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Dietary fibre: bowel scourer AND gut bacteria food.

Dr Anneline Padayachee (PhD)
Director, The Food and Nutrition Doctor
Adjunct Snr Lecturer, University of Queensland

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Microbiome basics

- The basics of the gut microbiota are all covered in the video available at:
- https://www.drannelinepadayachee.com/blog/basicsofguthealth
- Topics include defining probiotics, prebiotics, synbiotics.
  - The role of digestive processing through the gastro-intestinal tract
- It will help out everything else into context.

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Aims

- The role for fibre in diet:
  - bulk, fermentation, delivery of nutrients and phytochemicals
  - Prebiotic effect of food components
- Fibre: what is it?
  - Plant cell wall components – cellulose, pectins, arabinoxylans, hemicelluloses
  - Functional roles – visocity, fermentation
  - What does soluble vs insoluble mean?
- Processing impact:
  - Particle size of fibre – raw vs cooked
- Resistant starch:
  - Types
  - Processing effect on content

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Part 1:
Fibre: bowel scourer, prebiotic, uber-eats delivery.

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BRISTOL STOOL CHART

Type 1	Separate hard lumps	Very constipated
Type 2	Lumpy and sausage like	Slightly constipated
Type 3	A sausage shape with cracks in the surface	Normal
Type 4	Like a smooth, soft sausage or snake	Normal
Type 5	Soft blobs with clear-cut edges	Lacking fibre
Type 6	Mushy consistency with ragged edges	Inflammation
Type 7	Liquid consistency with no solid pieces	Inflammation

Cabot Health, Bristol Stool Chart / CC BY-SA (https://creativecommons.org/licenses/by-sa/3.0)

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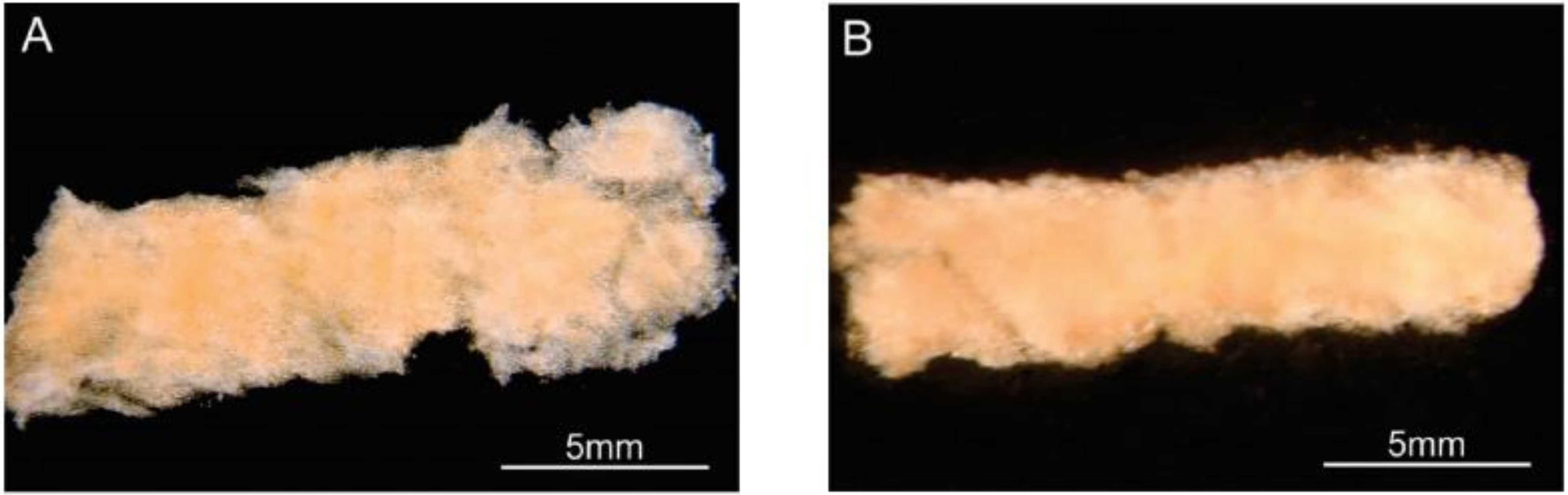

Figure 1. Raw grated carrot shreds: (**A**) undigested control; (**B**) material recovered at the terminal ileum 10 h postingestion. Note the limited change to gross structure.

(Tydeman, Parker et al. 2010)

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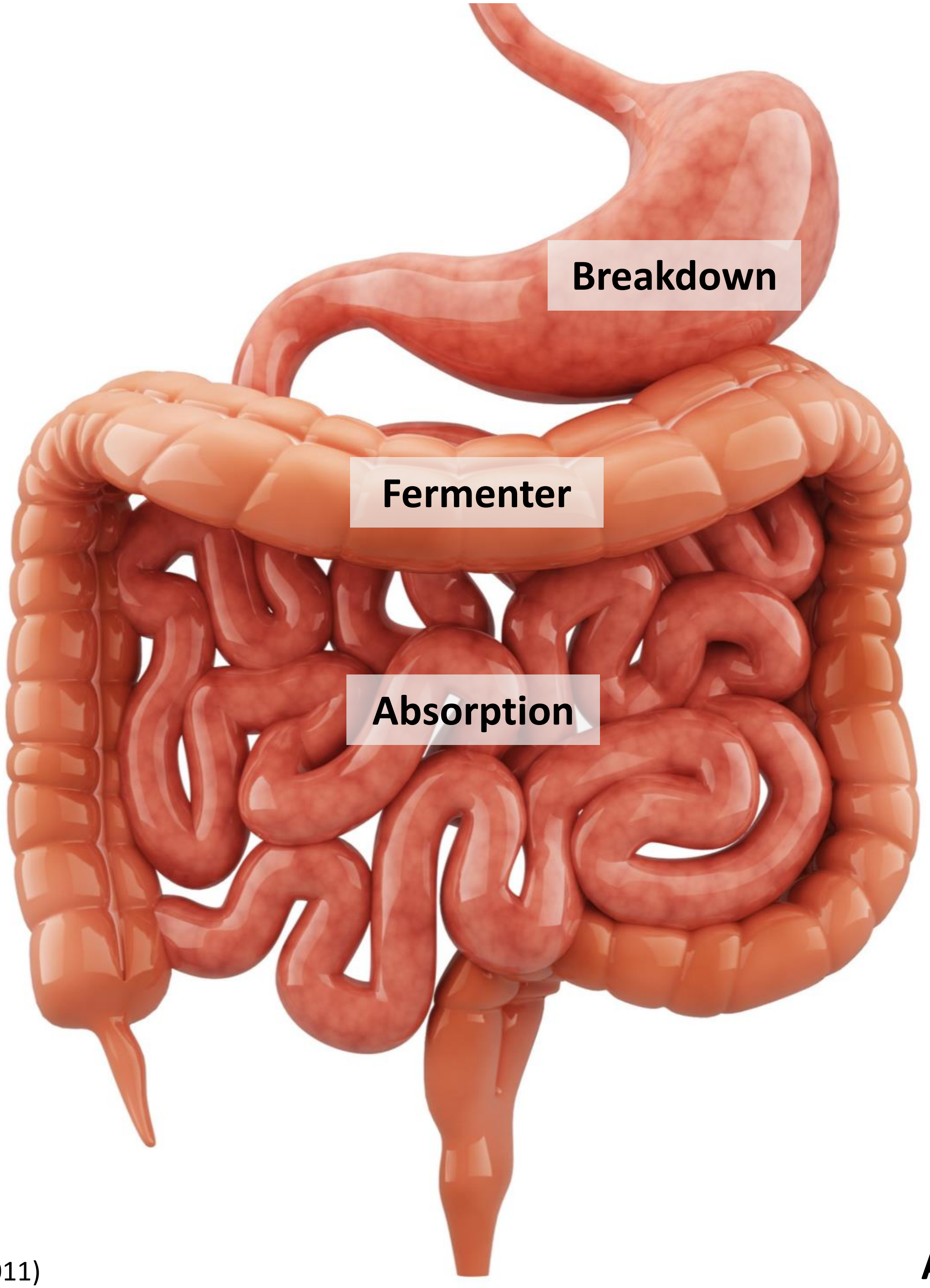
Aerobic bacteria

pH 1-2
Contents: pepsin, amylase (from salivary glands), mucus

$<10^3$
- *Lactobacilli*
- *Streptococci*



pH 6-7
Duodenum
Jejunum
Ileum
Contents: pancreatic acid, bile salts, mucus

$<10^{4-7}$
- *Lactobacilli*
- *E. coli*
- *Enterococcus faecalis*

pH 5-7
Ascending, Transverse & Descending colon
Contents:
Bicarbonate, mucus

$<10^{10-12}$
- Lactic acid (producing) bacteria
- *Bacteroides*
- *Bifidobacterium bifidum*

Anaerobic bacteria

Adapted from (Prakash, Tomaro-Duchesneau et al. 2011)

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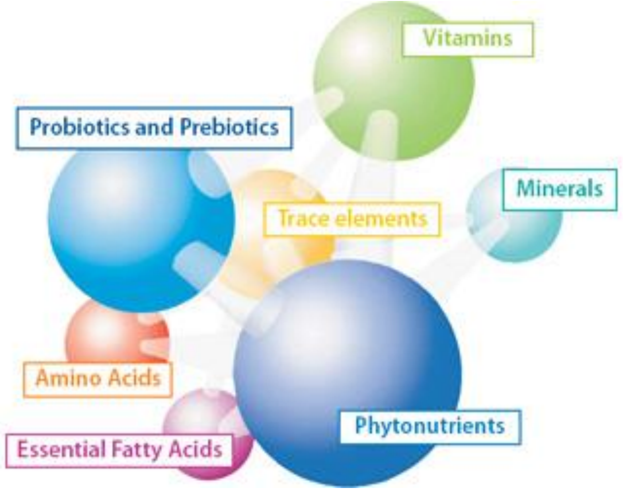

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Part 2:
Fibre: what is it?

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Table 1. Dietary fiber content of common fruits and vegetables (adapted from Slavin (2012) and Kumar (2012).

	Vegetables (per 100 g)				Fruit (per 100 g)		
	Total dietary fiber (g)	Soluble dietary fiber (g)	Insoluble dietary fiber (g)		Total dietary fiber (g)	Soluble dietary fiber (g)	Insoluble dietary fiber (g)
Beetroot	7.8	5.4	2.4	Apple	2.4	0.7	1.7
Cabbage	2.5	0.6	1.9	Grapes	0.9	0.4	0.5
Cucumber	0.6	0.1	0.5	Lemon	2.2	1.3	0.9
Celery	1.6	0.1	1.5	Mango	1.8	0.7	1.1
Lettuce	12.3	0.2	10.5	Peach	2.9	1.3	1.6
Onion	0.9	0.4	0.5	Pineapple	1.5	0.04	1.4
Tomato	1.2	0.1	1.1	Strawberry	2	0.5	1.5

(Padayachee, Day et al. 2017)

