Plant & Food RESEARCH
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The New Zealand Institute for Plant & Food Research Limited

Fruit Phytochemicals to Aid Exercise Recovery

- A Platform of Research on New Zealand Blackcurrants

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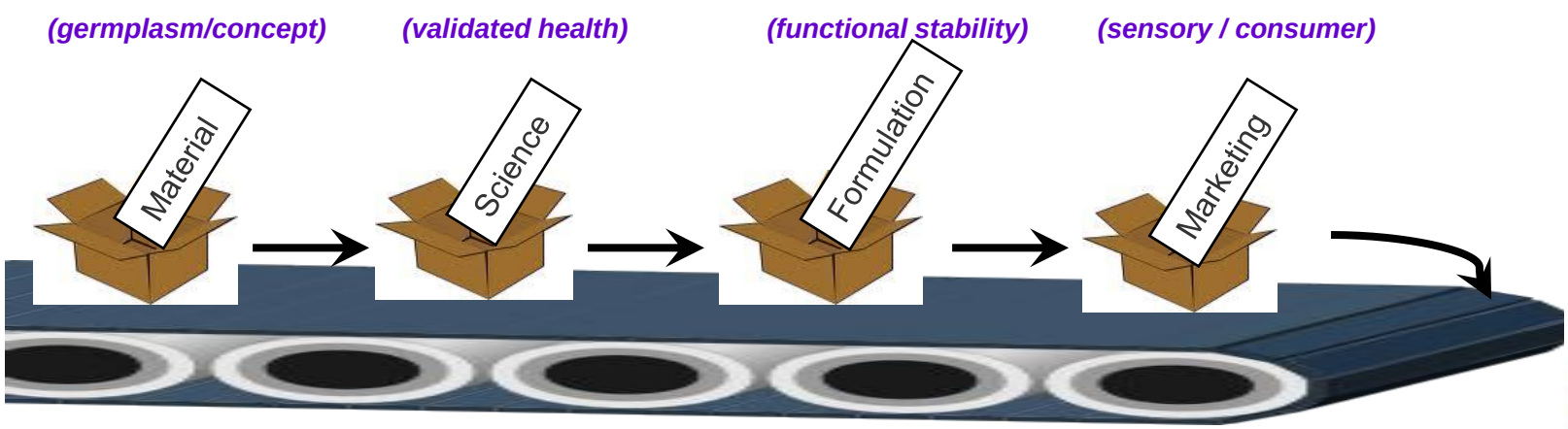
Ruakura
Hawke's Bay
Palmerston North

Motueka
Nelson
Marlborough
Lincoln
Clyde
Dunedin
Gore

900 staff
600 scientists

- From Germplasm to Concept
- From Concept to Validation

Creation of concepts/prototypes based on our underpining science



Scope:

Whole fruit (new cultivars)

Ingredients

Validated concept products

Targeted Health Areas

Science discovering the goodness in fruits, vegetables and natives

- Physical Fitness / Performance / Recovery / Energy and Enhanced Training from Exercise
- Mental Health / Mood / Psychological Stress & Cognitive Performance
- Inflammation – Gut, Airway, Skin

Aim: To understand the bioactivity of fruit & vegetable phytochemicals to produce fresh and processed functional foods with a proven health efficacy

Medium-High Health/Functional 'Supportive' Evidence

Approach

- **Chemical / compositional analysis**
- ***in vitro* model development for bioactive screening & discovery of mechanisms**
- **Animal feeding trials or *ex vivo* (tissue) analysis**
- **Human intervention trials (bioavailability/functionality)**

