Adding value to pet food products with the inclusion of sorghum ingredients

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Ingredients utilized in pet food

1st — **Farm & Mill-based ingredients**

4M tons

2nd — **Meat & Poultry Products**

1.83M tons

3rd — **Rendered Protein Meals**

1.5M tons

Grains

Pulses

Cereal by-products

Fruits

Others

By weight, **whole grains** are the **most used ingredients** in dog and cat food

Source: Institute for Feed Education & Research, 2020

Grains utilized in pet food

Barley $\boxed{\text{Rice}}$ $\boxed{\text{Corn}}$ Flaxseed Linseed

Millet Oats Pearled Barley Quinoa

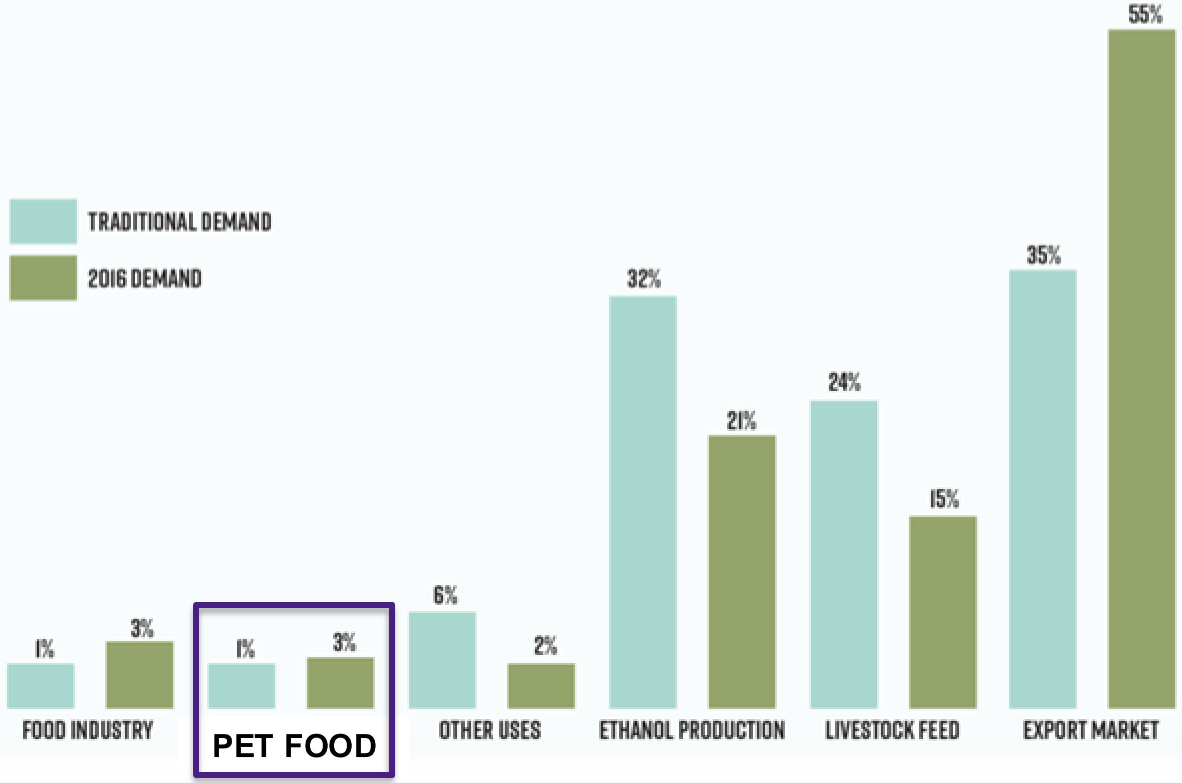
Rye Sesame Seeds **Sorghum**

Sunflower Seeds $\boxed{\text{Wheat}}$

Sorghum usage

15 pet food companies

+ 130 products



Why sorghum?

Sorghum

Processing

Attributes

Novel products

Sustainability

Digestibility

What is Sorghum?

Functional properties

Sorghum

Perennial grain usually grown as annual crop

Originates from northeast Africa and Asia

Grow in semi-arid environments

***Sustainable** choice*

SORGHUM
THE RESOURCE CONSERVING INGREDIENT™

Sorghum

- 30% less water

91% of sorghum acres are rain fed

1.5 trillion gallons of irrigation water savings per year

- CO_2 emissions

Captures more carbon during respiration

-0.21 CO_2e per kg*

*EcoPractices 2020 On-farm Practices Report for Nu Life Market

Sorghum

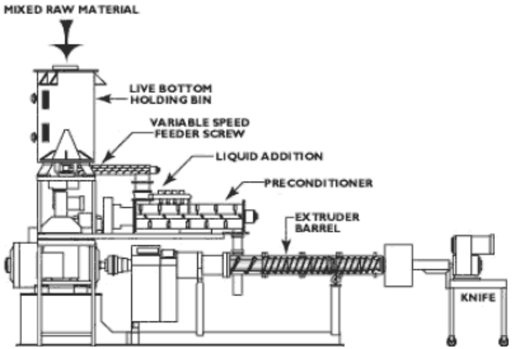
Different varieties

White and red sorghum

pet food

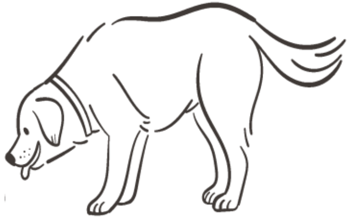
Sorghum in pet food

Consumer



Processing

Acceptability



Digestibility
Health benefits

Sorghum in pet food

Gluten-free

Non GMO

Ancient grain

Sustainable

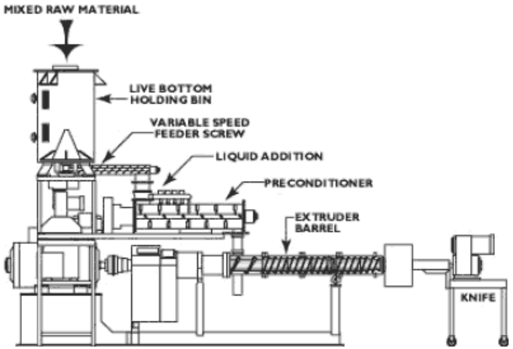
Nutritional composition

Item,%	Corn	Sorghum*	Brewer's rice
Dry matter	89	89	89
Organic matter	98	98	98
Crude protein	11	~9-11	7.6
Fat	5.2	~2.5- 6	3.8
Starch	78	~60-75	88
Total dietary fiber	4.1	~7-15	1.6
Soluble fiber	0.62	~1-3	0.23
Insoluble fiber	3.45	~5-13	1.41

*Murray et al. 2001, Carciofi et al. 2008, Von Schaumburg et al. 2021, De-Oliveira et al. 2008, Teixeira et al. 2019 and 2021

Sorghum in pet food

Consumer



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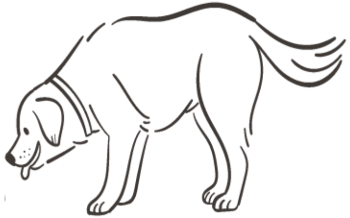
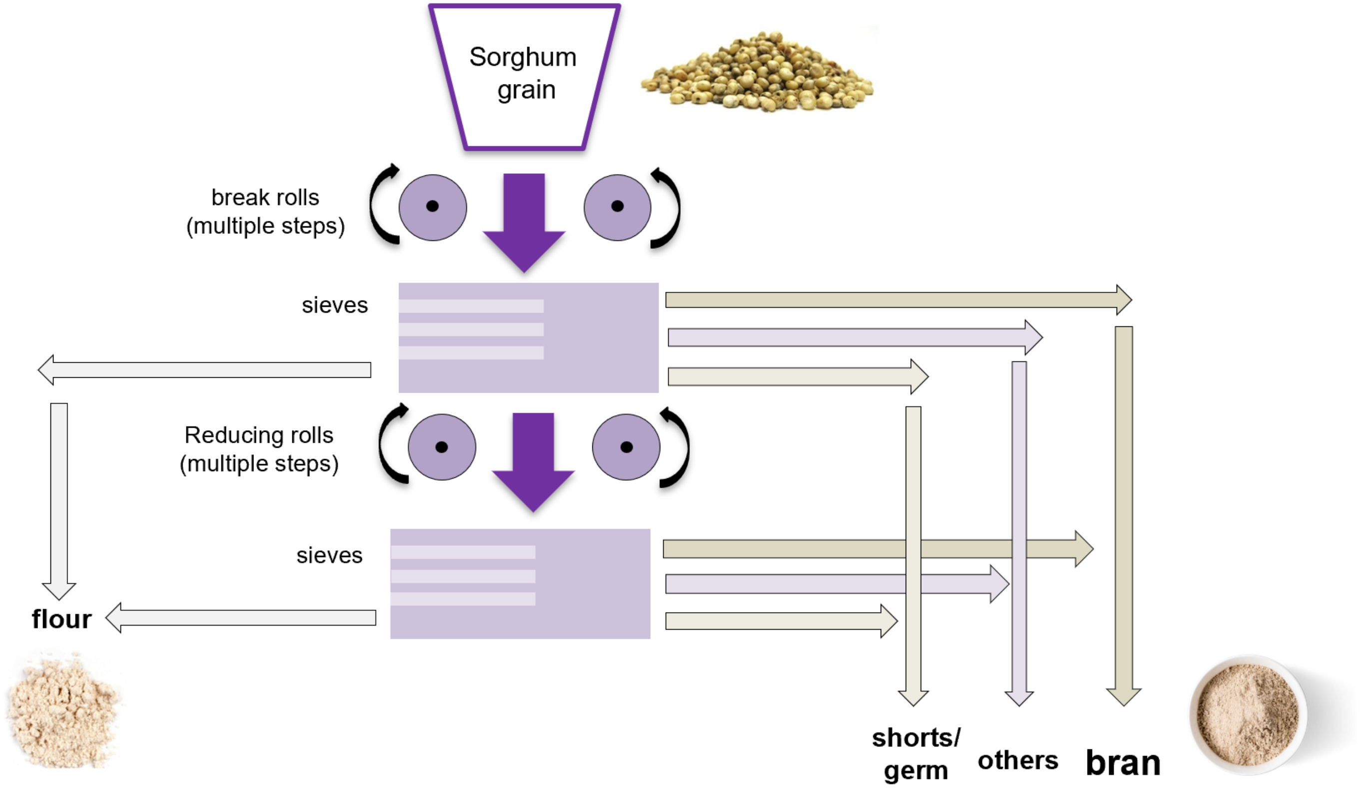