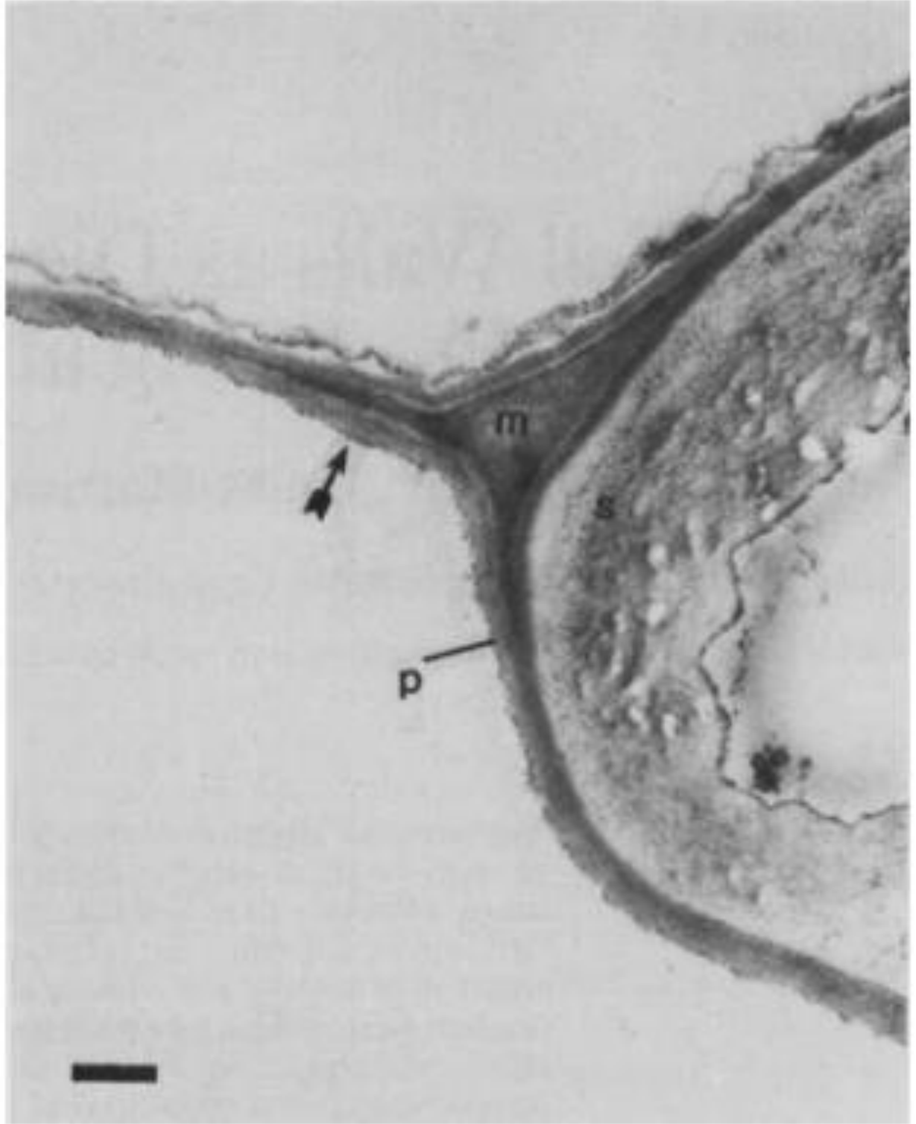

Fig 1. An electron micrograph displaying primary and secondary layers of plant cell walls. p, primary cell wall; m, middle lamella; s, secondary cell wall. The arrow denotes the position of the plasma membrane. Bar—2·5 μm.

(McDougall, Morrison et al. 1996)

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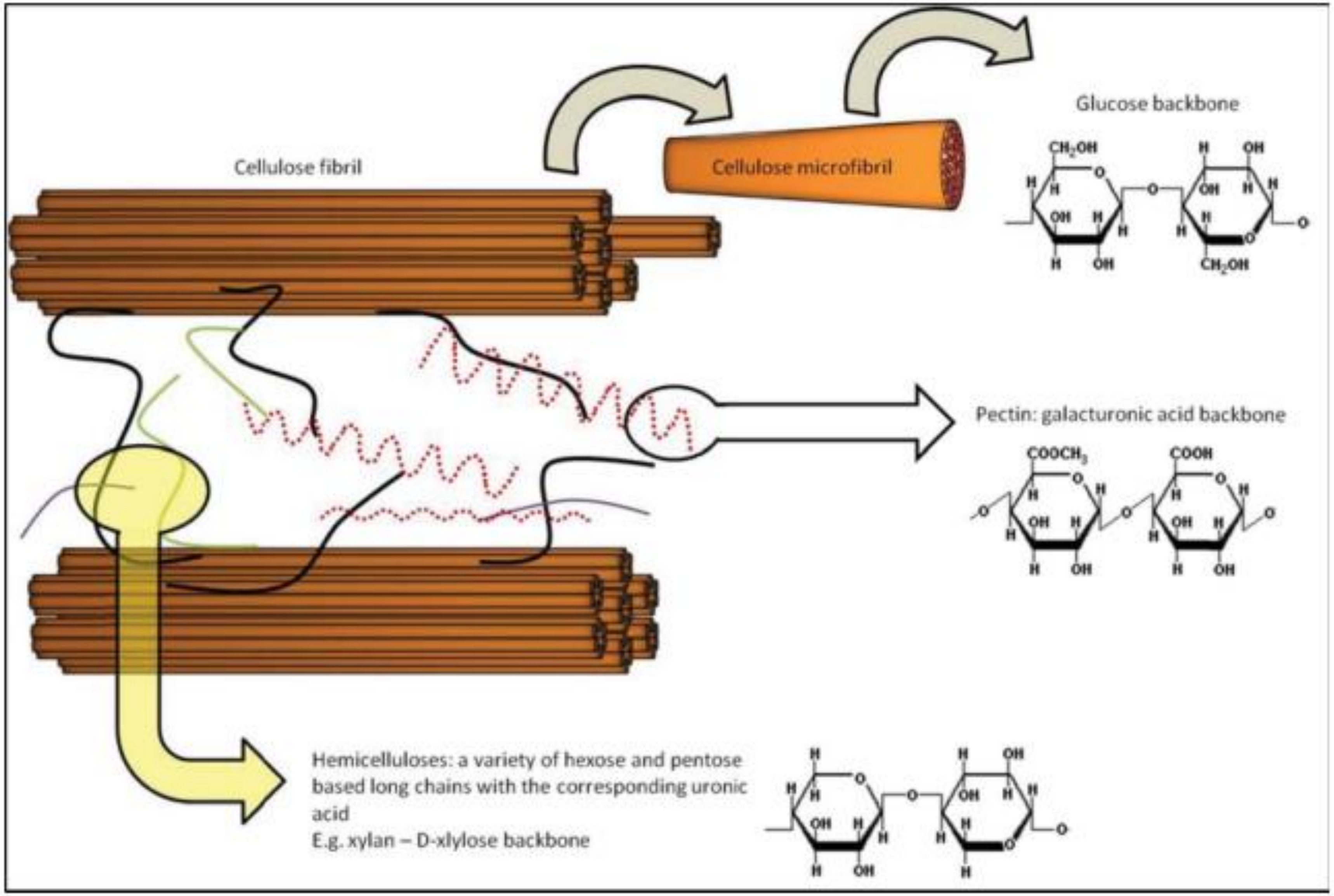

Figure 1. The plant cell wall's cellulose-hemicellulose-pectin crosslink network (Adapted from Cosgrove (2005)).

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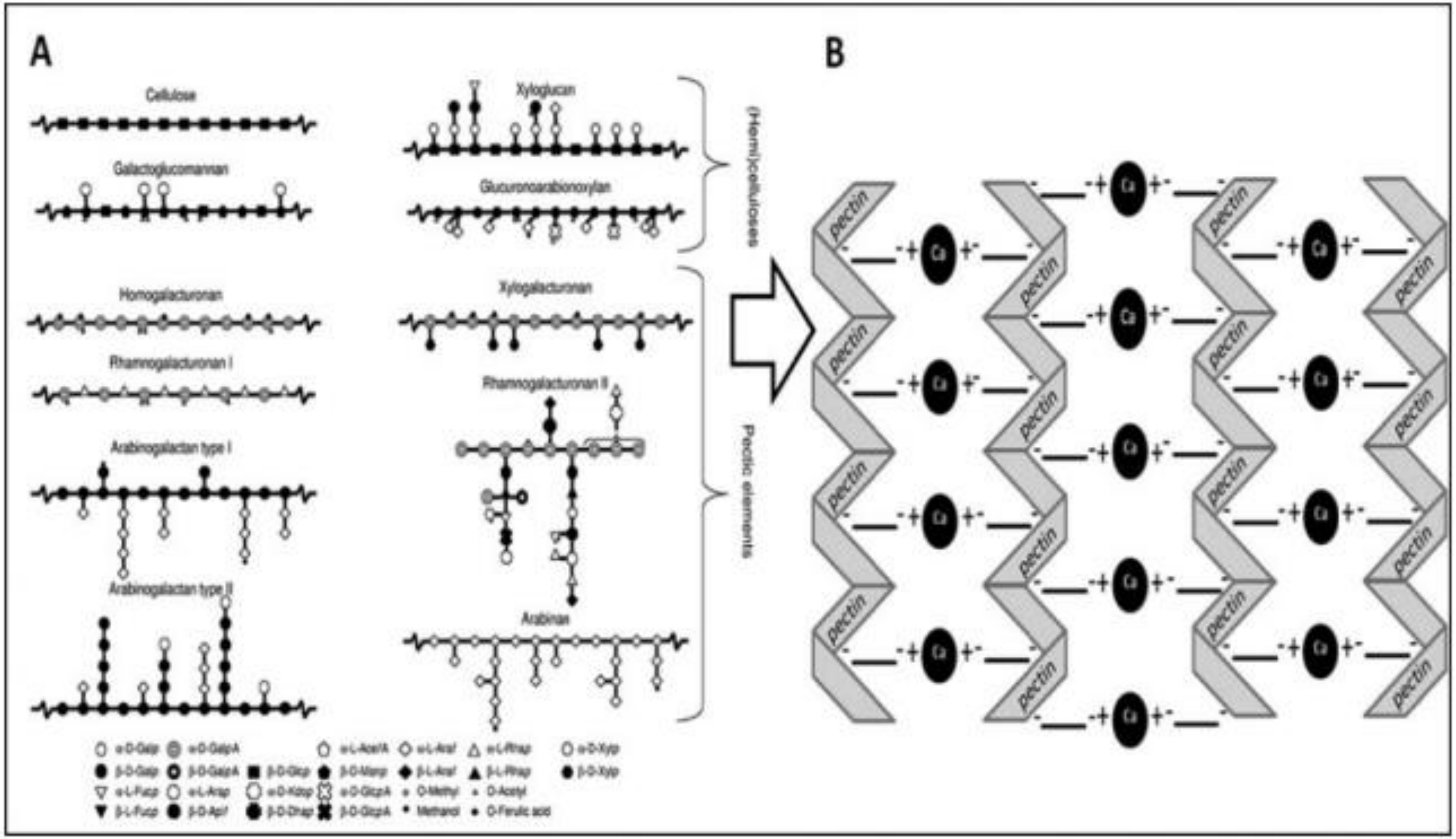

Figure 2. Pectin structural complexity: (A) Pectin structures; (B) Pectin-Ca^{2+} egg-box model of Ca2+ binding with pectin strands forming a gel structure. (Adapted from Hilz (2007) and Morris et al. (1982)).

(Padayachee, Day et al. 2017)

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Part 3:
Fibre: the effect of processing

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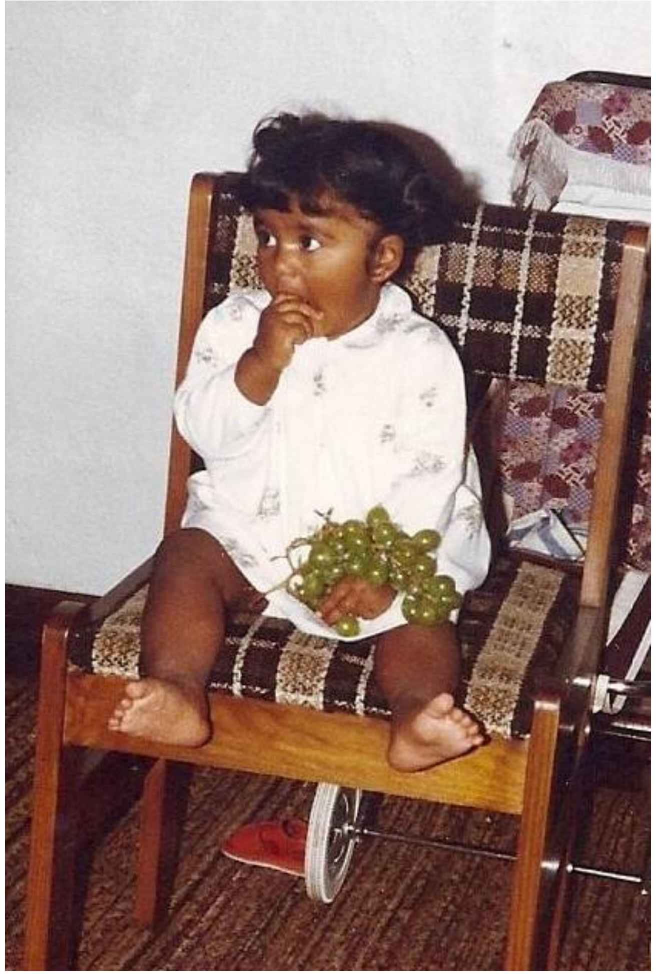