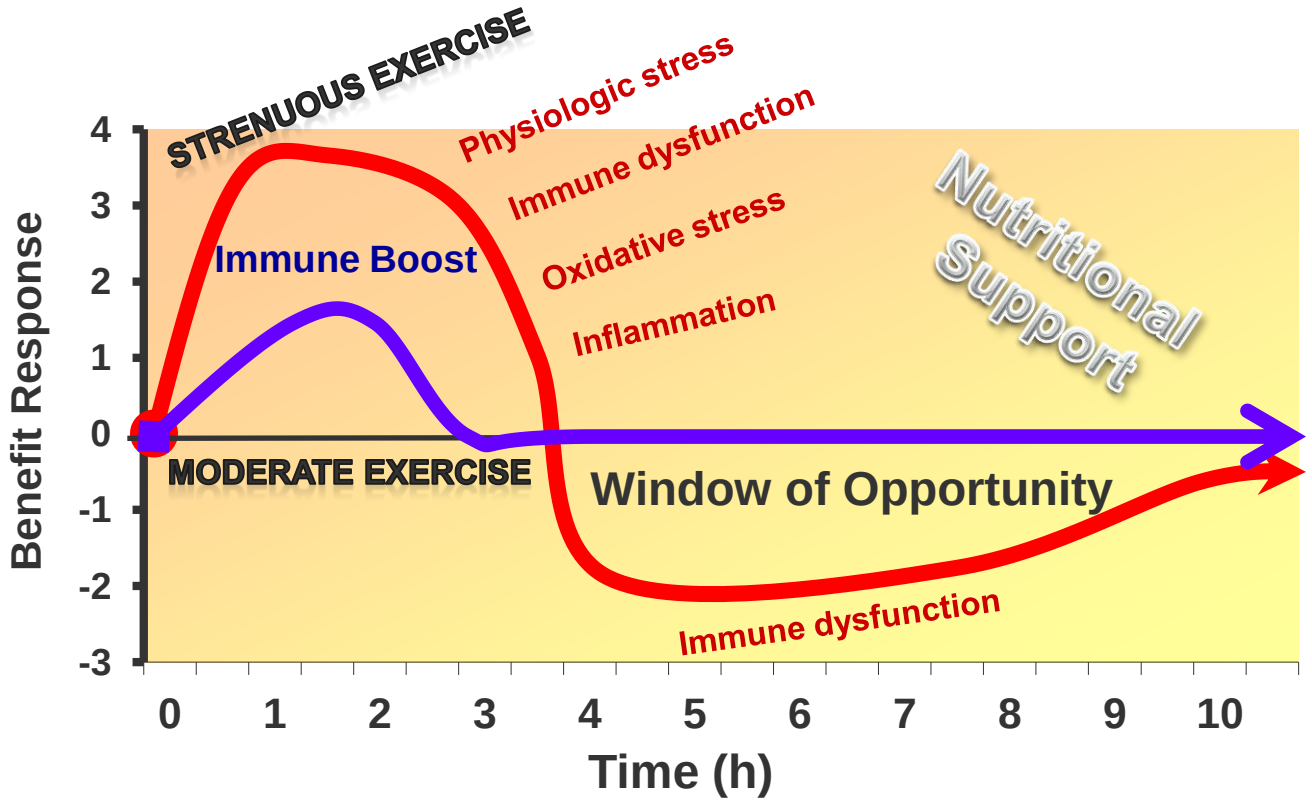
Cultivar composition

Cellular Screening

Animal/Ex vivo feeding trials

Human Feeding Trials

Exercise Workout and Benefit - Relationship



Nutritional Support for Exercise – the Evidence

1984-1995

Heavy exertion linked to increased illness rates, increased inflammatory cytokines, immune dysfunction

1995-2005

Series of studies by Gatorade Sports Science Institute show that carbohydrate counters exercise-induced inflammation but not immune dysfunction

1997-2013

Vitamin C, vitamin E, fish oil, ibuprofen, and complex vitamin-mineral supplements do not counter exercise-induced inflammation, oxidative stress, immune dysfunction

Vitamins 'undo exercise efforts'

Taking vitamins after exercise may undo some of the beneficial effects of the workout, research suggests. Some advocate taking antioxidants like vitamin C and E to help protect the body from harmful chemical by-products it creates in breaking into a sweat