Digestibility
Health benefits

Sorghum – milling



Sorghum fractions in dog food

Sorghum Flour

Sorghum Germ

Sorghum Mill-feed

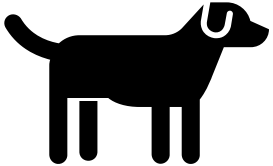
Sorghum fractions in dog food

Item	Sorghum to the mill	Flour	Mill-feed
Yield, kg	1,525	1,041	414
Yield, %	100	68.3	27.2
Moisture, %	12.22	11.59	10.87
Crude Protein, %	10.8	10.2	13.9
Crude Fat, %	6.59	5.12	4.96
Crude Fiber, %	1.70	n.d.	5.05
ADF, %	3.80	1.40	7.70
NDF, %	6.70	1.50	16.80
TDF, %	8.80	3.20	20.0
Soluble Fiber, %	2.60	2.50	1.60
Insoluble Fiber, %	6.20	0.70	18.30
Lignin, %	n.d.	n.d.	2.90
Total Starch, %	61.5	67.0	43.8
Ash, %	1.31	1.53	2.20

Owner and pet acceptance

Pet and owner acceptance of dry dog foods manufactured with sorghum and sorghum fractions

Brizio Di Donfrancesco [a], Kadri Koppel [a], Charles Gregory Aldrich [b]



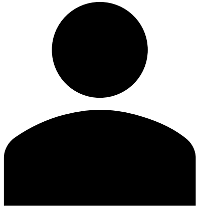


Table 1. Experimental diets composition: control (CD), whole sorghum (WSD), sorghum flour (FD) and sorghum mill-feed (MF).

Ingredients, %	CD	WSD	FD	MF
Brewers' rice	21.21	–	–	–
Maize	21.21	–	–	–
Wheat	21.21	–	–	–
Whole sorghum	–	64.69	–	–
Sorghum flour	–	–	63.11	–
Sorghum mill-feed	–	–	–	67.65
Chicken by-product meal	20.94	20.02	20.00	20.00
Chicken fat	5.36	5.54	6.69	3.30
Beet Pulp	4.00	4.00	4.00	4.00
Maize gluten meal	3.00	3.00	3.00	3.00
Calcium carbonate	0.75	0.35	0.26	0.67
Potassium chloride	0.49	0.52	0.65	0.19
Salt	0.46	0.45	0.47	0.43
Dicalcium phosphate	0.87	0.95	1.27	0.24
Choline chloride	0.20	0.20	0.20	0.20
Vitamin premix	0.15	0.15	0.15	0.15
Trace mineral premix	0.10	0.10	0.10	0.10
Natural antioxidant (dry)	0.07	0.07	0.07	0.08

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Nutrient	CD	WSD	FD	MF
Moisture, %[a]	6.91	7.13	5.56	6.17
Dry matter, %	93.09	92.87	94.44	93.83
Protein (crude), %	21.70	21.1	21.5	24.6
Fat (acid hydrolysis), %	11.40	11.7	10.3	9.17
Fiber (crude), %	0.78	1.04	0.38	2.29

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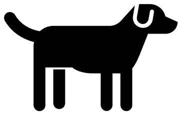
Home use test (client owned dogs)

Single bowl test



(n=30)

5 d 5 d 5 d 5 d 5 d

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5 d 5 d 5 d 5 d 5 d

Similar acceptability among control and sorghum diets

Owner and pet acceptance

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Table 4. Consumer panel (N = 105) of dog owners evaluation of "liking" (1–9 hedonic score; 1 = dislike to 9 = likes extremely) control (CD), whole sorghum (WSD), flour (FD) and sorghum mill feed (MF) containing diets.

	CD	WSD	FD	MF
Overall Liking	6.44[a]	6.59[a]	6.17[b]	6.08[b]
Overall Appearance Liking	6.60[a]	6.67[a]	6.23[b]	6.00[b]
Color Liking	6.46[a]	6.59[a]	6.34[ab]	6.12[b]
Aroma Liking	5.89	6.09	5.91	5.91

*Means with the same letter are not significantly different ($P<0.05$). Scores not sharing the same letter were significantly different ($p<0.05$).

Larger

Darker

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Processing effects

Effects of milling sorghum into fractions on yield, nutrient composition, and their performance in extrusion of dog food

Isabella Corsato Alvarenga, Zhining Ou, Shawn Thiele, Sajid Alavi, Charles Gregory Aldrich

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Total starch, %	46.9	45.6	50	35.3

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- ✓ **Whole sorghum** process similar to corn and rice
- ✓ Expands well

Table 5. Least square means* ± standard error of the mean (SEM) of processing data collected during production of extruded control (CON), whole sorghum (WSD), sorghum flour (FLD), and sorghum mill-feed (MFD) diets.

Item	CON	WSD	FLD	MFD	*P*
Flow rate, kg/h	$152^{a} \pm 2.2$	$149^{a} \pm 1.6$	$150^{a} \pm 1.0$	$133^{b} \pm 2.2$	0.0071
Density OE[1], g/L	$325^{b} \pm 2.2$	$333^{b} \pm 3.8$	$286^{c} \pm 1.4$	$425^{a} \pm 19.5$	0.0002
Density OD[2], g/L	$304^{bc} \pm 2.7$	$317^{ab} \pm 6.0$	$285^{c} \pm 3.9$	$391^{a} \pm 17.7$	0.0098
FS[3] speed, rpm	13.3	13.3	13.3	13.0	0.9436
PC[4] steam, kg/h	17.5 ± 0.20	17.3 ± 0.36	17.5 ± 0.27	17.5 ± 0.27	0.9611
PC water, kg/h	$15.8^{a} \pm 0.24$	$15.6^{a} \pm 0.49$	$15.8^{a} \pm 0.57$	$13.3^{b} \pm 0.03$	0.0012
PC temp, °C	$98.3^{ab} \pm 0.46$	$98.5^{a} \pm 0.21$	$98.2^{ab} \pm 0.31$	$97.1^{b} \pm 0.12$	0.0141
EX[5] shaft speed, rpm	$322.7^{b} \pm 3.57$	$319.7^{b} \pm 0.80$	$319.4^{b} \pm 0.82$	$383.7^{a} \pm 0.21$	<.0001
EX steam, kg/h	$19.33^{a} \pm 0.10$	$19.47^{a} \pm 0.21$	$5.34^{b} \pm 0.47$	$3.19^{b} \pm 0.60$	<.0001
Motor load, %	45.9 ± 1.44	46.6 ± 1.14	46.4 ± 1.44	41.2 ± 0.99	0.0633
EX water, kg/h	$7.69^{b} \pm 0.09$	$7.61^{b} \pm 0.02$	$7.76^{b} \pm 0.03$	$10.17^{a} \pm 0.02$	<.0001
Knife speed, rpm	937 ± 5.6	930 ± 3.3	943 ± 18.0	991 ± 18.4	0.1071
SME[6], kJ/kg	102.2 ± 10.34	109.7 ± 8.03	105.9 ± 10.79	92.6 ± 9.70	0.6278

[ab]Variable means within a row with unlike superscripts differ ($P < 0.05$).

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✓ Sorghum flour = bulk density

✓ Sorghum mill-feed = bulk density

As full replacement (high inclusion)

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Processing – additional applications

Characterization of white and red sorghum flour and their potential use for production of extrudate crisps

Julia Guazzelli Pezzali, Anu Suprabha-Raj, Kaliramesh Siliveru, Charles Gregory Aldrich

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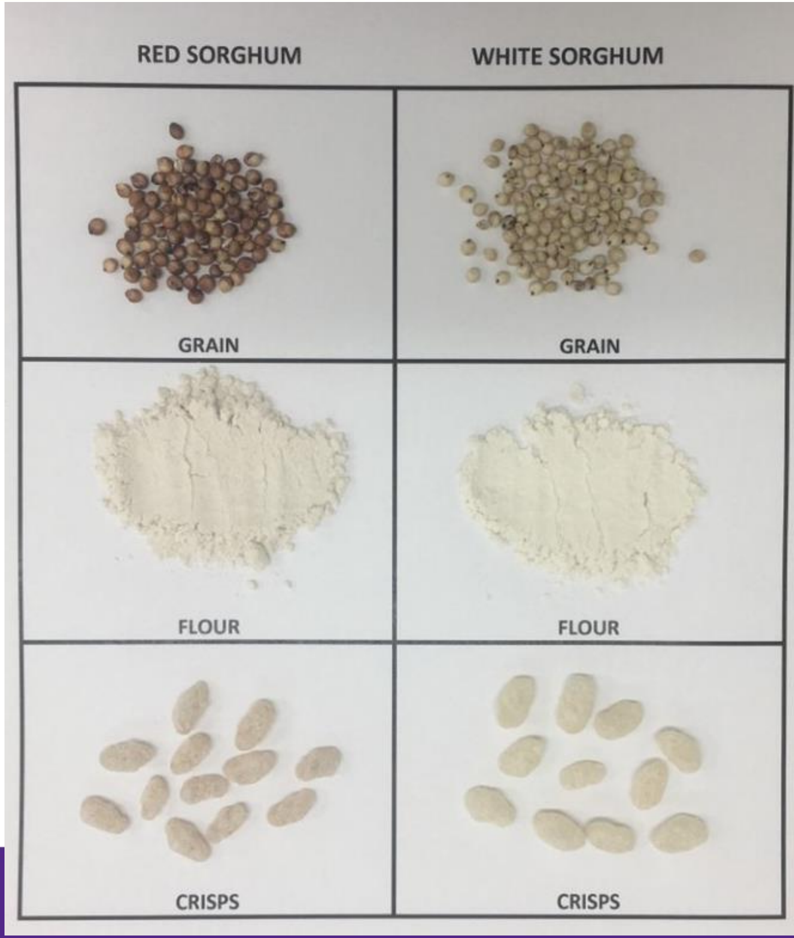