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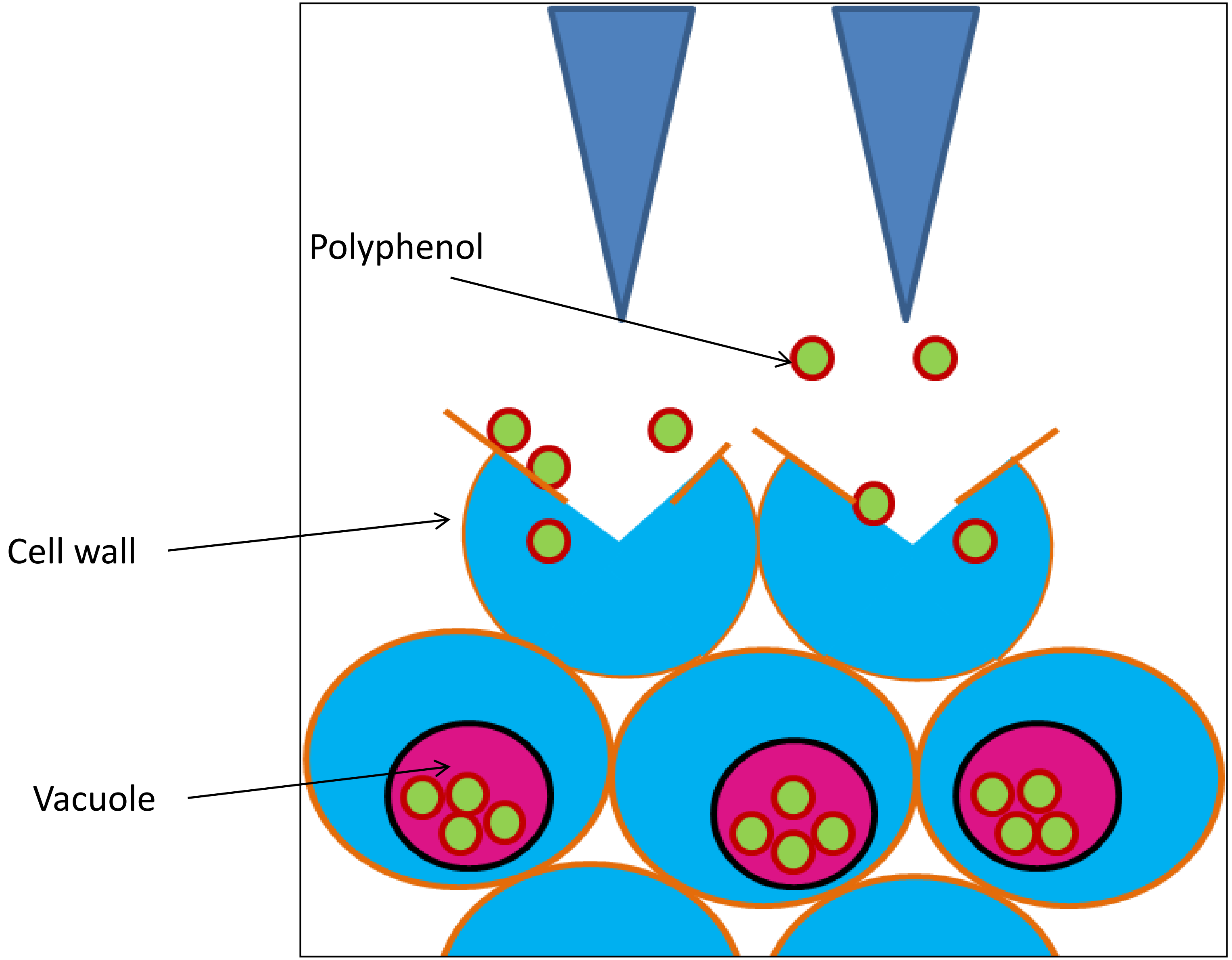

(Padayachee 2010)

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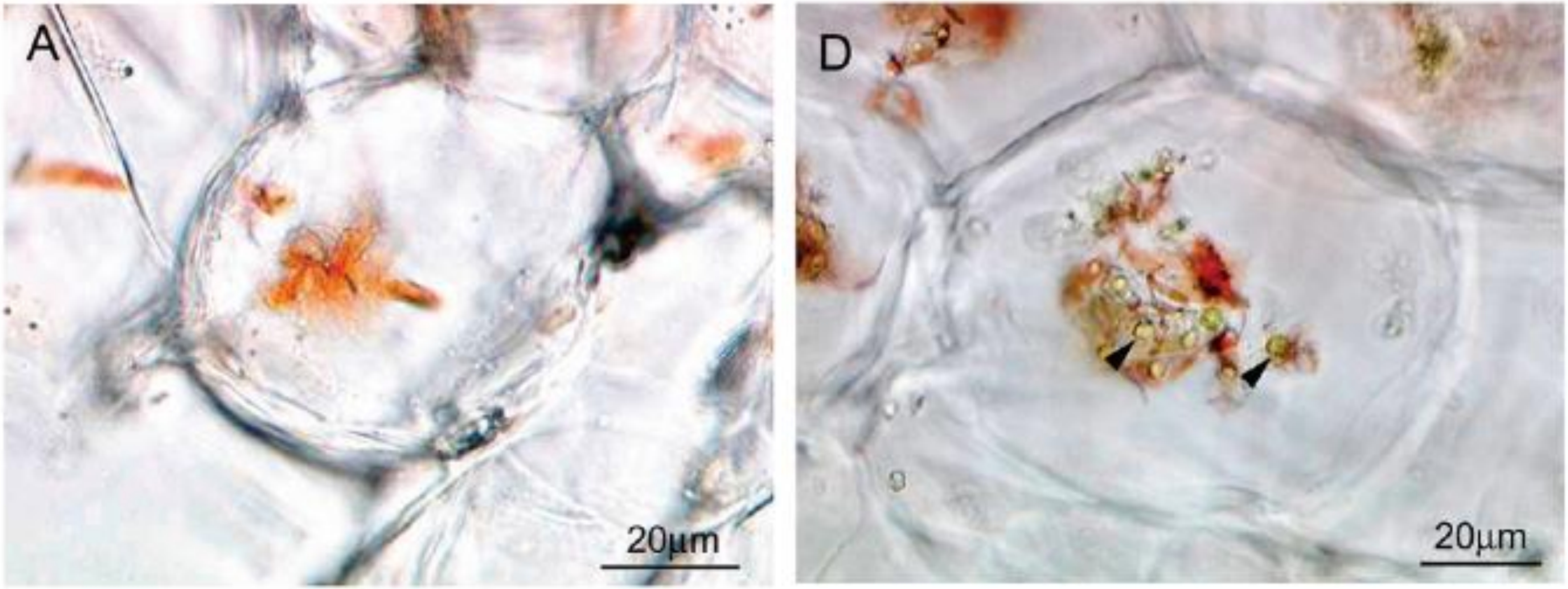

Figure 2. Effect of in vivo residence time on raw grated carrot shreds recovered from ileostomy patients: (**A**) edge of section of undigested raw shreds (control); (**B**−**D**) edge of sections of shreds after residence of 10 h. Note the presence of yellow lipid droplets (arrowheads in **D**) and orange carotene crystals. Samples were unstained.

(Tydeman, Parker et al. 2010)

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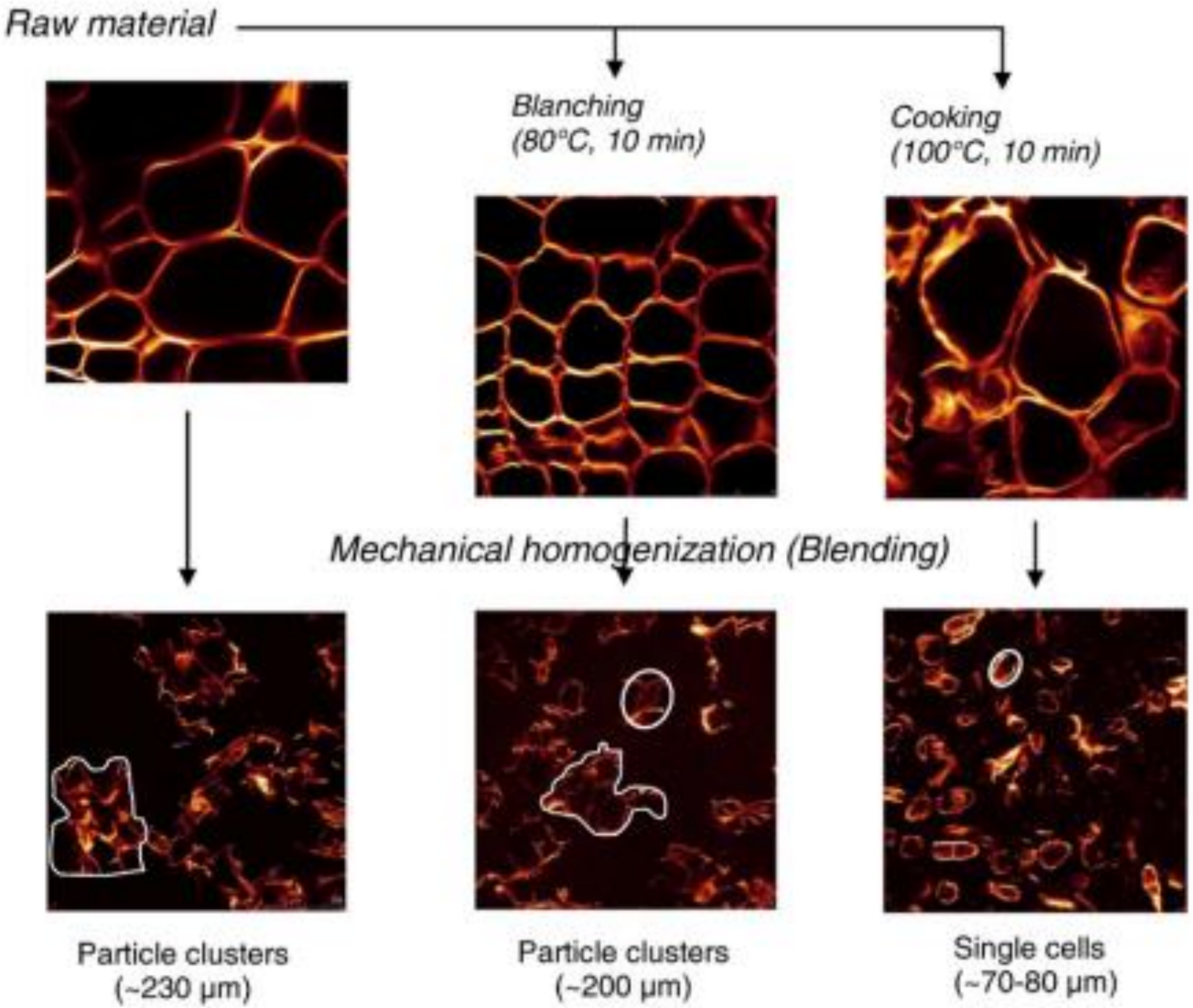

Fig. 2. CLSM images of carrot tissues before and after thermal processing (blanching at 80 °C for 10 min and cooking at 100 °C for 10 min), and purees containing disrupted cell wall particles by mechanical homogenisation of raw, blanched and cooked carrot tissues, respectively. Image size: 750 µm × 750 µm.

(Netzel, Netzel et al. 2011)

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Table 1. Particle Sizes of Carrot Cell Wall Dispersions Obtained with Different Heating and Blending Conditions

	heating		blending				
sample code[a]	temperature (°C)	time (min)	setting	time (min)	principal particle morphology	particle size, $d_{0.5}$ (μm)	total solids (%)
CWP1	80	30	1	2	large cell clusters	298	2.7
CWP2	80	30	1	8	small cell clusters	137	3.2
CWP3	100	30	1	8	single cells	75	2.8
CWP4	100	40	5	8	cell fragments	50	3.4

[a]CWP = cell wall particle dispersion.

