**	**Thin Flake**
Rumen	75.8	88.2	90.1
Post- Rumen	78.6	81.3	86.6
Total Tract	95.0	97.9	98.8
DE Mcal/ kg	3.24	3.36	3.40

Dry Rolled vs. Steam rolled ($p < 0.05$)

(Zinn 1993)

Influence of flaking density

	Corn		
Dry density, kg/L[a]	<.28	.28 to .37	>.37
ADG, kg	1.45	1.39	1.39
DMI, kg	7.85	7.31	7.40
Feed/gain	5.4	5.2	5.3
ME,[b] Mcal/kg DM	4.01	4.16	4.10

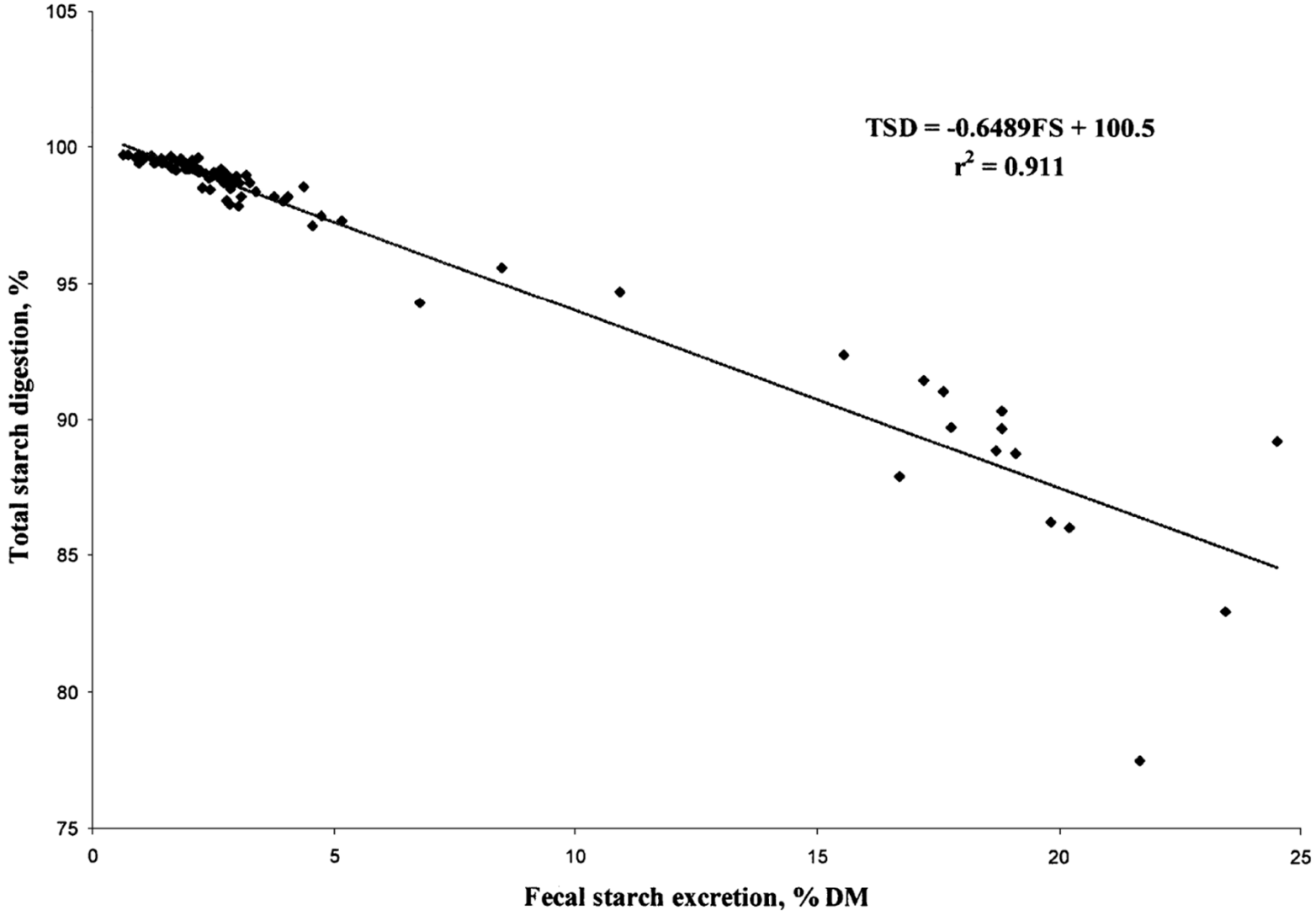
Owens et al., 1997; JAS

Roller gap effects and fecal starch

	Flake density, kg/L			
Item	0.26	0.31	0.36	0.41
Roll gap, mm				
0	1.40	3.49	5.09	10.89
1	1.36	3.35	4.82	8.73
Difference, %	–2.9	–4.3	–5.5	–24.7

Zinn et al., 2002; JAS

Assessing adequacy of processing



Summary

- Corn contains more starch and more energy than barley
- But, corn contains less CP and high inclusion may require use of protein supplements – consider this in the cost
- Use of ground, dry rolled, or tempered corn is unlikely to optimize starch digestion
  - Increasing the severity of processing will likely not improve this outcome
- Due to the starch endosperm structure corn requires more extensive processing
  - High moisture ensiling
  - Steam flaking
- Fecal starch evaluation is a useful tool