Processing – additional applications

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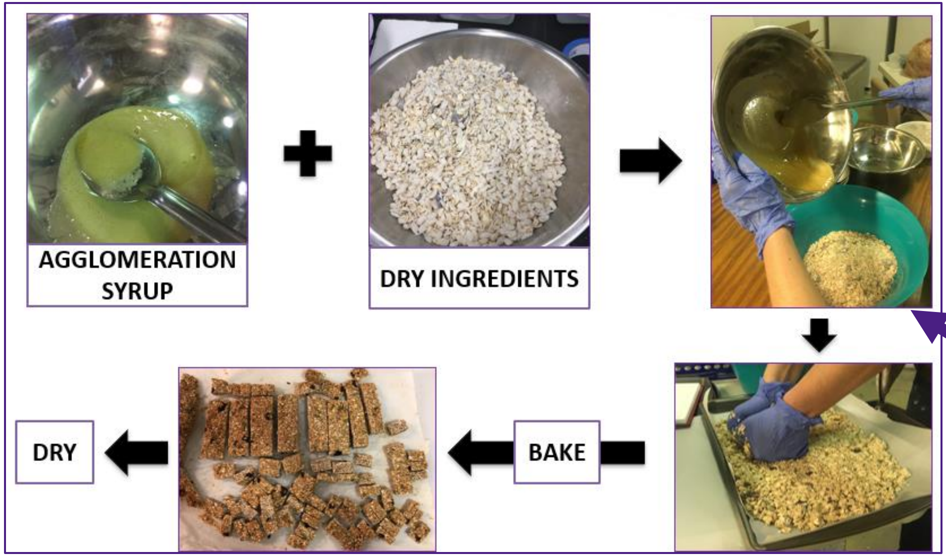
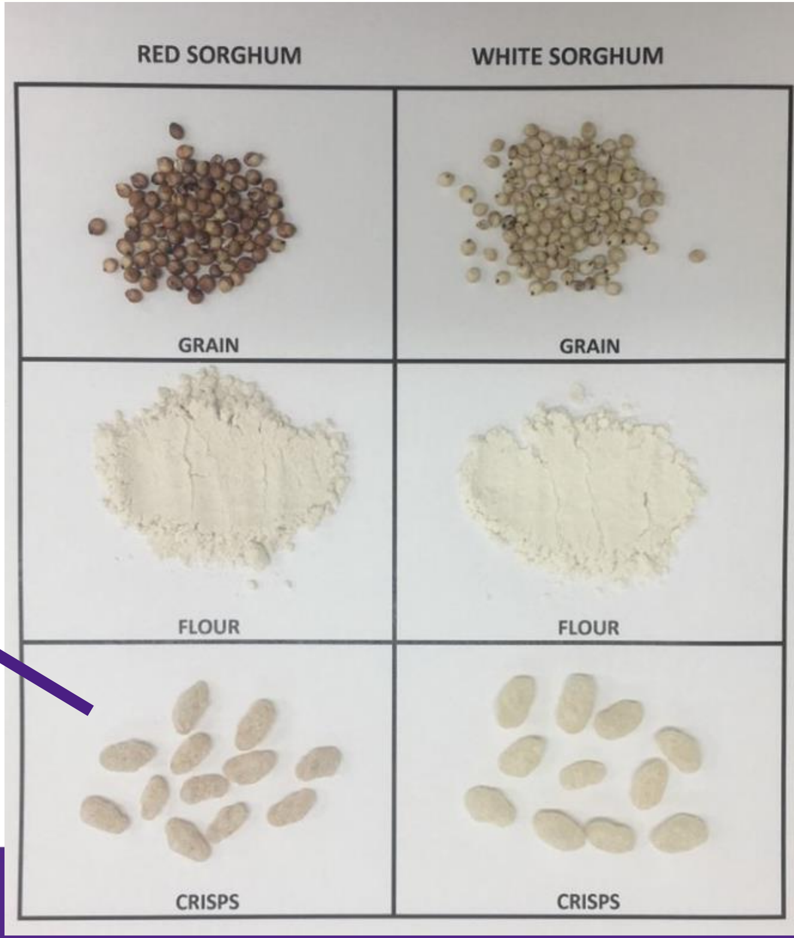
Julia Guazzelli Pezzali, Weilun Tsai, Kadri Koppel, Charles Gregory Aldrich

First published: 25 June 2021 | https://doi.org/10.1111/joss.12689





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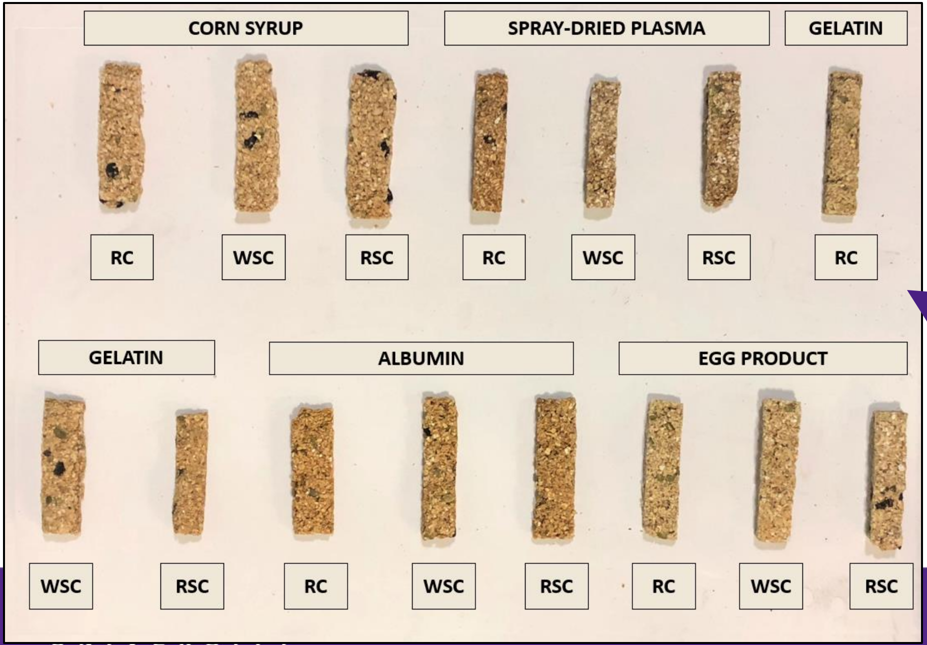

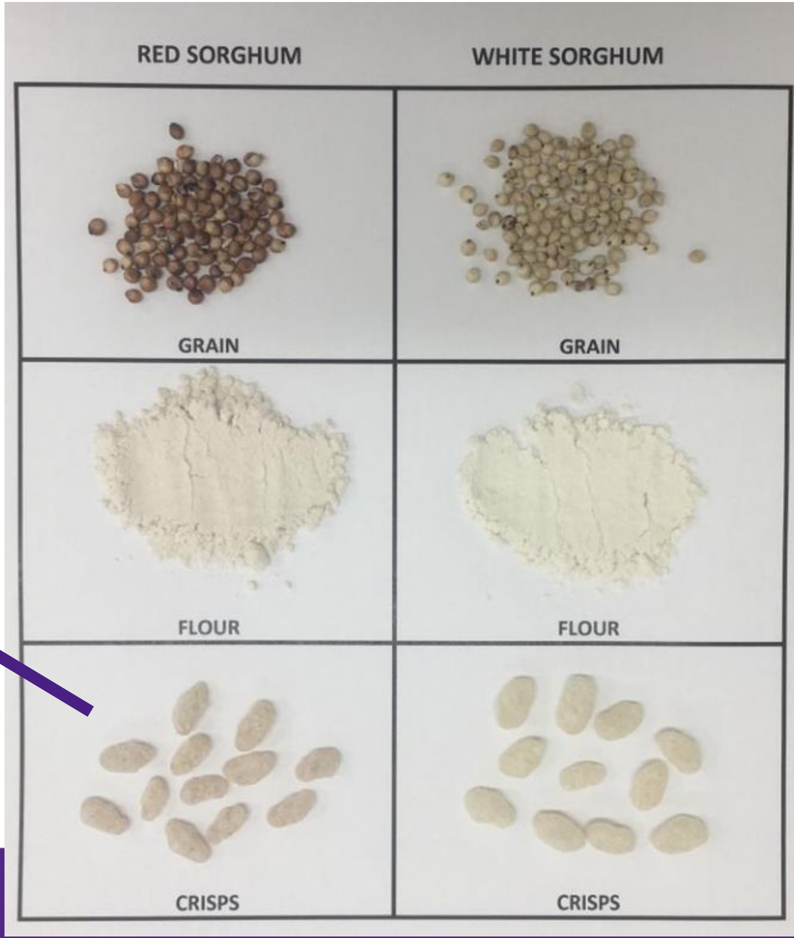

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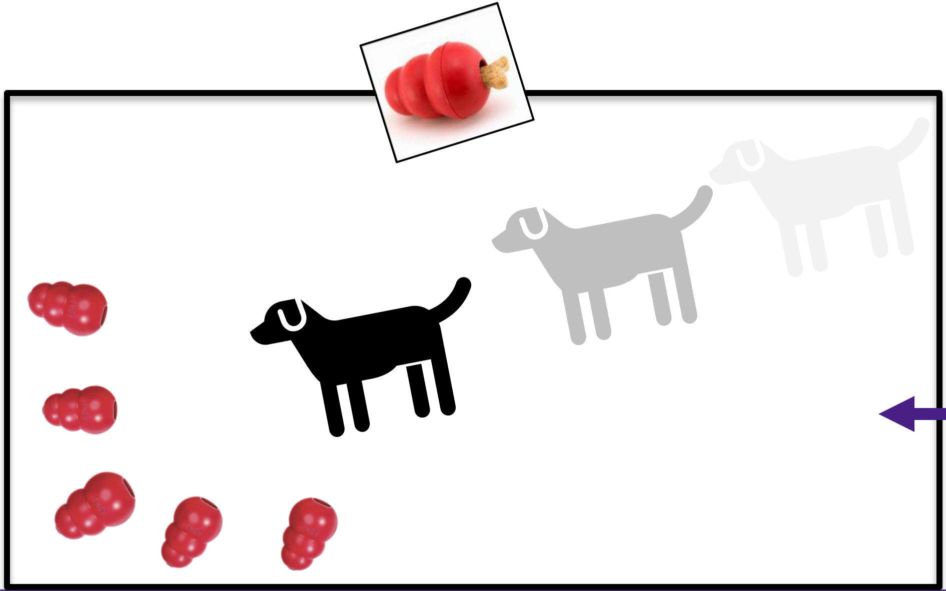