(Day, Gomez et al. 2012)

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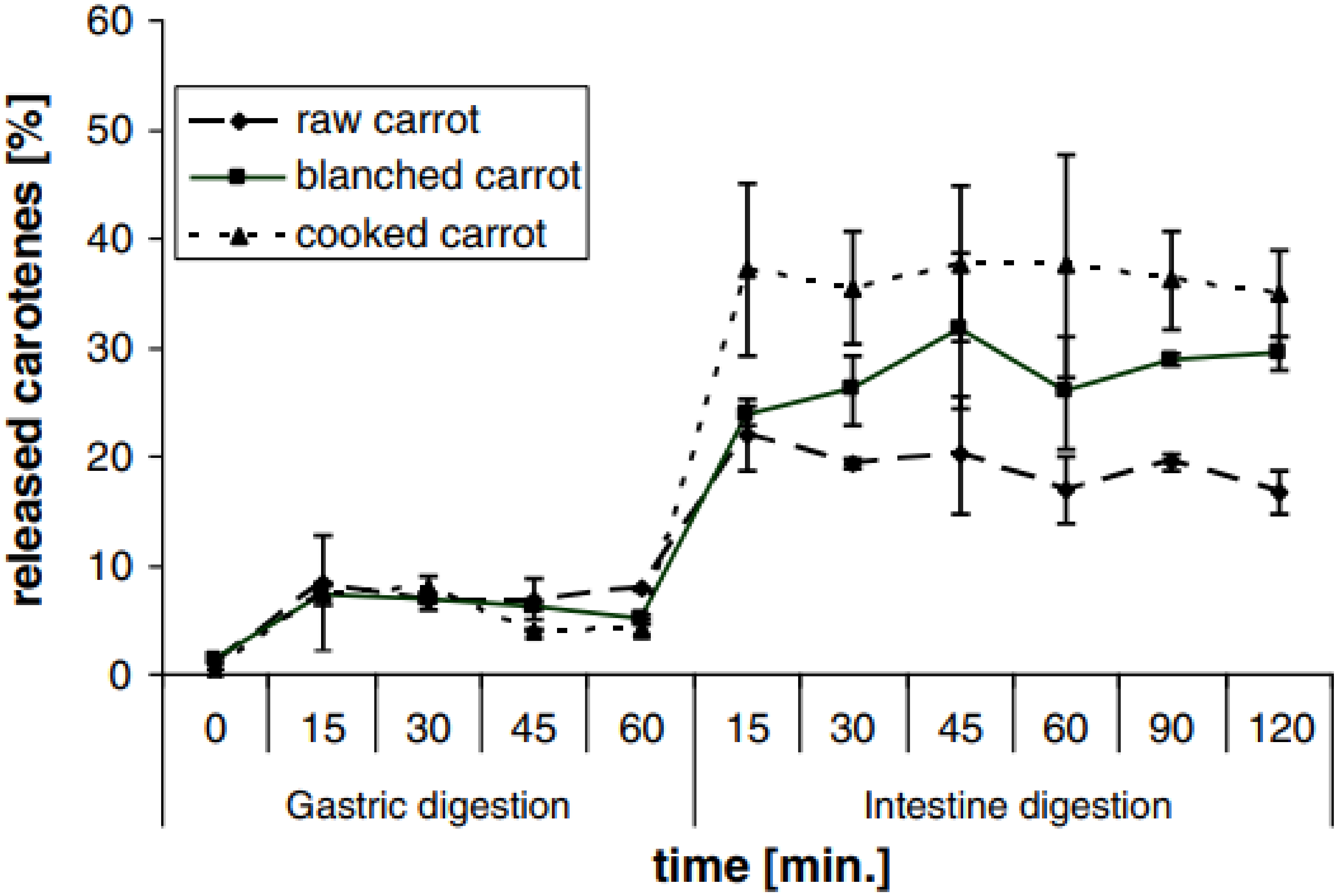

Fig. 3. Released total carotenes during the mimicked gastric and intestinal digestion of raw, blanched, and cooked carrot puree. Data (means ± SD of n = 2 trials) as percent release of carotenes (released amounts *vs.* applied doses); applied doses: 6.75 ± 0.73, 6.44 ± 0.01, and 6.86 ± 0.41 mg per 100 g for raw, blanched, and cooked carrot puree.

(Netzel, Netzel et al. 2011)

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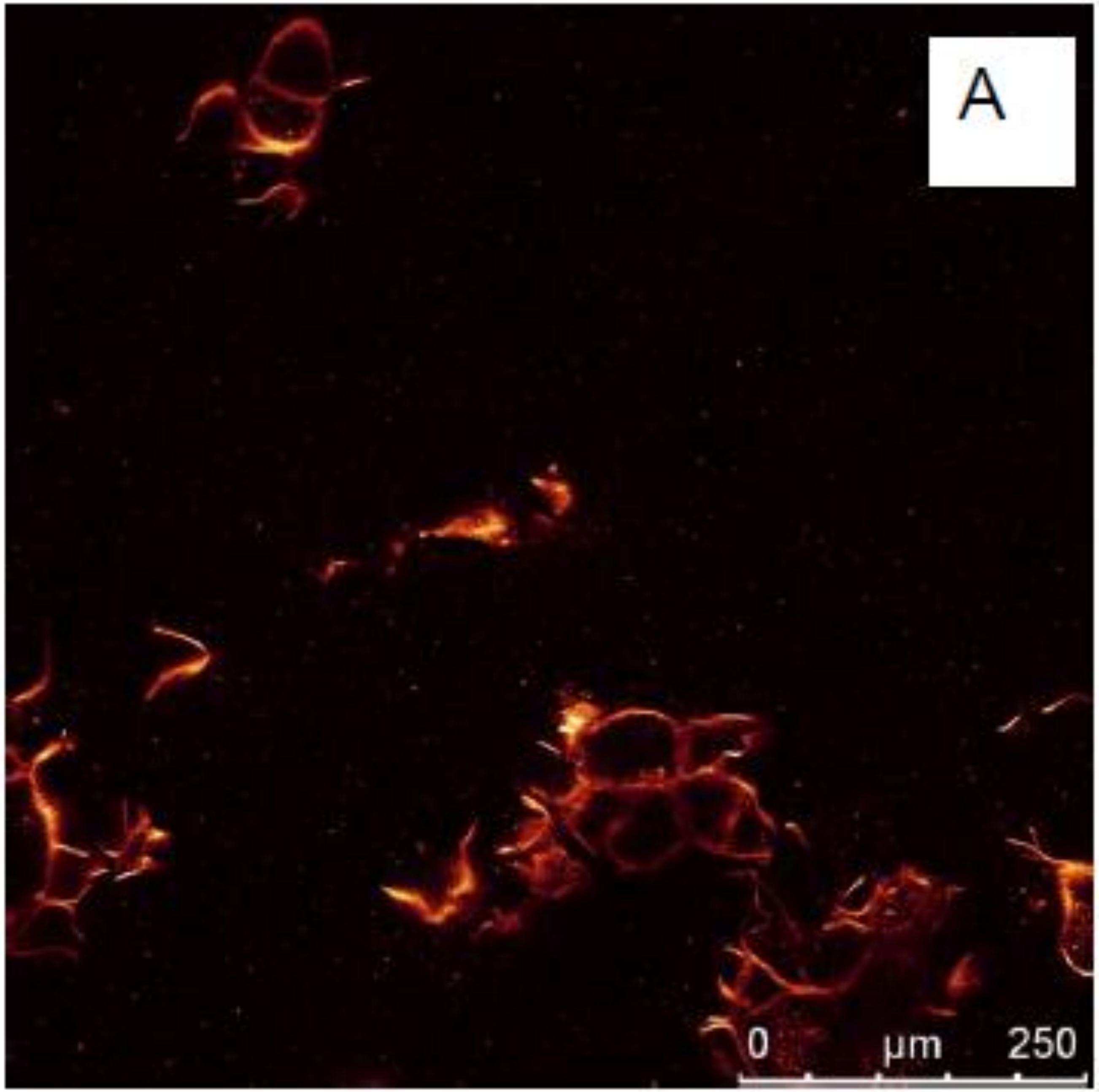
(Padayachee, Netzel et al. 2013, Padayachee, Day et al. 2017, Gu, Howell et al. 2019)

Shows the cell wall of whole cells in purple carrot



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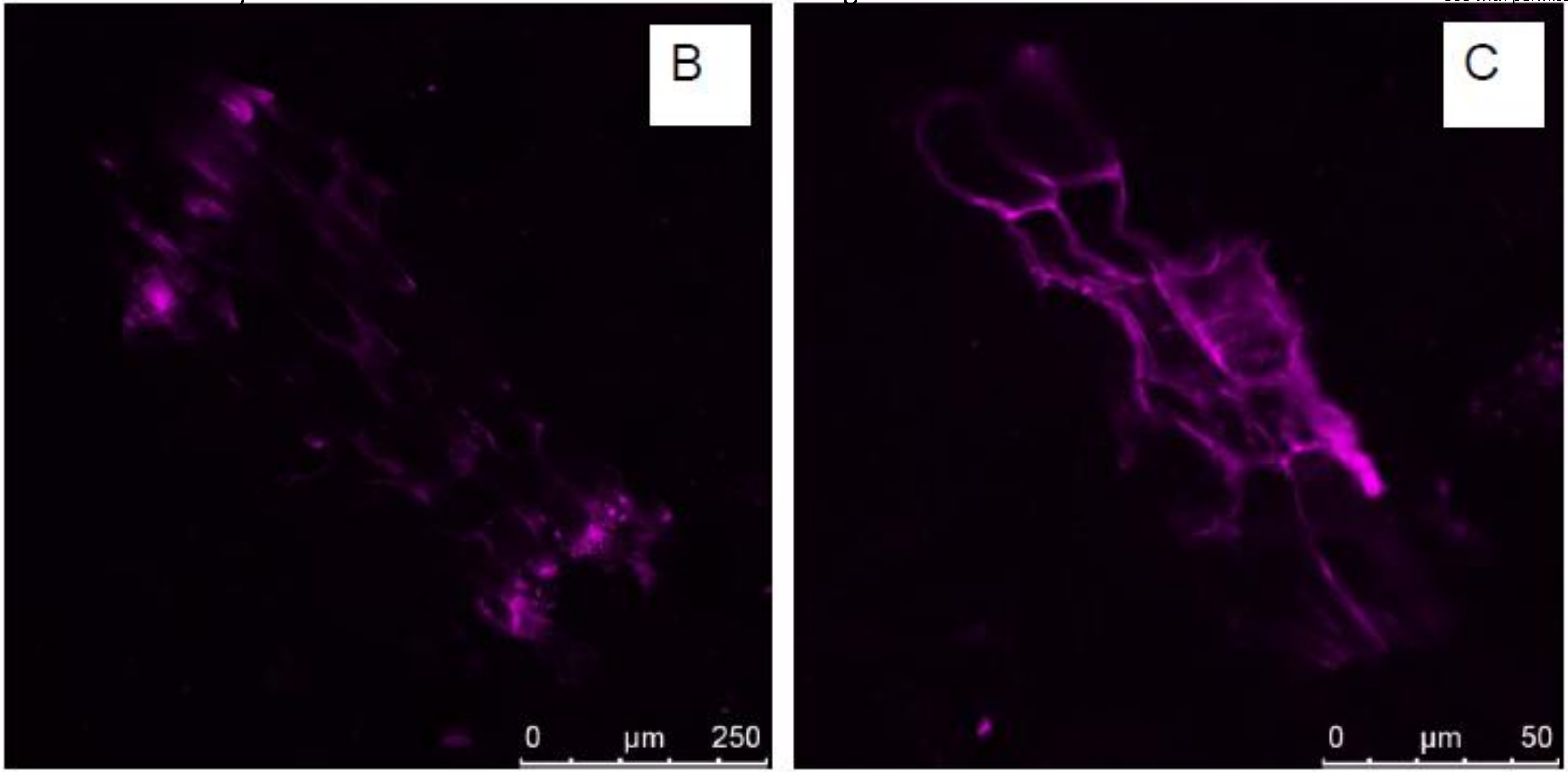
Shows the anthocyanins that are bound to the cell walls before digestion



(Padayachee, Netzel et al. 2013)