BBC NEWS

NUTRITION SUPPLEMENT	RATIONALE	RECOMMENDATION BASED ON CURRENT EVIDENCE
Carbohydrate	Maintains blood glucose during exercise, lowers release of stress hormones; counters negative immune changes post-exercise	Recommended; up to 60 g per hour of heavy exertion
Fruit & vegetable extracts rich in polyphenols & flavonoids	Act by modulating exercise induced inflammation; also decreases oxidative stress.	Recommended, but most research focused on oxidative stress
Quercetin	Strong anti-inflammatory, anti-oxidative, and anti-pathogenic effects; increase in mitochondrial biogenesis and performance.	Recommended when mixed with other flavonoids and nutrients
Bovine colostrums	Mix of immune, growth, and hormonal factors improve immune function and lower illness risk	Mixed results, and more data needed
Probiotics	Improve intestinal microbial flora, and thereby enhance gut and systemic immune function	Mixed results, and more data needed
β-glucan	Receptors found on intestinal wall immune cells interact with β-glucan improving innate immunity.	Mixed results: mushroom β-glucan may effective, but more data needed
Vitamin E	Quenches exercise-induced reactive oxygen species (ROS) and augments immunity	Not recommended; may be pro-oxidative and pro-inflammatory
Vitamin C	Quenches ROS and augments immunity	Not recommended; not consistently different from placebo
Multiple vitamins and minerals	Work together to quench ROS and reduce inflammation	Not recommended; not different from placebo; balanced diet is sufficient
Glutamine	Important immune cell energy substrate that is lowered with prolonged exercise	Not recommended; body stores exceed exercise-lowering effects
N-3 PUFAs (fish oil)	Exerts anti-inflammatory and immune-regulatory effects post-exercise	Not recommended; no different from placebo
Herbal supplements (e.g., Ginseng, Echinacea)	Contain bioactive molecules that augment immunity and counter infection	Not recommended; humans studies do not show consistent support within an athletic context

What can Berries Offer?

Current sports nutrition products focus on ‘hydration’, ‘rehydration’ and ‘energy supply’

Berries may assist to promote physical wellbeing:

- Modulating oxidative damage
- Modulating inflammation
- Assisting immune function
- Aiding recovery and performance

Berryfruit composition – an opportunity ?