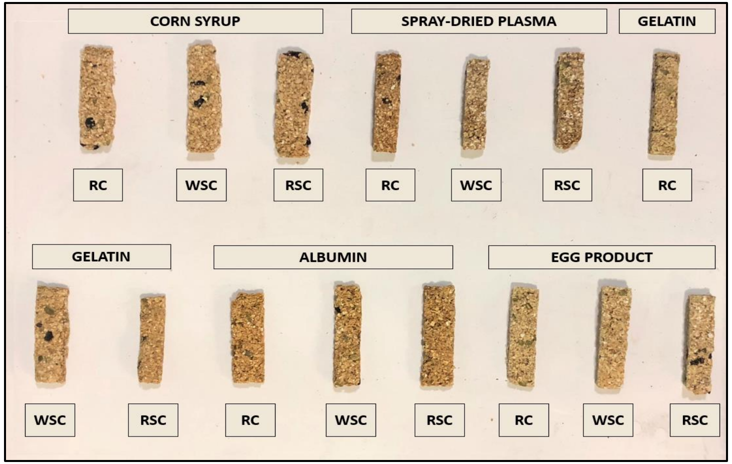

Three ranking tests:

1. RSC w/ different binders
2. WSC w/ different binders
3. RSC w/ different binders
4. Most preferred binder w/ different crips

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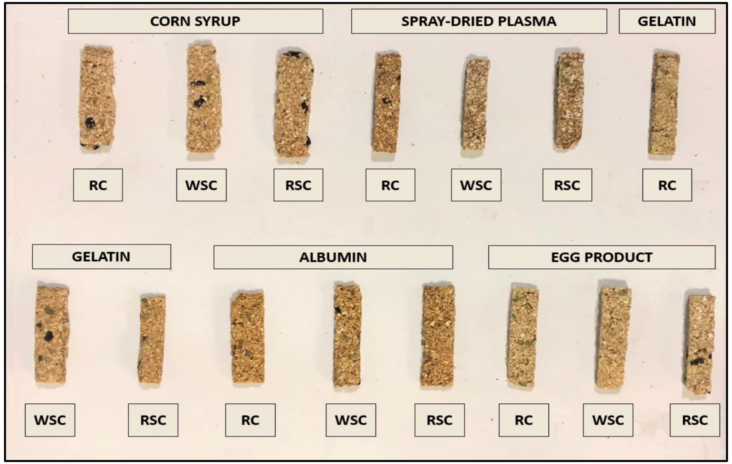
1 – moist preferred, 5 – least preferred

	Treatments						
Ranking test	CS	SDP	GL	AL	EP	SEM	p=
1. RC	3.12	2.79	3.38	2.73	2.78	0.195	.0973
2. WSC	2.80^{ab}	2.68^{b}	3.17^{ab}	2.75^{ab}	3.41^{a}	0.194	.0110
3. RSC	2.90^{ab}	2.40^{b}	3.62^{a}	2.90^{ab}	3.06^{ab}	0.188	.0004



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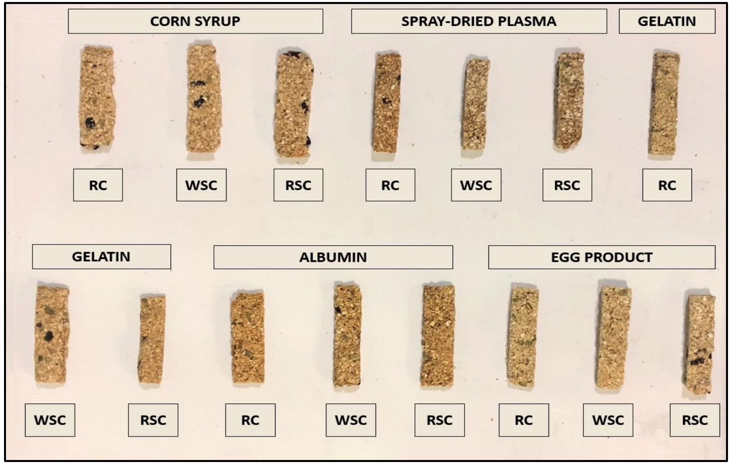
3. RSC	2.90[ab]	2.40[b]	3.62[a]	2.90[ab]	3.06[ab]	0.188	.0004
	RC	WSC		RSC			
4. SDP	1.81	2.05		2.14		0.129	.2900

Note: Different letters following the row in the same column indicate a significant difference ($p < .05$). Abbreviations: AL, albumin; CS, corn syrup; EP, egg product; GL, gelatin; RC, rice crisp; RSC, red sorghum crisp; SDP, spray-dried plasma; WSC, white sorghum crisp.

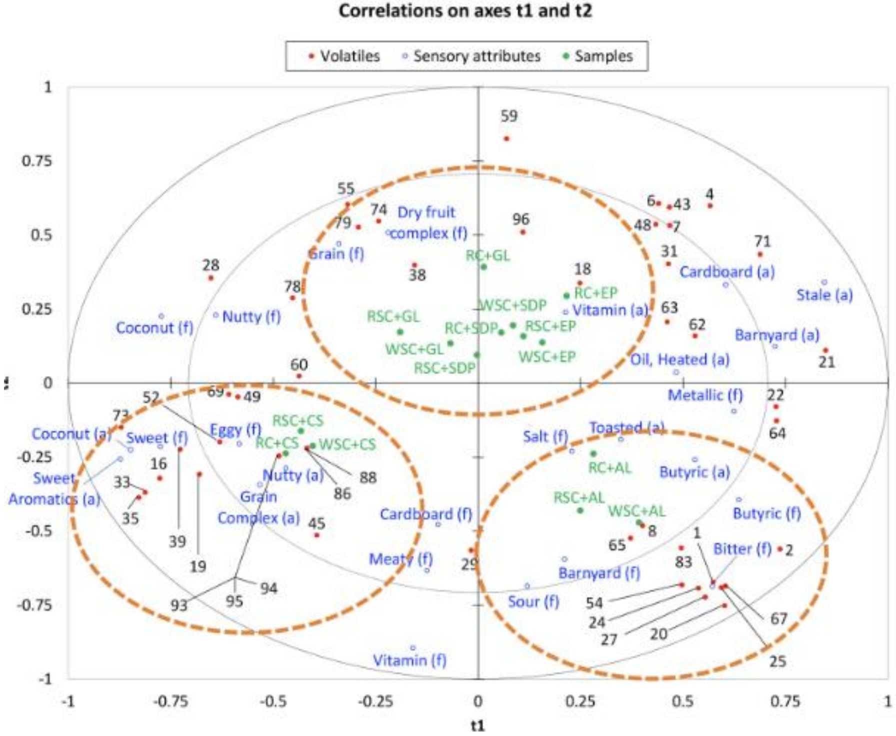


Processing – additional applications

The use of protein binders and sorghum crisps as potential ingredients in a cereal bar for dogs

Julia Guazzelli Pezzali, Weilun Tsai, Kadri Koppel, Charles Gregory Aldrich

First published: 25 June 2021 | https://doi.org/10.1111/joss.12689



Plot of partial least square regression analysis of volatile compounds and sensory attributes

Group by binder, **not crisp source**

Processing – additional applications

Sensory attributes, dog preference ranking, and oxidation rate evaluation of sorghum-based baked treats supplemented with soluble animal proteins