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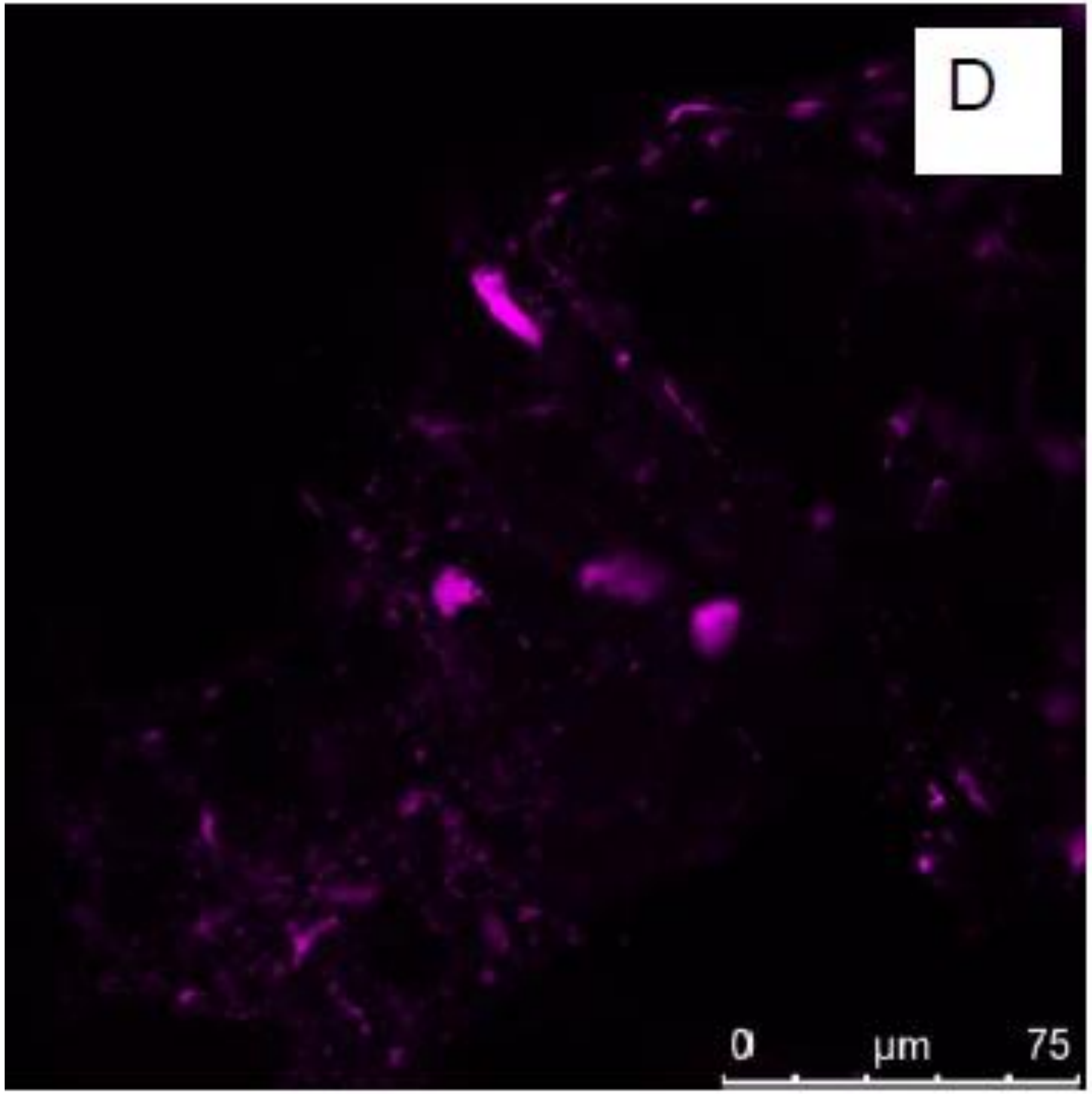
Shows the anthocyanins that are bound to the cell walls after gastric & small intestinal (in vitro) digestion



(Padayachee, Netzel et al. 2013)

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Digestive Release

80% of total

60% of total

Storage Time after puree made (h)	Anthocyanin initially bound to PCW matter (Baseline 3) (µg/g)	Gastric Release – Anthocyanins (µg / 20 mg dry weight) (S.D.)	Gastric + S.I. Release – Anthocyanins (µg / 20 mg dry weight) (S.D.)	PAs initially bound to PCW matter (Baseline 3) (µg/g)	Gastric Release – PAs (µg / 20 mg dry weight) (S.D.)	Gastric + S.I. Release – PAs (µg / 20 mg dry weight) (S.D.)
0	2516	16.0 (± 1.7)	13.0 (± 1.6)	2112	13.2 (± 1.0)	10.4 (± 2.4)
4	2362	18.4 (± 0.1)	12.4 (± 0.1)	2069	11.1 (± 1.0)	11.3 (± 1.6)
24	2394	15.4 (± 0.7)	12.0 (± 2.0)	2044	10.2 (± 1.6)	10.0 (± 1.4)
144 (6 d)	2292	24.0 (± 1.8)	26.1 (± 0.8)	1988	14.8 (± 1.5)	17.2 (± 7.8)
288 (12 d)	2693	41.6 (± 12.4)	41.8 (± 12.1)	2058	28.8 (± 4.0)	32.2 (± 7.7)
432 (18d)	2549	75.0 (± 4.0)	53.2 (± 12.8)	2122	57.3 (± 3.8)	42.2 (± 9.7)

< 2% polyphenol release during gastric and small intestinal digestion

(Padayachee, Netzel et al. 2013)

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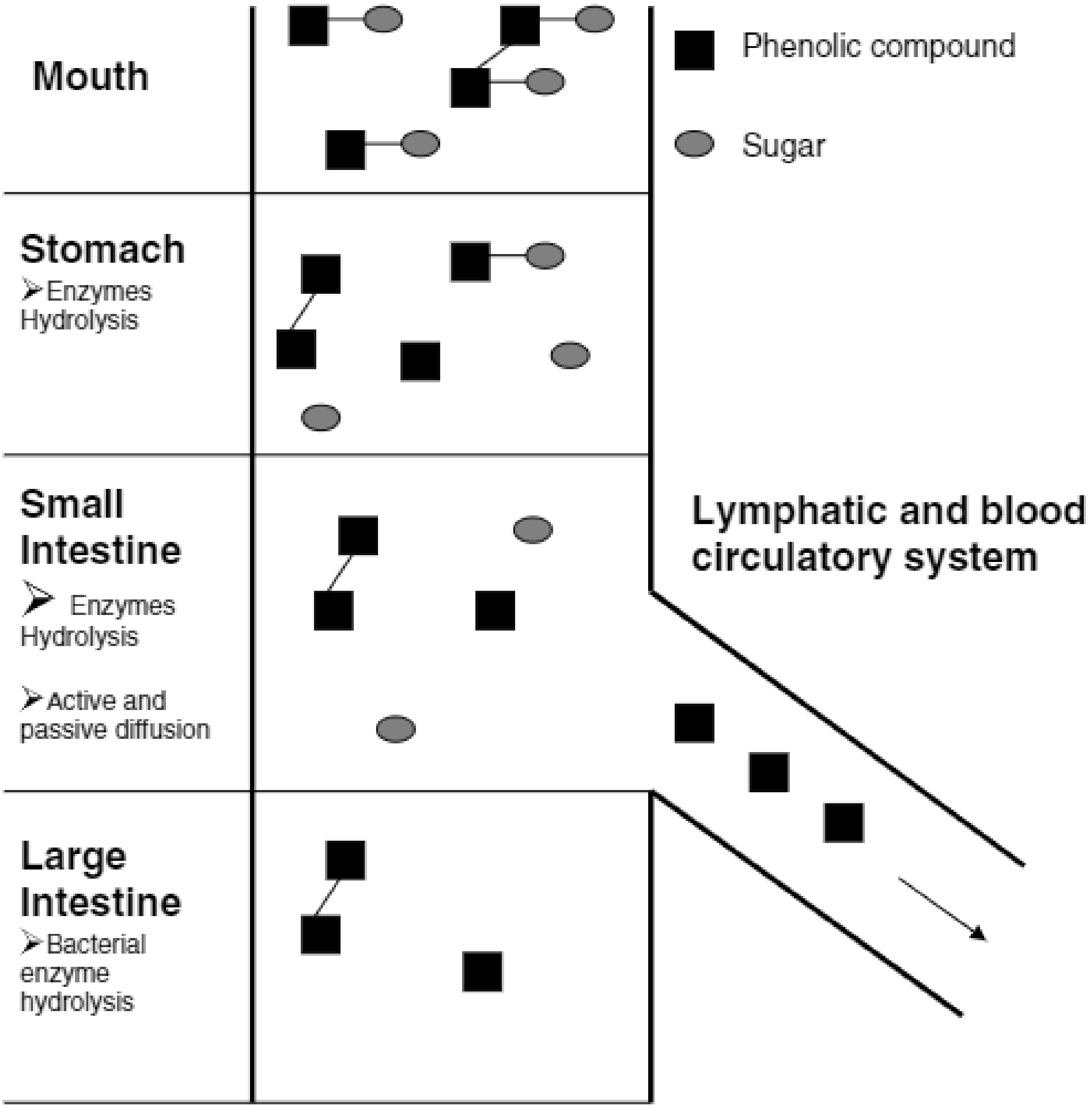
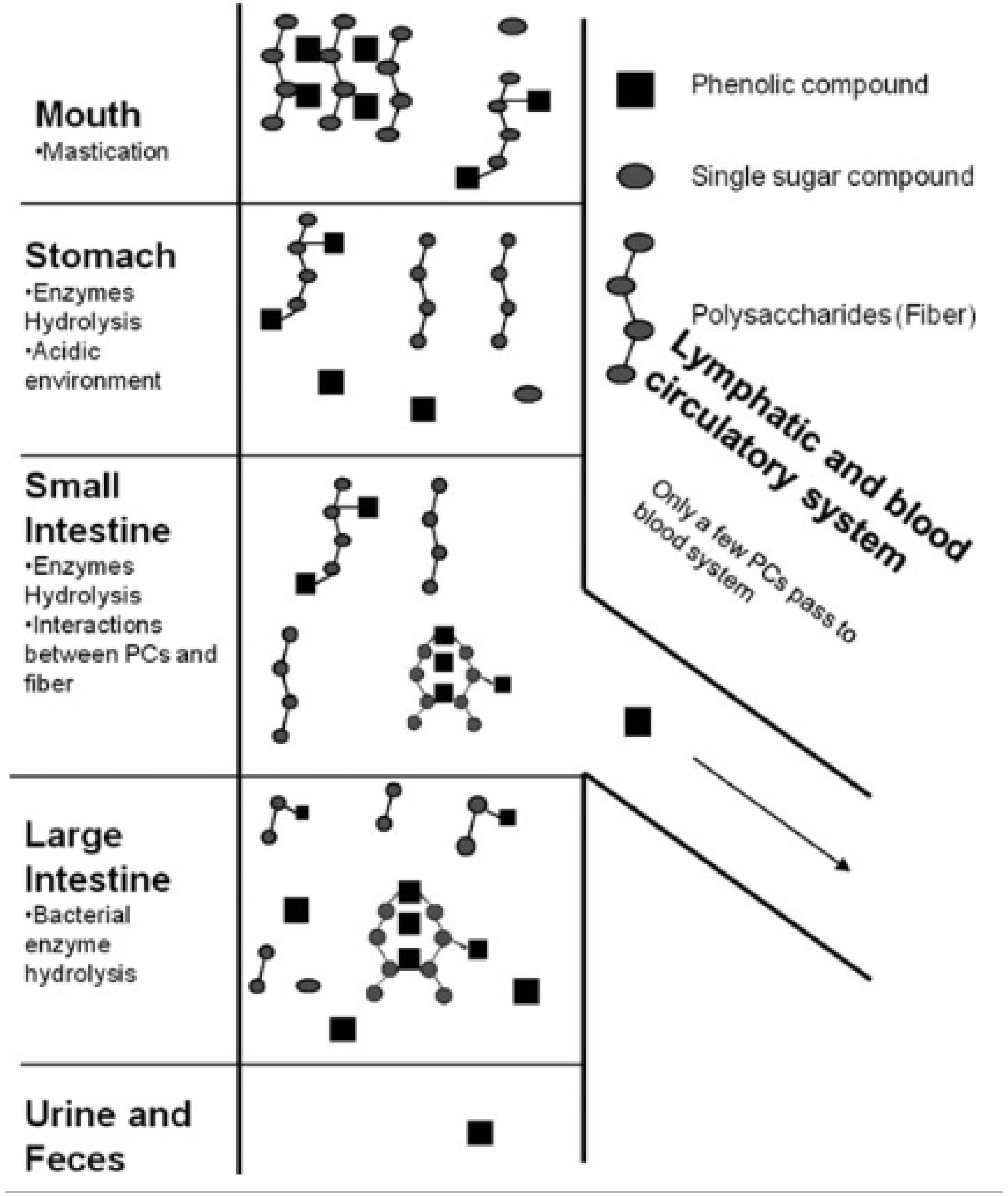
Beverages / No Fibre



(Palafox et al 2011)