Blackcurrant samples for anthocyanin and phenolic analysis

				Anthocyanins								Other																																			
Cultivar	year	Sample	code	Del-glucoside	Del-rutinoside	Cyan-rutinoside	Petun-rutinoside	Unk antho	Peon-rutinoside	Cyan-rutinoside	Antho Total	479, 175	609 Caffeic	341 Caffei	593, 341 C	325 p-Cour	337, p-Cou	325 p-Cour	426 Unk	522, 341 C	673, 341, 1	377 Unkno	449, 287 di	339 Unk	385, 223, 5	449, 287 di	391 Unk	465 Unk	625, 479, 3	479, 317, N	436, Unk	521, 317, N	391 unk	403, Unkno	447, 301, C	463, 301 Q	325 p-Cour	463, 301 Q	420, 163 p	505, 285 K	449, 287 di	593, 317 M	447, 285, K	450, 317 M	477 Unk	486 Unk	481, 295 U
				32.9	129.2	94.2	5.1	3.1	2.4	2.0	269	20984	41619	78927	126342	19486	41173	52967	26582	21652	14100		130942	26644	20490	81144	33144	23520	1889938	807781	120433	111715	17999	47334	114463	267036	10348	267036	233987	63500	11927	117676	127219	163384	22620	248332	21402
				30.5	119.8	89.0	4.5	3.0	2.2	2.0	251		6189	8466	8264	15358	34854	3432	26159	1257	18468	3593	13638	42449	22712	38836	6872	23658	1595787	7228	1988	16533	23471	6457	129169	288393	539	288393	28465	88731	1556	14425	121648	2332	2557	267568	1457
				31.4	127.6	93.5	4.0	2.2	2.3	1.9	263	12301	60424	63136	101804		43364	28024	19290	6088	6116		89015	19263	39561	46552	56388	17754	1090103	724408	82484	115334	10676	25168	92504	325585	11110	322365	126712	85044	23932	96188	114327	109864	31546	195510	35552
				37.2	163.2	135.5	1.8	0.9	2.3	1.3	342	12781	819	45835	129672	3238	1936	26216	52935	21		638	71891	2172	368	29693	32467	26154	138156	84858	12133	166683	2468	4852	9118	343449	643	343449	14792	12166	42313	129581	126534	12932	54924	22747	28792
				25.3	89.6	71.4	3.7	2.3	1.1	1.3	195	30228	43579	66206	98890	25060	23845	65580	31615			10488	82312		30796	43268	75696		1125023	420356	140368	106096	19904	47367	79857	247273	30412	247273	318841	93158	5389	141025	101129	102103	23700	648134	37736
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				18.2	96.0	89.2	4.1	2.4	1.3	0.7	212	12986	93139	114388	111195	20636	60076	53024	45564	16244	13556		282083	54456		108309	27313	23204	1215167	404109	122671	165636	7469	37975	223044	234435	4948	234435	218964	172856	29717	194148	36116	176894	29822	241310	17300
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				20.3	73.9	63.7	4.1	2.5	1.0	0.7	166		3532	4696	18144		3536	896	19262	5212	14938		18673	41996		4212	35936	32786	69268	4458	6954	138644	9686	85748	17752	246296	1674	24991	11685	75433	28483	67548	16984	78838	624	123134	11611
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				31.1	86.0	69.1	3.4	2.2	3.7	1.8	197		28322	69559	63398	21474	37108	30918	16060			10928	154650	10912	14530	51662	25981	16376	694192	495272	114216	103682	25848	29979	100584	396586	11736	396586	144422	92219	25136	111738	189884	188395	76694	183224	31977
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				29.1	123.5	78.7	4.9	2.8	2.0	1.5	242		98720	108374	127932	32350	73686	54962	56468	20004	22060	5999	187137	31957	16479	28088	25366	48500	1157728	559583	179423	155675	14270	38720	92184	200120	10291	200120	297693	89509	22814	154147	65826	296691	27540	254307	11064
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				44.3	116.0	130.1	3.7	2.4	1.8	2.0	300		109207	92592	102411	46408	31924	59484	21447		14020	8485	143301	16440	2925	13025	18696	26081	1294072	893554	156867	241244	11495	40134	44661	339816	9272	317754	318980	147489	25058	197572	105600	187075	8738	346360	26372
				43.7	115.0	119.7	3.6	2.2	1.9	1.0	287	18757	98831	71344	239238	22084	63292	71446	23926		10947	14208	107846	17298	15892	45651	7856	37507	1648152	946631	172721	194101	26847	46944	68302	282320	13324	282320	316770	109004	34992	141073	119628	225440	38166	392524	18404
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				25.1	87.7	72.5	4.3	2.6	1.1	0.7	194	23294	103170	64268	89784		26100	93188	81232		5284		104676	6780	21795	35096	39909	17383	1040444	955440	82954	158832	47641	34756	40330	431171	2868	429953	208720	171356	13466	49427	59088	115405	88671	163493	37552
				19.4	92.5	87.6	3.3	2.1	1.2	1.4	207		80798	73612	115228	45089	49331	22458	15891	6932	23321	25964	138027	6695	18191	41889	21613	44105	1136285	367923	182196	125880	32193	48448	168844	360237	13550	360237	241469	56042	37009	197177	227276	131906	18133	253840	3212
				21.2	99.0	88.5	4.6	3.0	1.8	1.0	219	7060	21142	57877	81332	37660		49943	27762	6688		12095	117740		10866	41725	17938	18621	1603954	457175	134100	108155	17776	41022	116087	206988	5758	206988	289340	86845	23403	163224	29636	131731	30691	206688	15890
				24.5	113.1	95.7	5.1	3.2	2.0	1.1	245	21314	46291	77409	76902	57688	20660	33188	21874	9156			122631		33525	43391	18803	43367	1720023	598604	89435	111236	27808	22723	66291	198538	22692	198538	274324	54011	17998	96804	62783	105334	33398	229148	21878
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				25.6	118.0	111.9	3.4	2.1	1.6	1.1	264		81773	29501	122537	35442	49217	46487	29627		16636	4909	119653	7784	3294	18927	7035	19935	1190730	835116	185420	102029	25101	29988	45048	252277	9635	212978	249006	67896	4436	85087	102067	168412	9715	194896	9724
				36.0	138.5	100.4	5.3	2.9	1.7	0.8	286	10308	63107	86682		39416	24439	33748	25999			13260	106036	24886	28454	49948	38851	39446	1338208	801264	121808	228189	26516	28309	59297	274754	6615	274754	173710	100837	9668	182271	104714	109140	23678	303755	34084
				36.3	129.4	100.5	5.5	3.2	1.5	0.8	277	19269		82948	75016	43068	15216	42602	29120		16648		116296	8964	16349	41643	20732	95460	1037429	475416	71459	236454	6658	42168	83482	275485	14436	275485	168716	126591	21524	191055	116476	118585	33682	247063	39610
				12.4	55.8	63.1	3.4	2.5	0.7	0.6	139	10408	45206	48088	81199	34596	49128	60376	19500	9413	21472	19472	186538	31396	10880	27591	25084	62764	615394	271720	72925	119190	7607	58256	73185	258966	26142	258966	166255	157341	15824	161109	307972	127527	43770	111266	3256
				35.1	89.6	72.6	4.4	2.6	1.5	1.6	207	39220	80514	99259	151296	26972	51479	79105	42283	6477	9050	17417	174997	17841	15490	15642	51018	28460	1889877	1292854	230687	165082	8208	46760	44654	434520	19428	434520	327919	100286	2332	173228	148868	198167	34668	420766	20694
				25.1	104.7	89.2	4.2	2.5	1.8	1.2	229		43988	70790	103195	42260	43428	52328	21028	14616	24376	11520	122352	10160	8147	26092	20251	29403	1191513	751972	92944	116269	22044	55042	48169	262931	9318	262931	129918	113024	16228	126994	135671	121883	45063	194654	7340
				24.0	104.7	86.3	3.9	2.4	1.6	1.1	224		8338	59354	97555	19388	53236	15962	59412		946	8117	149674	134	2628	55433	32428	41443	13628	972419	212	28331	26213	71212	4684	542826	19283	542826	226541	215368	19114	1855	238687	2558	8265	39569	38476