Krystina A Lema Almeida, Kadri Koppel ✉, Charles G Aldrich ✉

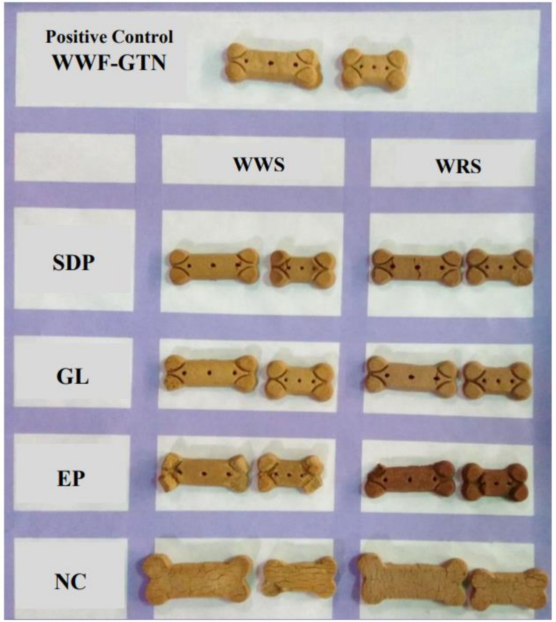
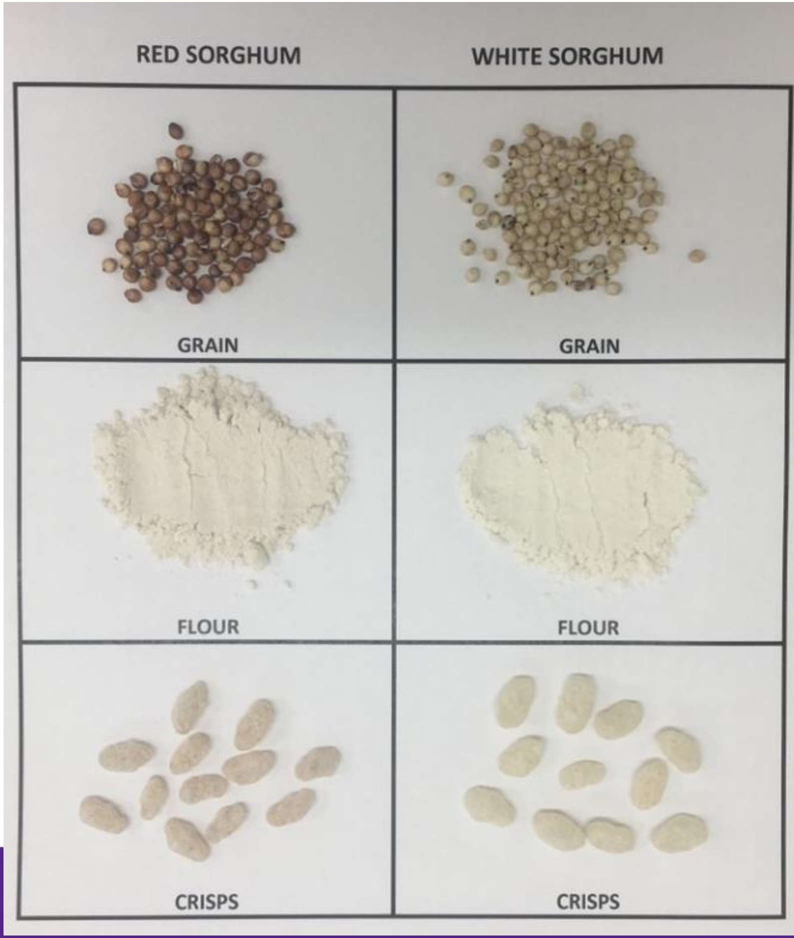
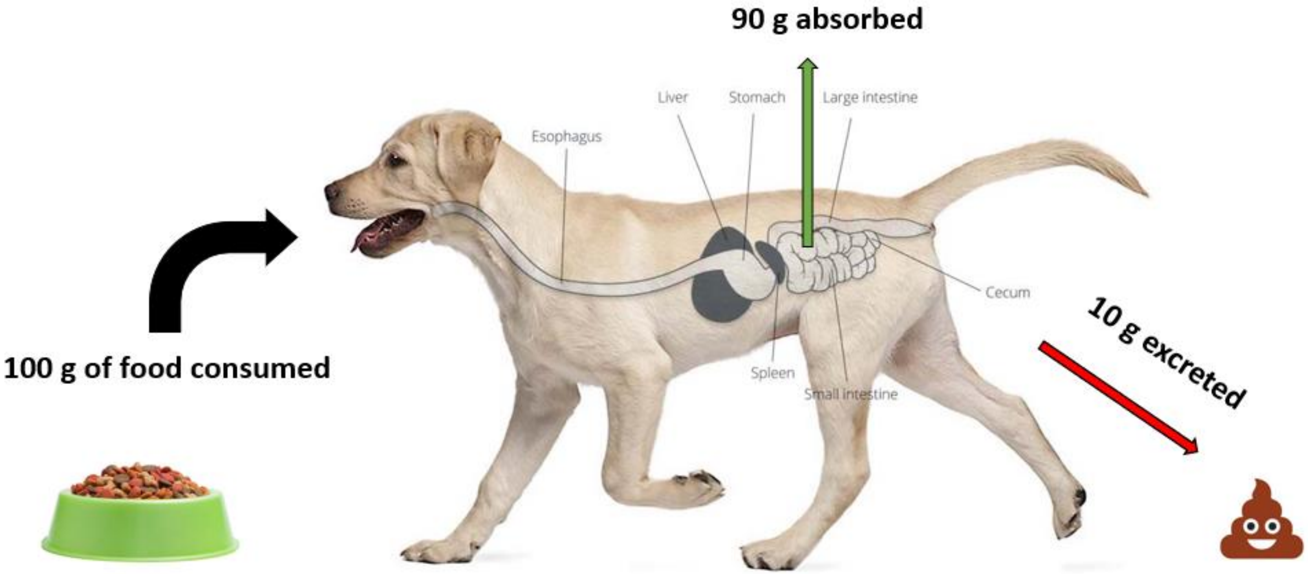


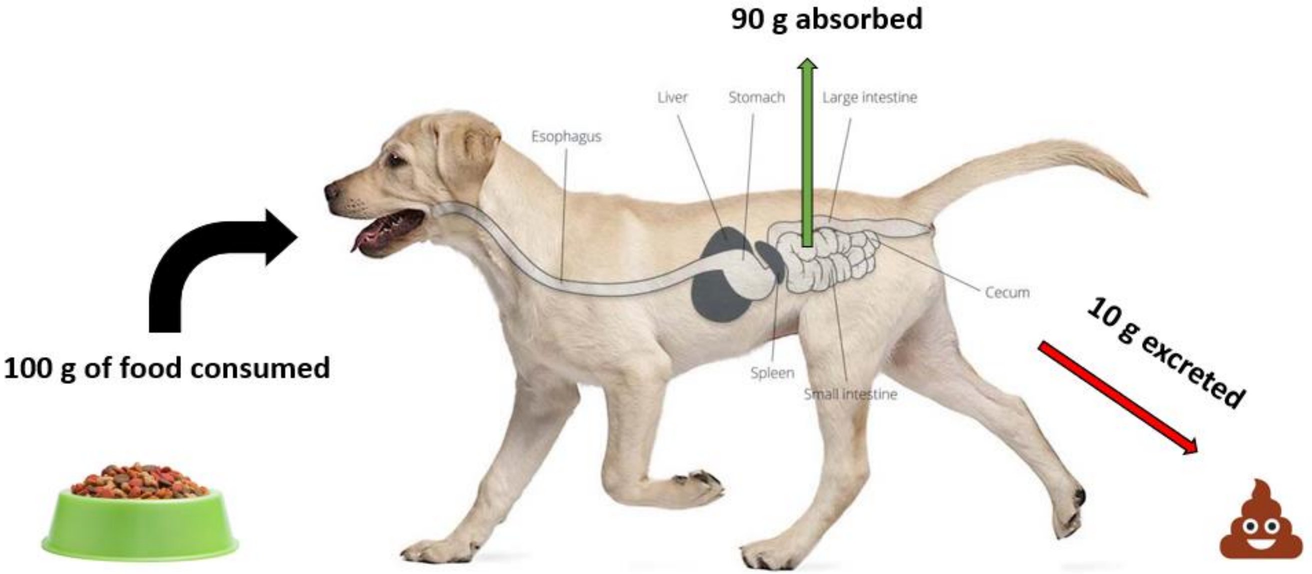
Figure 3.1 Baked dog treats produced with different cereals and soluble animal proteins combinations.
WWF= whole wheat flour, WWS= whole white sorghum, WRS= whole red sorghum, GTN=gluten, NC=no protein, SDP=spray dried plasma, EP=egg protein, GL=gelatin



Digestibility



Digestibility



Apparent total tract (fecal) digestibility: 90%

Digestibility

Table 4. Nutrient intakes and digestibilities by ileally cannulated dogs (n = 6) fed diets containing grain flours

Item	Barley	Corn	Potato	Rice	Sorghum	Wheat[a]	SEM
	Diet						
Intake, g/d							
Dry matter	391	399	401	379	430	395	19.6
Organic matter	364	370	365	341	398	369	17.7
Crude protein	109^{c}	122^{cd}	110^{c}	110^{c}	137^{d}	117^{c}	5.6
Fat	67	74	67	70	80	74	3.4
Starch	158	150	160	146	153	159	7.1
TDF[b]	35^{d}	20^{c}	31^{d}	22^{c}	38^{d}	22^{c}	2.5
Ileal digestion, %							
Dry matter	74.9	73.5	66.7	77.5	74.1	81.2	3.02
Organic matter	80.9^{d}	79.8^{cd}	73.6^{c}	83.1^{d}	79.5^{cd}	85.7^{d}	2.43
Crude protein	81.1^{d}	72.5^{cd}	63.6^{c}	76.2^{d}	76.9^{d}	81.5^{d}	3.20
Fat	89.9	91.3	89.8	92.9	90.9	94.2	1.09
Starch	99.38^{c}	99.53^{cd}	99.57^{cd}	99.82^{e}	99.67^{de}	99.78^{e}	.06
TDF	12.2	–4.6	–9.7	20.1	15.1	5.1	13.2
Total tract digestion, %							
Dry matter	82.5^{d}	85.4^{e}	83.6^{de}	83.9^{de}	79.7^{c}	83.5^{de}	.83
Organic matter	87.0^{d}	89.5^{f}	87.9^{de}	88.9^{ef}	84.4^{c}	88.2^{def}	.64
Crude protein	83.4^{c}	86.5^{d}	82.9^{c}	84.9^{cd}	83.3^{c}	84.9^{cd}	.81
Fat	92.4	94.3	93.8	94.0	92.6	93.7	.57
Starch	99.85^{de}	99.80^{cd}	99.80^{cd}	99.91^{e}	99.77^{c}	99.88^{e}	.02
TDF	41.7	13.2	36.6	24.0	18.3	13.7	8.68

[a]Total tract digestibility data based on n = 5.
[b]Total dietary fiber.
[c,d,e,f]Means in the same row not sharing common superscript letters differ ($P < .05$).

Murray et al. 1999

Digestibility

Food intake, feces collected (on dry matter basis) per day, number of defecations per day, fecal scores and apparent total tract digestibility (ATTD) of dogs fed control (CON), whole sorghum (WSD), flour (FLD) and mill-feed (MFD) diets (N = 12).

Item	**CON**	**WSD**	**FLD**	**MFD**	**SEM**	***P***
Food intake, g/d	185	186	181	195	6.5	0.4818
Wet feces, g/d	75.2^{c}	95.6^{b}	60.6^{c}	159.7^{a}	5.03	<.0001
Dry feces, g/d	42.0^{c}	55.7^{b}	32.6^{c}	95.4^{a}	3.24	<.0001
Defecations per day	2.18^{b}	2.38^{b}	2.10^{b}	3.02^{a}	0.098	<.0001
Fecal score (1–5)	3.60^{b}	3.68^{ab}	3.78^{ab}	3.92^{a}	0.068	0.0007
ATTD, %						
Dry Matter	83.0^{b}	81.1^{c}	86.0^{a}	65.9^{d}	0.44	<.0001
Organic Matter	88.0^{b}	85.8^{b}	90.7^{a}	70.6^{c}	0.34	<.0001
Gross Energy	87.2^{b}	85.4^{b}	90.3^{a}	70.2^{c}	0.68	<.0001
Crude Protein	77.5^{b}	76.3^{b}	81.8^{a}	67.2^{c}	0.73	<.0001
Crude Fat	91.5^{a}	88.4^{b}	91.4^{a}	77.9^{c}	0.37	<.0001
NFE (calculated)	94.2^{b}	91.6^{c}	96.3^{a}	77.0^{d}	0.35	<.0001
TDF	13.7^{b}	27.7^{a}	30.2^{a}	10.3^{b}	1.94	<.0001

^{abc} Means within a row that lack a common superscript differ ($P < 0.05$).