Fruits and Veg



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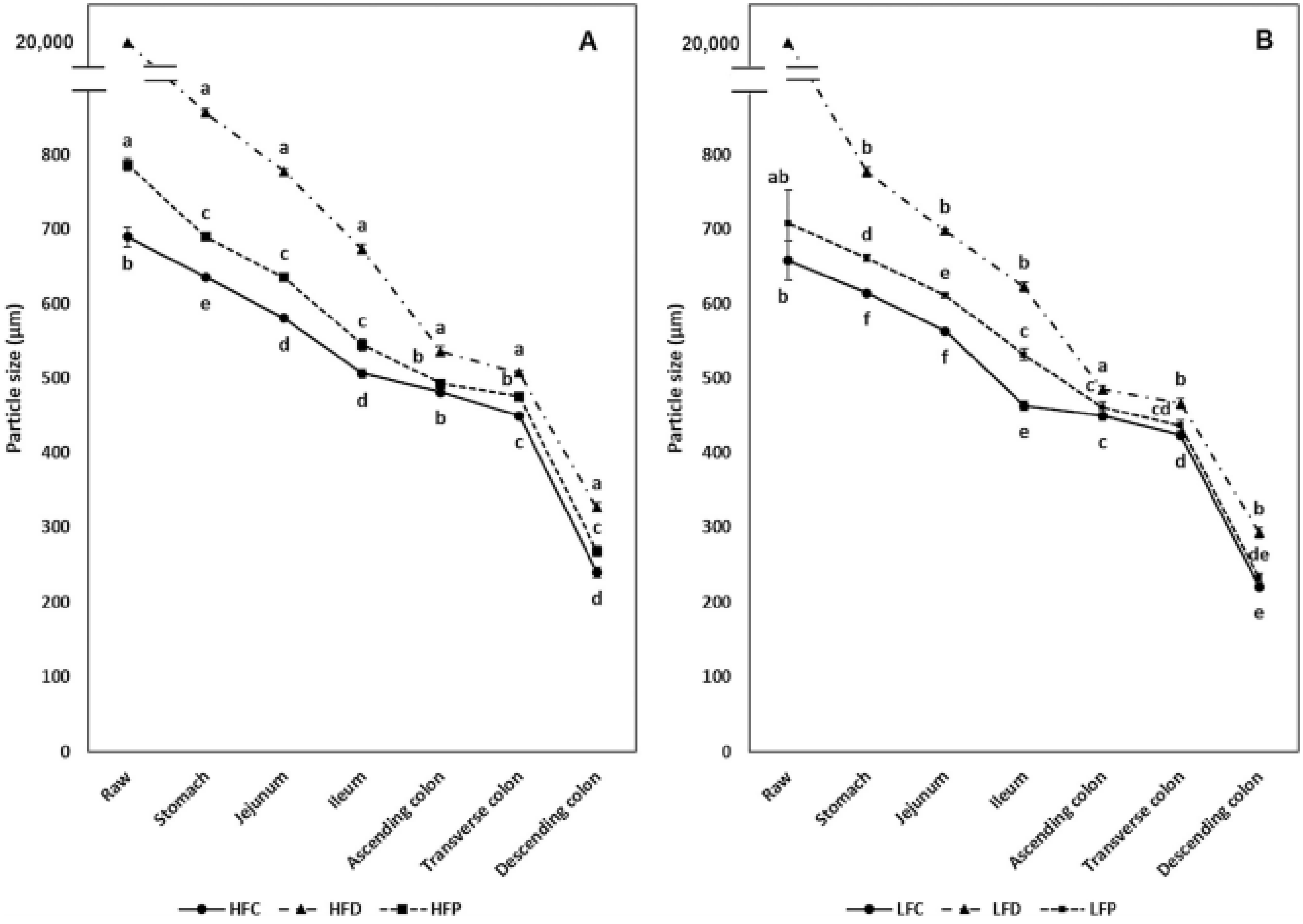

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(Gu et al 2019)

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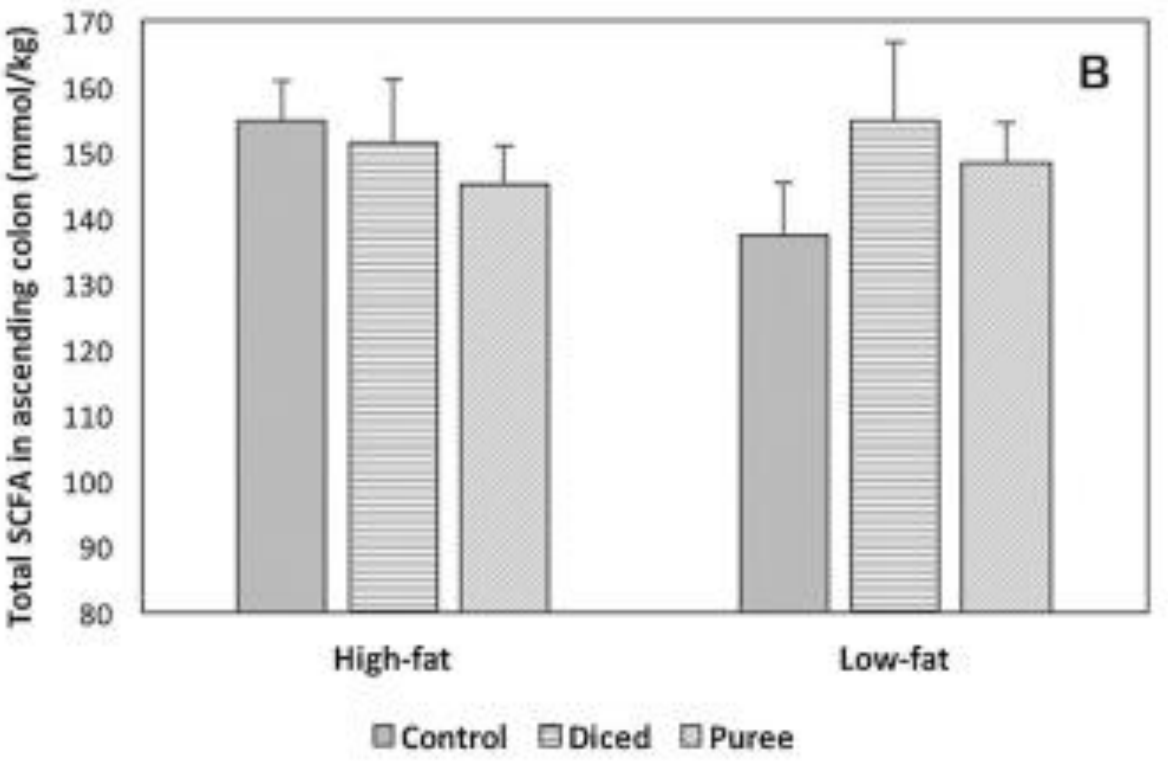

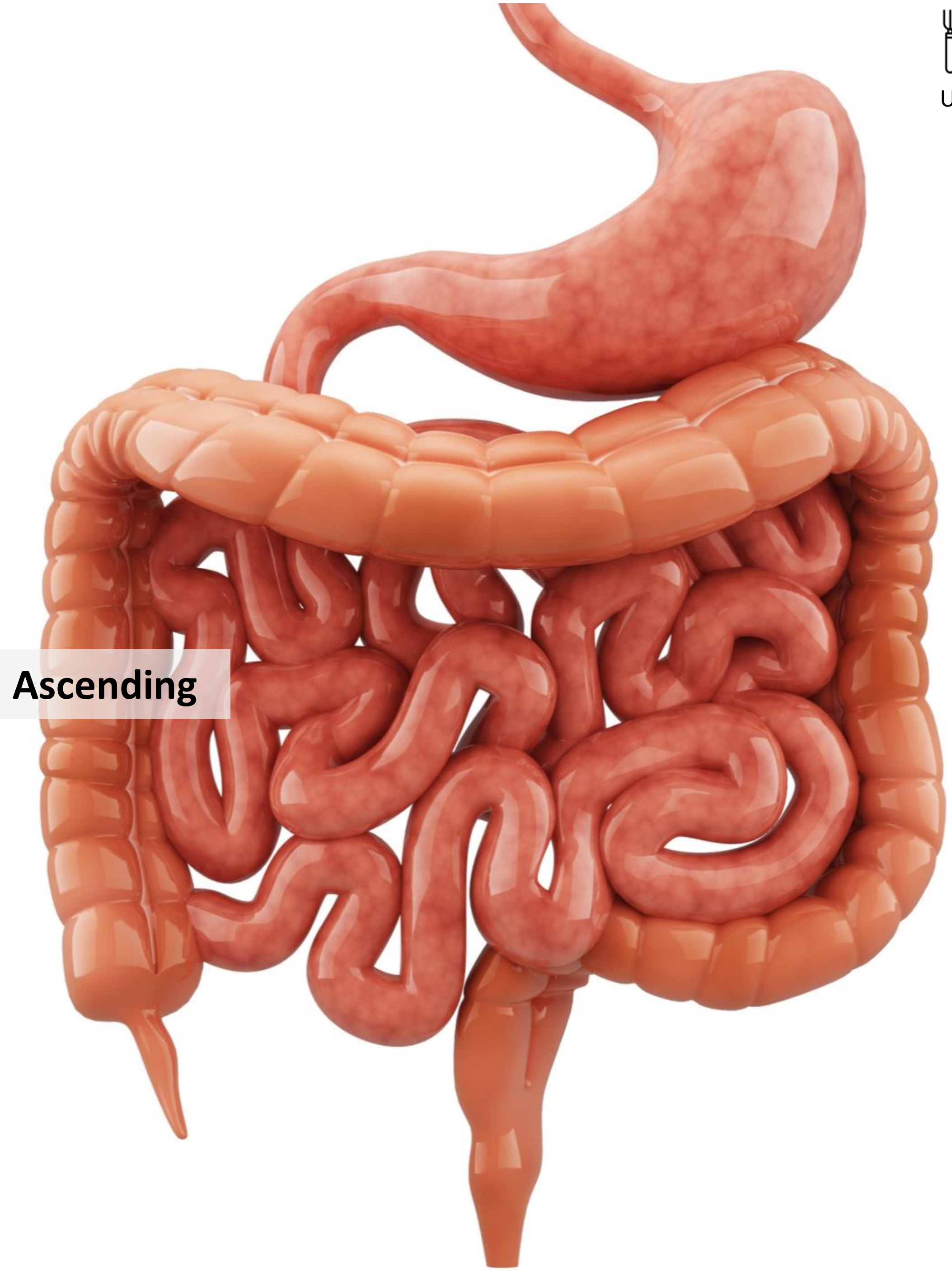

(Gu et al 2019)

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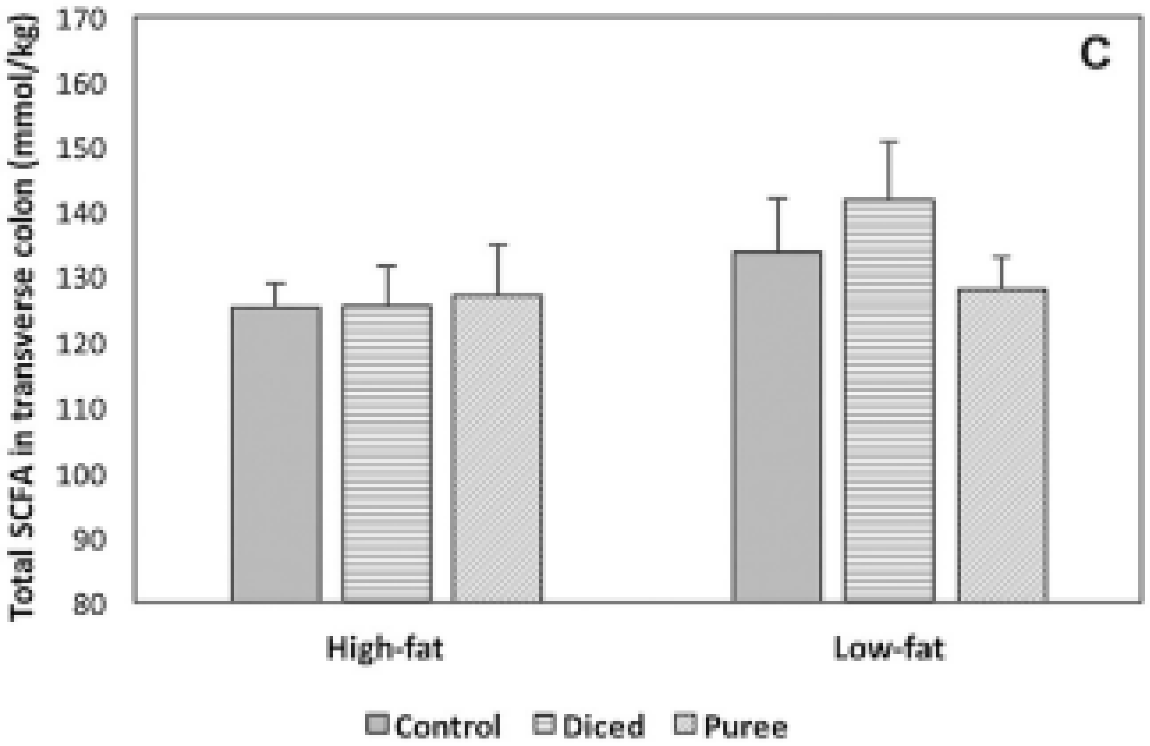
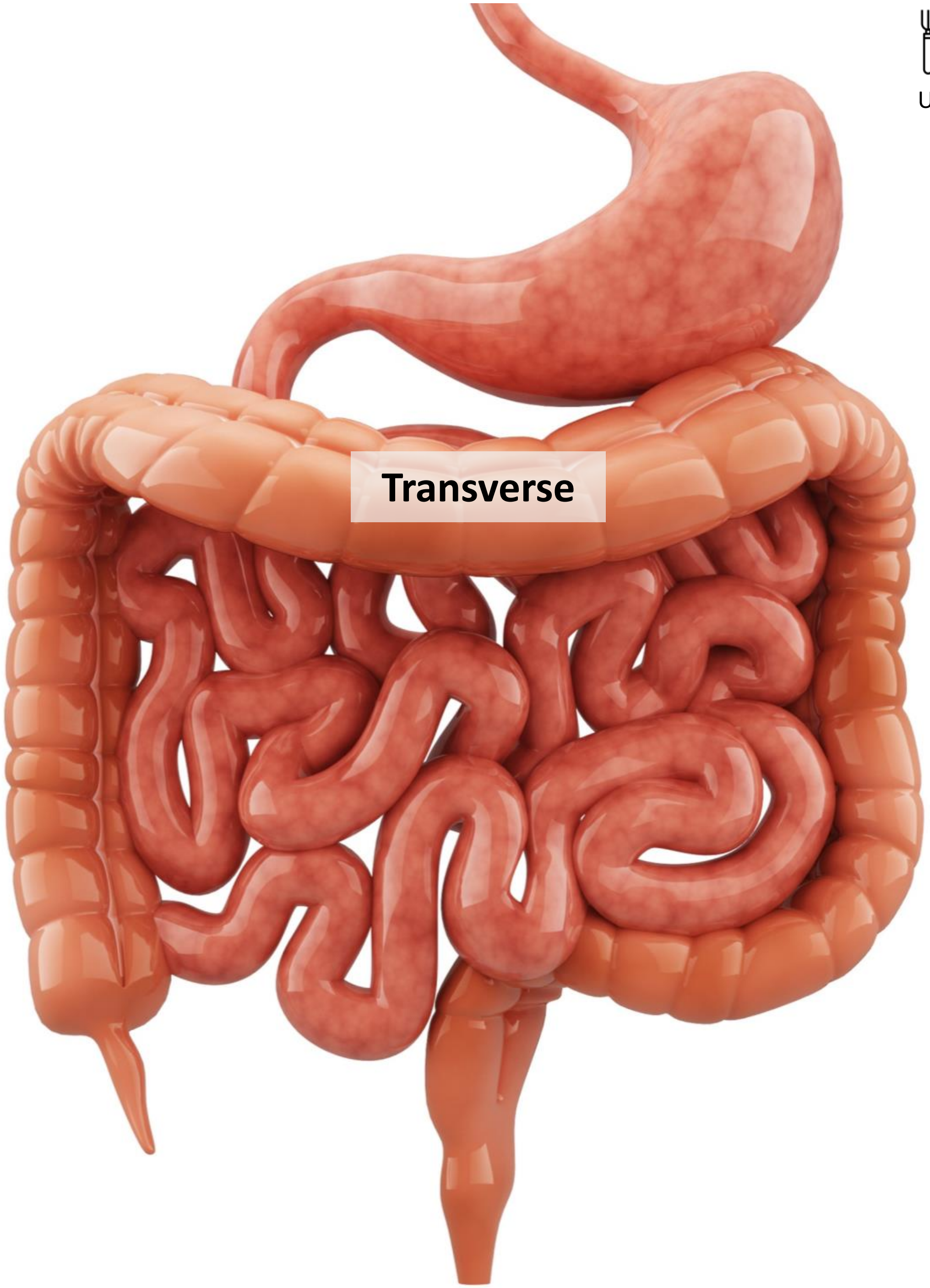
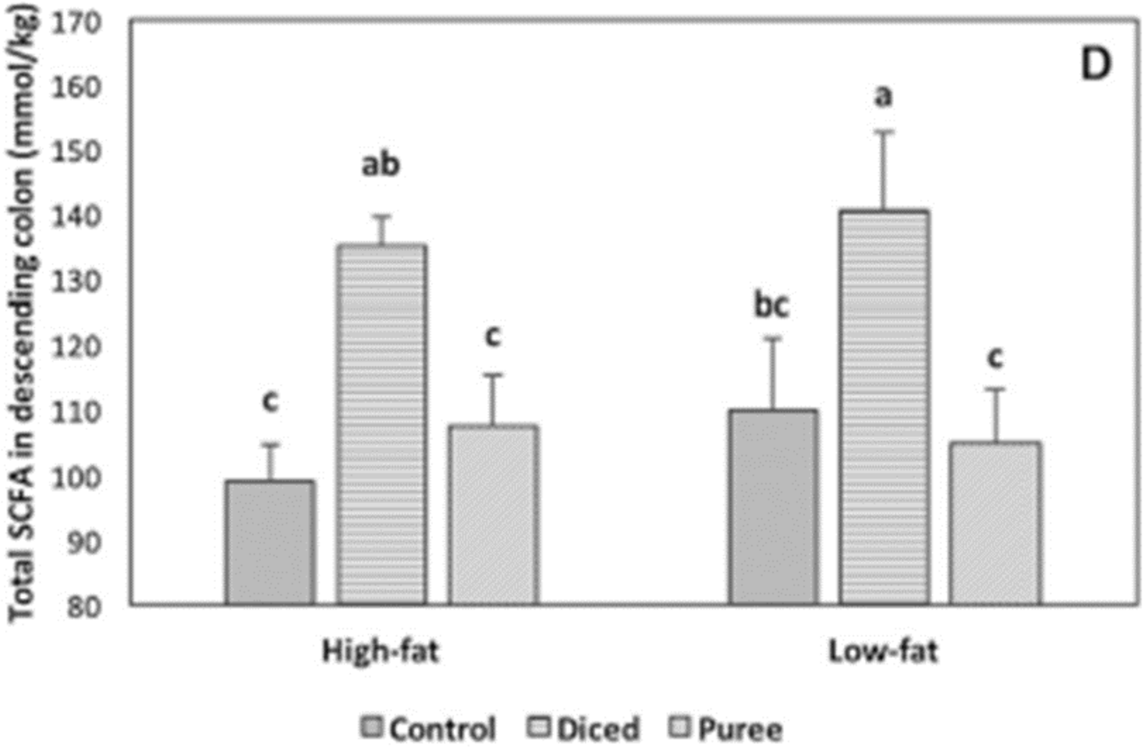
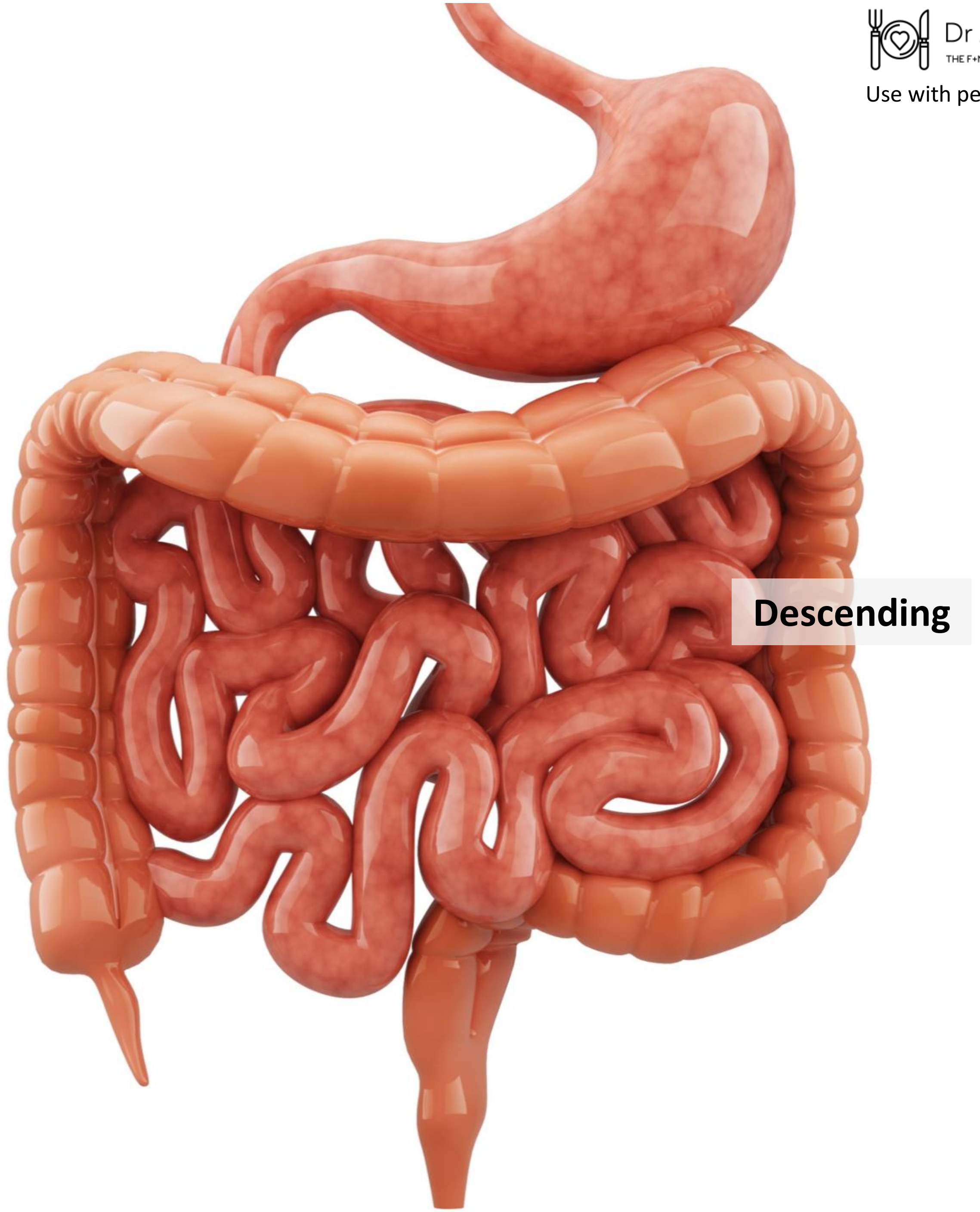




(Gu et al 2019)