NFE = nitrogen free extract; TDF = total dietary fiber.

Alvarenga et al. 2018

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Alvarenga et al. 2018

Digestibility

Full Access

Effects of six carbohydrate sources on dog diet digestibility and post-prandial glucose and insulin response*

A. C. Carciofi, F. S. Takakura, L. D. De-Oliveira, E. Teshima, J. T. Jeremias, M. A. Brunetto, F. Prada

First published: 28 June 2008 | https://doi.org/10.1111/j.1439-0396.2007.00794.x | Citations: 111

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Journal of Animal Science, Volume 93, Issue 6, June 2015, Pages 2956–2966,

Short communication

Digestibility and metabolizable energy of some carbohydrate sources for dogs

C.M.L.S. Fortes [a], A.C. Carciofi [b], N.K. Sakomura [c], I.M. Kawauchi [a], R.S. Vasconcellos [a]

Show more

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Published: May 16, 2019 • https://doi.org/10.1371/journal.pone.0208869

See the preprint

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300, 450, and 600 μm

↑ Particle size

↓ Digestibility

↑ Short chain fatty acids

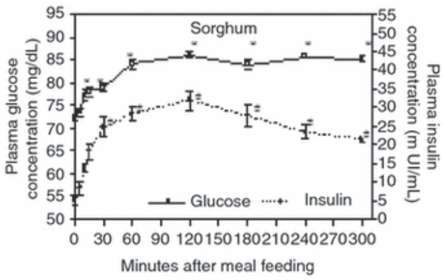
Digestibility

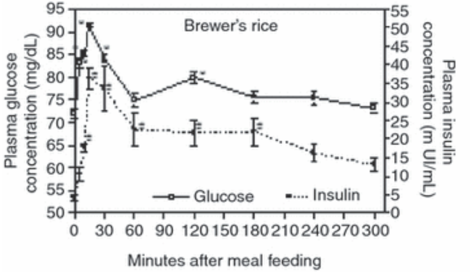
Metabolism

Metabolic effects

Glycemic index

Plasma glucose and insulin response curves of dogs fed experimental diets containing different starch sources





Carciofi et al. 2006

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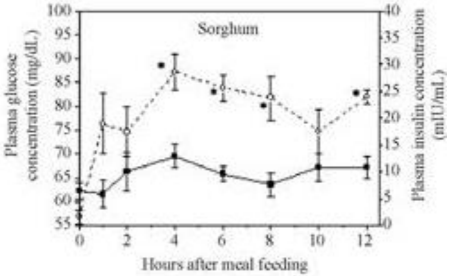
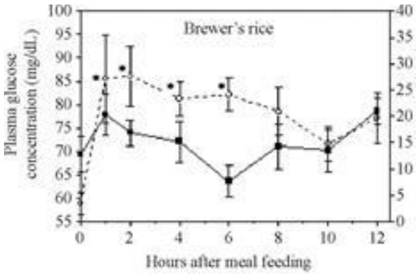
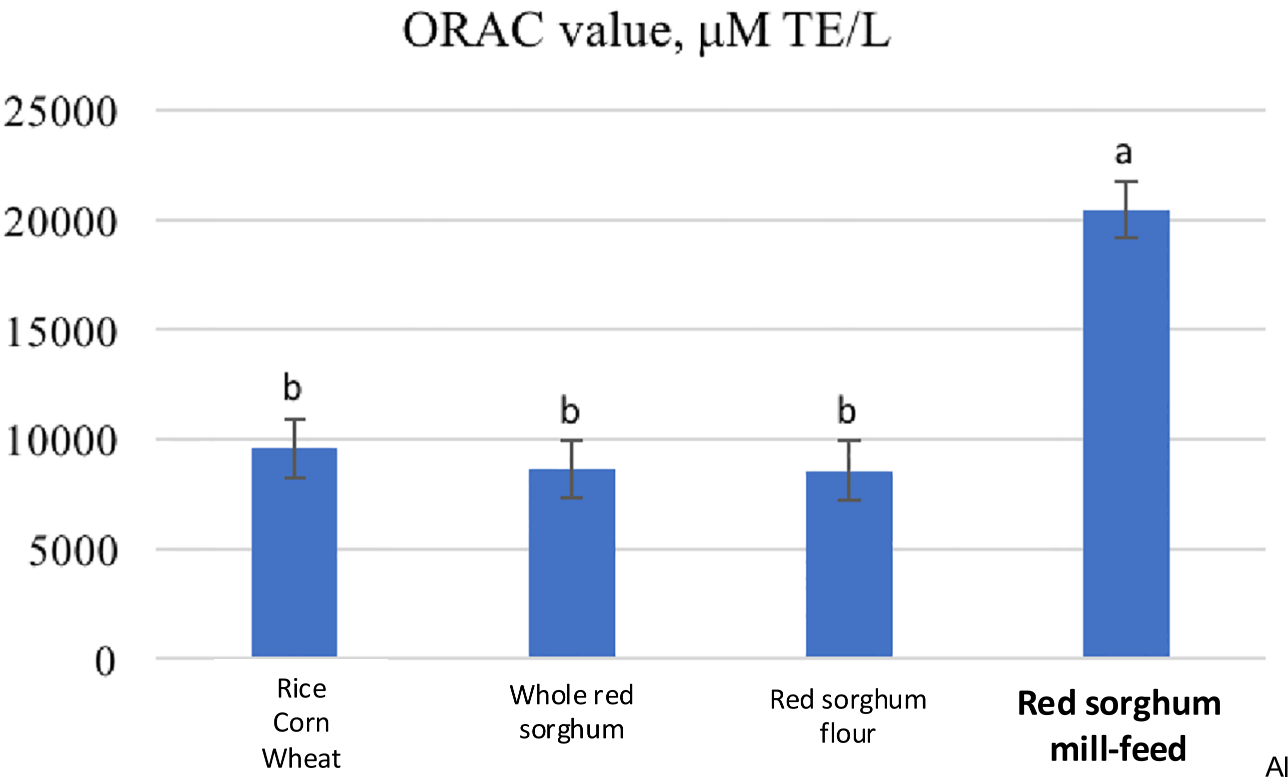




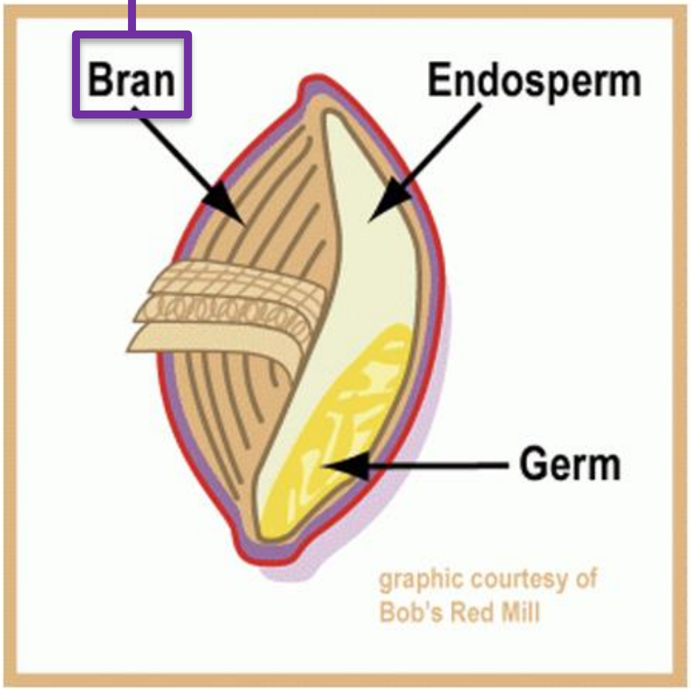
De Oliveira et al. 2008

Potential metabolic effects



Alvarenga et al. 2018

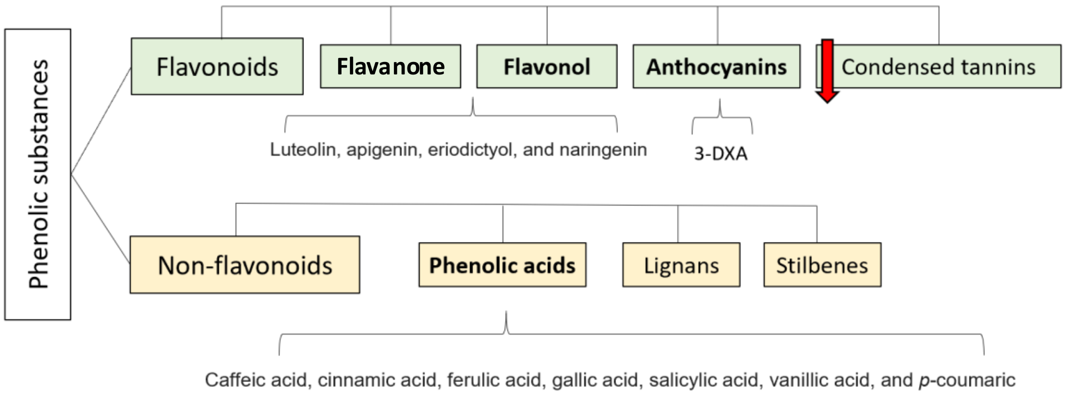
Sorghum grain - polyphenols



Polyphenols

- Secondary metabolites from plants

  Phenolic acid and flavonoid derivatives



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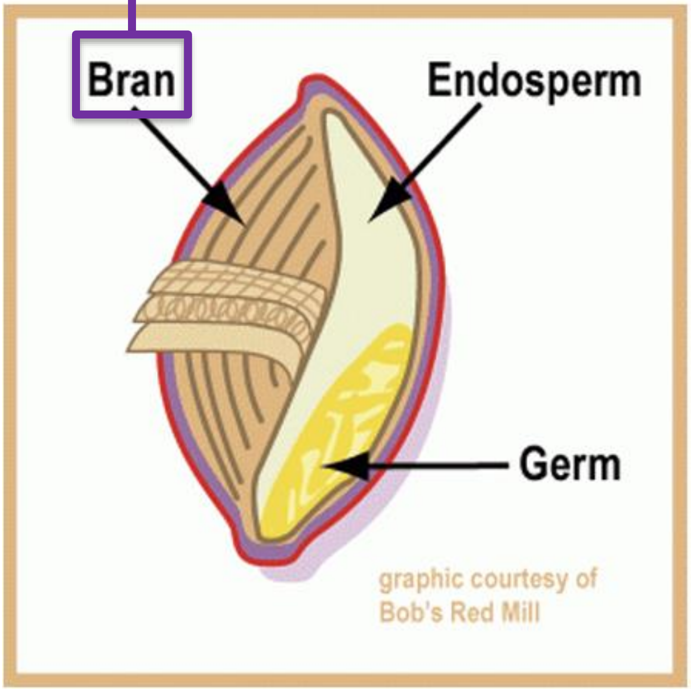