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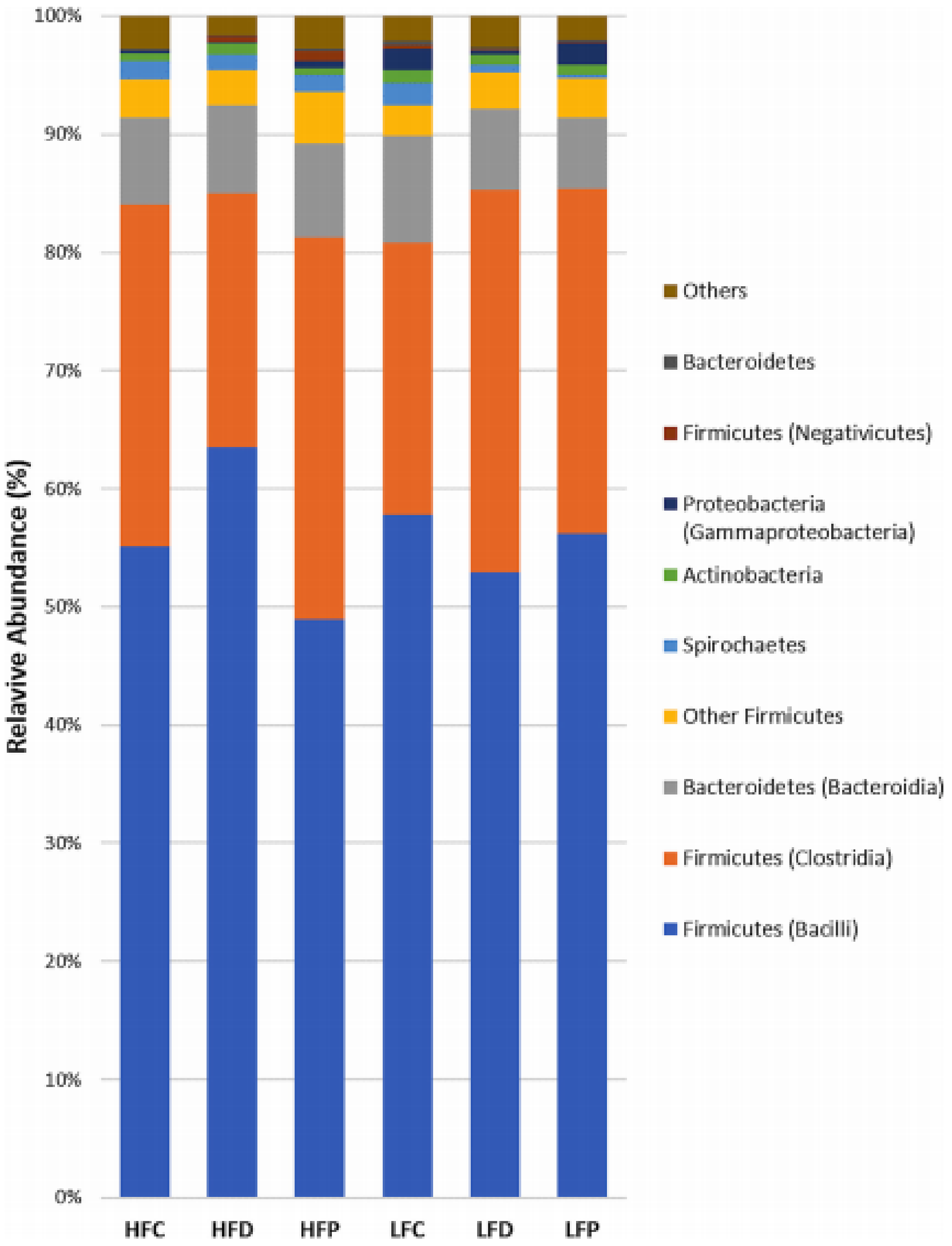

(Gu et al 2019)

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Part 4:
Resistant starch: basics

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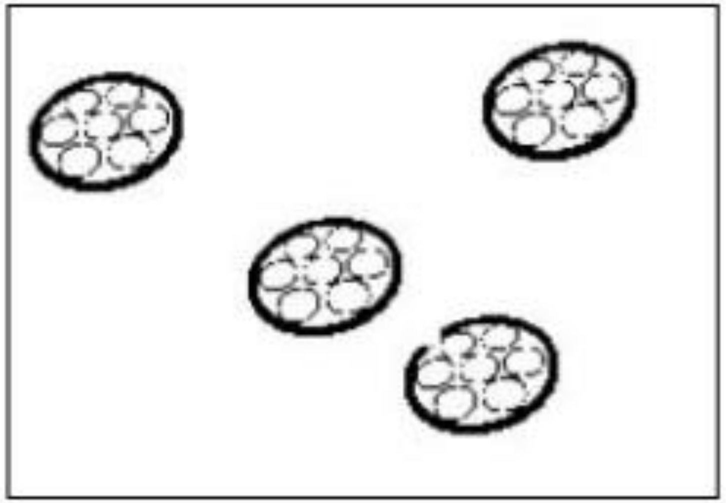
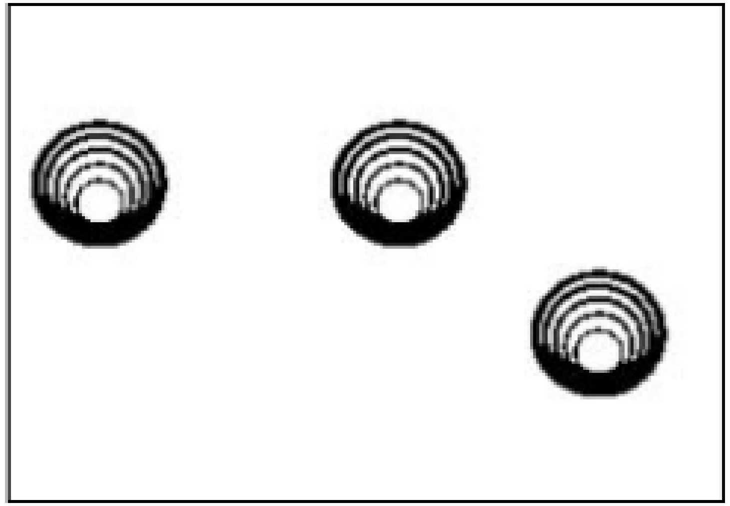
What is a resistant starch?





Starch that RESISTS digestion (with amylase) because:

1. Compact molecular structure of starch limits the accessibility of digestive enzymes

   E.g. physically inaccessible to the digestive enzymes as in seeds, grains and tubers.

2. Starch granules are configured in such a way which prevents their digestion

   E.g. unripe bananas, raw potatoes, and high amylose maize starch

3. Gelatinized starch when cooled form starch crystals (retrograded starch) which are resistant to digestive enzymes

   E.g. corn flakes, cooked + cooled pasta & potatoes

4. Chemical modifications like esterification, etherification, and cross bonding resist enzymatic digestion of starch

(Sajilata, Singhal et al. 2006, Ashwar, Gani et al. 2016)

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Types of resistant starches

Table 2. Classification of types of resistant starch (RS), food sources and factors affecting their resistance to digestion in colon[14,47,64,69–71]

RS type	Description	Food sources	Resistance minimized by	Digestion in small intestine
RS1	Physically protected	Whole or partly milled grains and seeds, legumes	Milling, chewing	Slow rate; partial degree; totally digested if properly milled
RS2	Ungelatinized resistant granules with type B crystallinity, slowly hydrolysed by α-amylase	Raw potatoes, green bananas, some legumes, high-amylose corn	Food processing and cooking	Very slow rate; little degree; totally digested when freshly cooked
RS3	Retrograded starch	Cooked and cooled potatoes, bread, cornflakes, food products with repeated moist heat treatment	Processing conditions	Slow rate; partial degree; reversible digestion; digestibility improved by reheating
RS4	Chemically modified starches due to cross-linking with chemical reagents	Foods in which modified starches have been used (e.g. breads, cakes)	Less susceptible to digestibility *in vitro*	Result of chemical modification; can resist hydrolysis
RS5	Amylose–lipid complexes	Foods with high amylose content	Not susceptible to hydrolysis by α-amylase	Can resist digestion

(Raigond, Ezekiel et al. 2015)

Table 1. Approximate total dietary fibre, starch and resistant starch of some food sources (g/100 g as eaten).

Source	Total starch	Total dietary fibre	Resistant starch
Legumes			
Red kidney beans	42.6	36.8	24.6
Lentils	53.3	33.1	25.4
Black-eyed peas	53.9	32.8	17.7
Cereal grains			
Barley	55.2	17.0	18.2
Corn	77.9	19.6	25.2
White rice	95.1	1.5	14.1
Wheat	50.8	17.0	13.6
Oats	43.4	37.7	7.2
Flours			
Corn	84.3	2.8	11.0
Wheat	68.8	12.1	1.7
Rice	86.9	5.1	1.6
Potato	81.0	2.1	1.7
Grain-based food products			
Spaghetti	73.0	5.6	3.3
Rolled oats	56.0	10.0	8.5
Cereal products			
Crisp bread	67.4	n/a	1.4
White bread	46.7	n/a	1.9
'Granary' bread	44.1	n/a	6.0
Extruded oat cereal	57.2	n/a	0.2
Puffed wheat cereal	67.0	n/a	1.2
Oat porridge	9.0	n/a	0.3
Cooked spaghetti	n/a	n/a	2.9
Cooked rice	n/a	n/a	3.7
Potato products			
Boiled potatoes	n/a	n/a	2.0
Chips	29.5	n/a	4.8
Mashed potatoes	n/a	n/a	2.4

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(Fuentes-Zaragoza, Sánchez-Zapata et al. 2011)

Table 2—In vitro digestibility of starch in a variety of foods (BNF 1990)[a]

Foods	% RDS	% SDS	% RS_1	%RS_2	%RS_3
Flour, white	38	59	—	3	Traces
Short bread	56	43	—	—	Traces
Bread, white	94	4	—	—	2
Bread, whole meal	90	8	—	—	2
Spaghetti, white	55	36	8	—	1
Biscuits made with 50% raw banana flour	34	27	—	38	Traces
Biscuits made with 50% raw potato flour	36	29	—	35	Traces
Peas, chick, canned	56	24	5	—	14
Beans, dried, freshly cooked	37	45	11	Traces	6
Beans, red kidney, canned	25	—	—	15	60

[a]Values are expressed as % of the total starch present in the food.

(Sajilata, Singhal et al. 2006)

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Table 4. Commercially manufactured resistant starches commonly used in various foods[42,70,85]

Brand name of commercial RS	Type	RS/TDF content[a]	Physiological and/or health benefits	Manufacturer
Hi-maize	RS2	30–60% TDF	Prebiotic properties; lowers fecal pH; increases level of SCFA (in particular butyrate, which may reduce cancer risk); increases bowel action with its mild laxative effect; increases bowel-beneficial microflora	National Starch and Chemicals Co., USA
Crystalean	RS3	19.2–41% RS	Prebiotic effect; increases proportion of butyrate; increases cell proliferation in proximal colon (in rats); provides soluble dietary fiber and prebiotic effects; low glycemic index	Opta Food Ingredients Inc., USA
Novelose 240	RS2	47% RS	Lowers glycemic response when used as a substitute for flour and other rapidly digested carbohydrates	National Starch and Chemicals Co., USA
Novelose 260	RS2	60% RS	Lowers glycemic response when used as a substitute for flour and other rapidly digested carbohydrates	National Starch and Chemicals Co., USA
Novelose 300	RS3	<30% TDF	Lowers glycemic response when used as a substitute for flour and other rapidly digested carbohydrates	National Starch and Chemicals Co., USA
Act*-RS3	RS3	53% RS	Health benefit potential; prebiotic effect; source of butyrate; supports immune system; reduces glycemic response; low calorific value; easily fermentable; very well tolerated	Cerestar (a Cargill company)
Fibersym HA	RS4	>70% TDF	Acts as prebiotic; reduces glycemic and insulin response of healthy individuals as well as type 2 diabetics	MGP Ingredients, Inc. (Atchison, KS) and Cargill
Fibersym 80ST	RS4	80% TDF	Acts as prebiotic; reduces glycemic and insulin response of healthy individuals as well as type 2 diabetics	MGP Ingredients, Inc. (Atchison, KS) and Cargill
Nutriose FB06	–	85% TDF	Low calorific value	Roquette Freres, France
Fibersol-2	–	90% TDF	Probiotic effect; intestinal regularity and blood sugar regulation	ADM/Matsutani
Hylon VII	RS2	23% TDF	Increases level of SCFA	National Starch and Chemicals Co., USA
Neo-amylose	RS3	87 or 95% RS	Prebiotic; protects against inflammatory intestinal disease; may protect against colorectal cancer; may help control blood glucose levels in diabetics	Protos-Biotech. (Celanese Ventures GmbH)

[a] RS, resistant starch; TDF, total dietary fiber.

(Raigond, Ezekiel et al. 2015)

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1. Dietary Fibre:
- Resists digestive breakdown
- Regulates intestines
- Prebiotic effect on gut microbes

2. Complex structure
- Cellulose (hard)
- Pectin (soft)
- Varies between plants

3. Processing:
- Particle size
- Intact cells
- Fermentation rate

4. Starch
- Rapid digestion
- Slow digestion
- Resistant digestion

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References

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Dr Anneline

THE F+N DOCTOR

www.drannelinepadayachee.com

hello@drannelinepadayachee.com

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Laetatio Pty Ltd trading as The Food and Nutrition Doctor (64 636 906 379), Norman Park, QLD, 4160.