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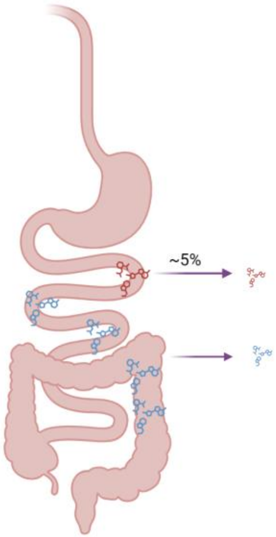


Local and systemic effects

Gut health

Antioxidant

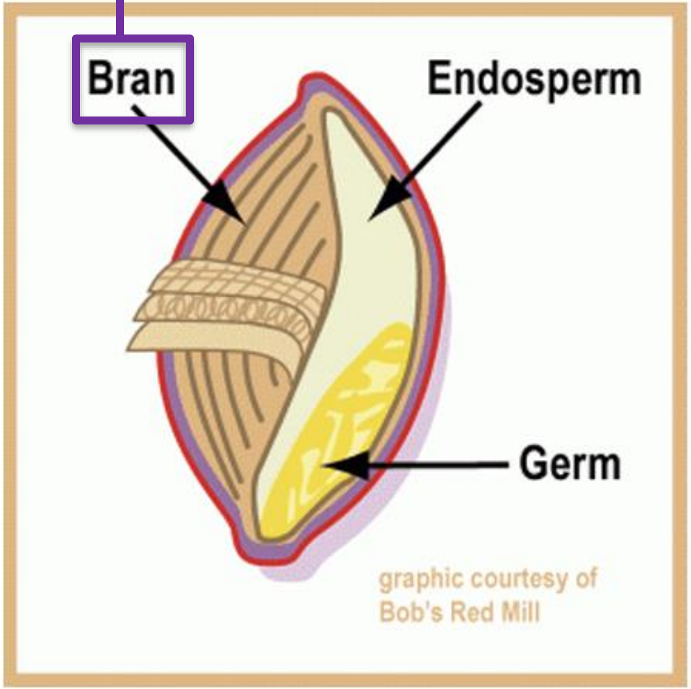
Anti inflammatory

Carbohydrate metabolism

Lipid metabolism

Girard and Awika (2018)

Sorghum grain - polyphenols



Polyphenols

- Color is due to phenolic flavonoid pigments

The darker the color → ↑ polyphenols

3-deoxyanthocyanin

Alfieri et al. (2017)

Sorghum grain - polyphenols

Antioxidant activity (ORAC) of sorghum grain and bran compared to common fruits and vegetables

	Commodity	ORAC (μmol TE/g, dry wt)	References
Sorghum	Tannin sorghum (grain)[a]	868	Awika et al. (2003b)
	Tannin sorghum (bran)[a]	3124	Awika et al. (2003b)
	Black sorghum (grain)	219	Awika et al. (2003b)
	Black sorghum (bran)	1008	Awika et al. (2003b)
	Red sorghum (grain)	140	Awika et al. (2003b)
	Red sorghum (bran)	710	Awika et al. (2003b)
	White sorghum (grain)	22	Awika et al. (2003b)
	White sorghum (bran)	64	Awika et al. (2003b)
Fruits and vegetables	Blueberry, lowbush	842	Wu et al. (2004)
	Strawberry	402	Wu et al. (2004)
	Plum	495	Wu et al. (2004)
	Watermelon	18	Wu et al. (2004)
	Apple, red delicious	295	Wu et al. (2004)
	Orange, navel	137	Wu et al. (2004)
	Broccoli	173	Wu et al. (2004)
	Carrot	108	Wu et al. (2004)
	Onion, red	93	Wu et al. (2004)
	Sweet pepper, green	105	Wu et al. (2004)
	Radishes	217	Wu et al. (2004)
	Potatoes, russet	63	Wu et al. (2004)

[a]Sumac variety.

↑ ORAC = ↑ Antioxidant capacity

Sorghum bran → ↑ Antioxidant capacity

https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/AREC/AREC-23/AREC-23NP-pdf.pdf

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	Onion, red	93	Wu et al. (2004)
	Sweet pepper, green	105	Wu et al. (2004)
	Radishes	217	Wu et al. (2004)
	Potatoes, russet	63	Wu et al. (2004)

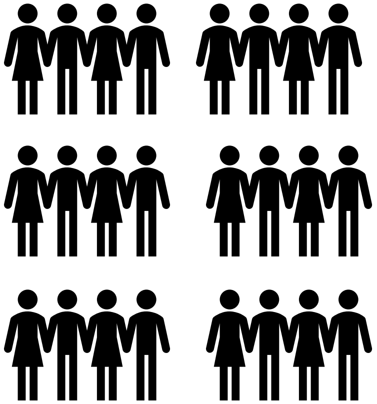
[a]Sumac variety.

↑ ORAC = ↑ Antioxidant capacity

Sorghum bran → ↑ Antioxidant capacity

https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/AREC/AREC-23/AREC-23NP-pdf.pdf

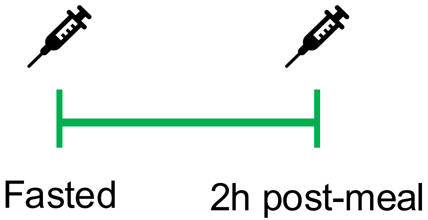
Acute effects of wheat vs sorghum pasta (humans)



30% Wheat pasta

30% White sorghum pasta

30% Red sorghum pasta

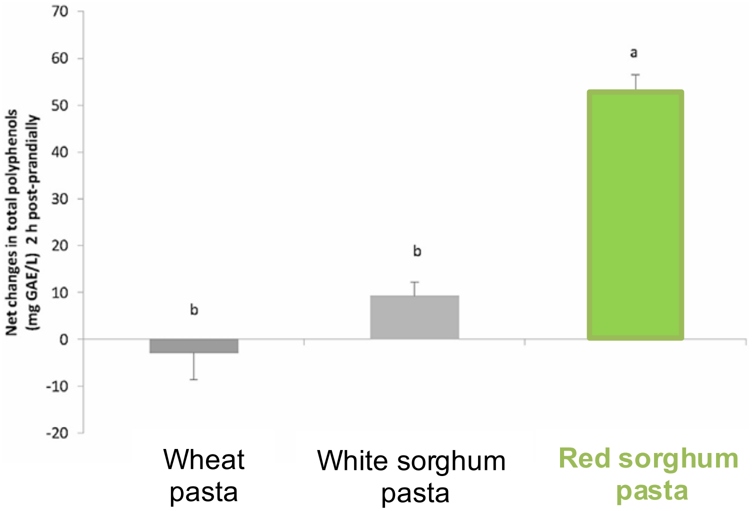


Khan et al. (2015)

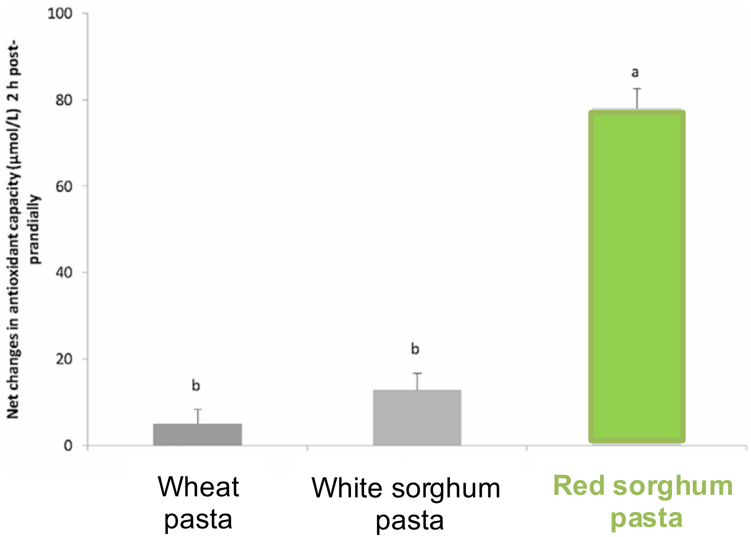
Acute effects of wheat vs sorghum pasta (humans)

Red sorghum pasta

⬆ Plasma total polyphenols



⬆ Antioxidant capacity



Khan et al. (2015)

Chemical and energy composition

Analyzed chemical and energy composition of white and red sorghum bran, and sorghum mill-feed

Item	Mill-feed	Red sorghum bran	White sorghum bran
Production days	3	3	1
Dry matter, %	93.7 ± 0.49	94.4 ± 0.79	92.41
		% dry matter basis	
Crude protein	10.8 ± 0.06	10.7 ± 0.52	11.2
Acid-hydrolyzed fat	9.70 ± 0.44	11.8 ± 0.45	10.3
Total dietary fiber	**22.39 ± 3.02**	**27.0 ± 0.93**	**25.5**
Insoluble	**19.8 ± 2.82**	**23.6 ± 0.80**	**22.9**
Soluble	2.64 ± 0.21	3.41 ± 0.16	2.53
Ash	4.63 ± 0.08	5.10 ± 0.28	4.25
		kcal/kg, dry matter basis	
Gross energy	4512 ± 45	4456 ± 134	4619

Phenolic concentrations

Item, ug/g DM	Rice	Barley	White sorghum A	White sorghum B	Oat	Burgundy sorghum	Millet	Sumac	White sorghum bran	Mill feed	Red sorghum bran
Gallic acid	2.8	16.6	9.4	6.8	Nq	6.3	21.9	42.3	97.4	109 + 35.6	247 + 18
4-Hydroxybenzoic acid	Nq	Nq	0.6	4.3	2.7	21.8	2.8	166.3	94.7	92 + 31.7	179 + 13.3
Vanillic acid	2.2	7.5	7.5	10.7	9.7	20.2	130.8	62.7	40.6	34 +6.9	68 + 5.8
Syringic acid	1	2	3.2	3.9	29.6	10	19.9	7.6	21.6	16 + 5.3	38 + 1.9
ρ-coumaric acid	2.3	26.7	20.5	21.5	69.3	20.4	320.7	45.2	40.6	190 + 91.5	143 + 45.8
Ferulic acid	45.7	244	208.5	171.6	160.1	236.2	455.1	388.1	849	916 + 137.7	1278 + 52.7
Sinapic acid	1.5	6.9	Nq	1	10.5	Nq	1.5	Nq	8.1	9 + 1.6	21 + 2.5
Total phenolic (ug/g)	313	692	700	741	903	1053	2119	3197	2315	3436 + 548	3519 + 333

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High variation

Phenolic concentrations

          

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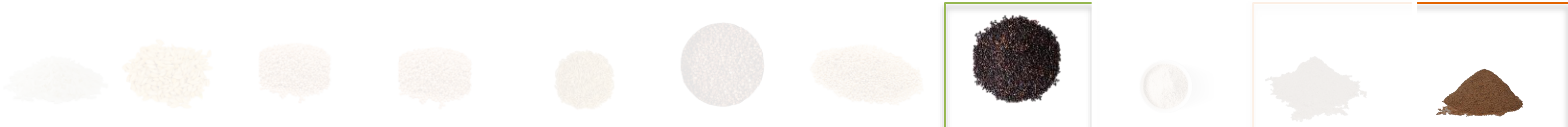
High variation

Phenolic concentrations



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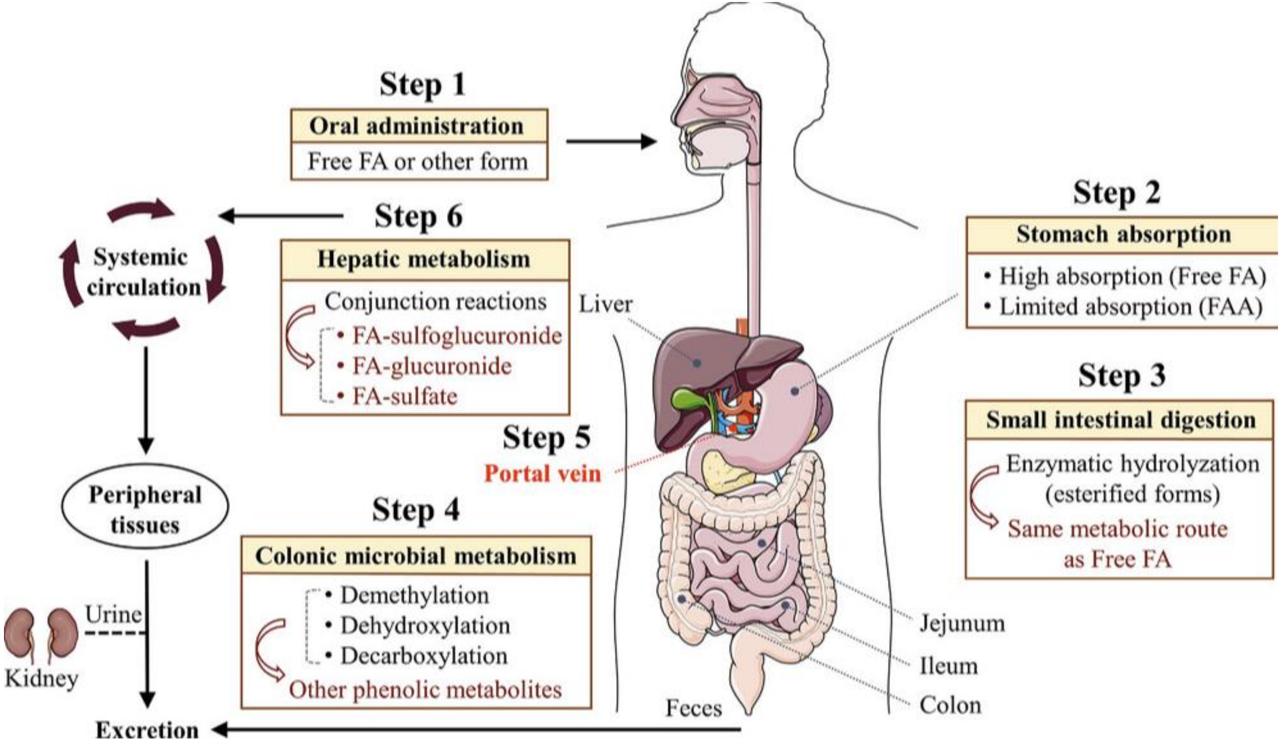
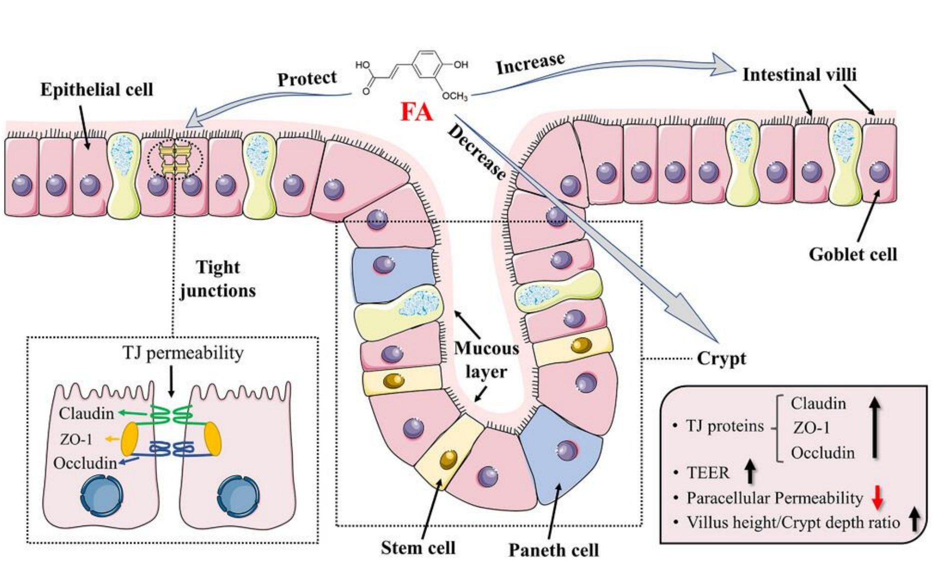
High variation

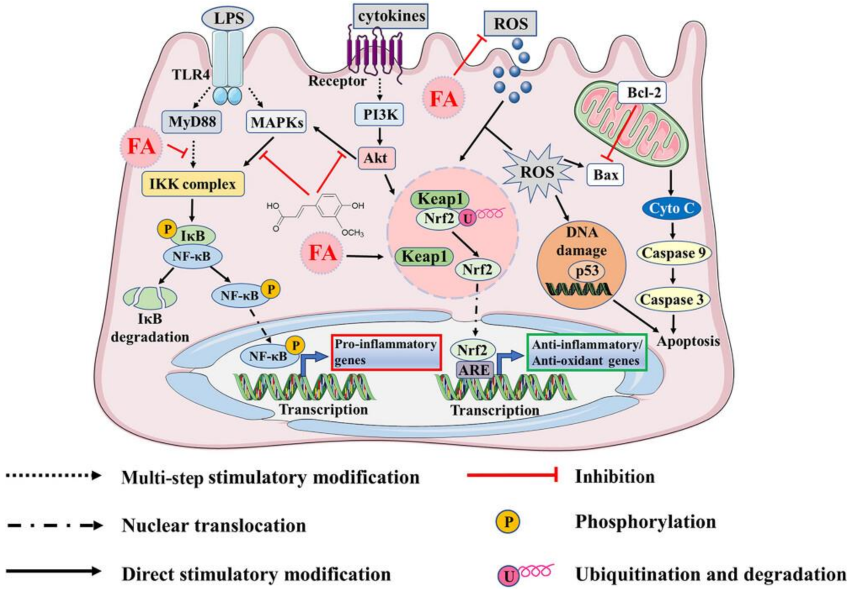
KANSAS STATE UNIVERSITY

Principal absorption and metabolism of FA in humans



Potential impact of FA on the intestine





Project overview

1

Nutrient analysis

Phenolic compound quantification

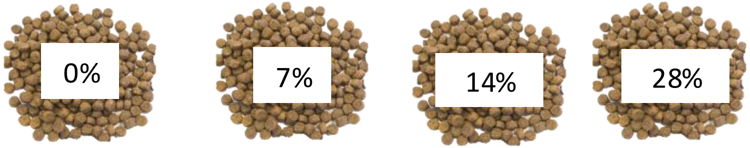
AOX

2

TPC
AOX

TPC
AOX

Polyphenol losses
Bioavailability?



Shelf life

3

n=12

4 x 4 Latin Square
28 d each period

CBC and biochemistry

Gut health markers

Fasted & Postprandial
Antioxidant markers
Lipid & protein oxidation

Summary

- Ancient grain, non-GMO, gluten-free, sustainable
- Whole grain process similar to other cereal grains
- Nutrient digestibility
- Opportunities to explore <u>sorghum products</u> and <u>polyphenol extracts</u>

AOX?

Antimicrobial agents?

Gut health?

Systemic affects?

Thank you!

jpezzali@ksu.edu

Colbey