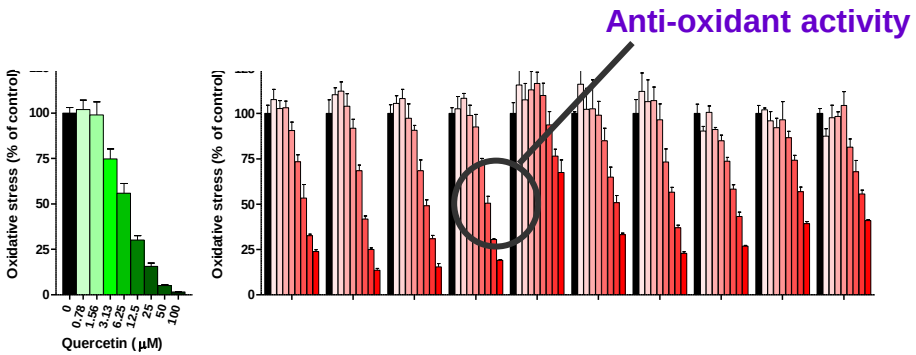
Over 3,000 berryfruit cultivars analysed : Total anthos, % anthos, Total phenolics (Hplc &Folin), ORAC, FRAP, Vit C

Underpinning future opportunities – Unique cultivars, Unique products

Cell-Based Assays – Physical Health

Physical health assays:

- Direct toxicity to muscle cells
- Oxidative stress protection
  – protection against ox stress
- Integrity protection/recovery
  – heat shock protein expression
  – damage & recovery model
- Oxidative protection
  – mitochondrial function
- Anti-inflammatory assays
  – IL6 generation (multiple stimulators)
- Adaptive anti-oxidative measures
  – e.g. SOD, catalase, GSH
- Etc, etc



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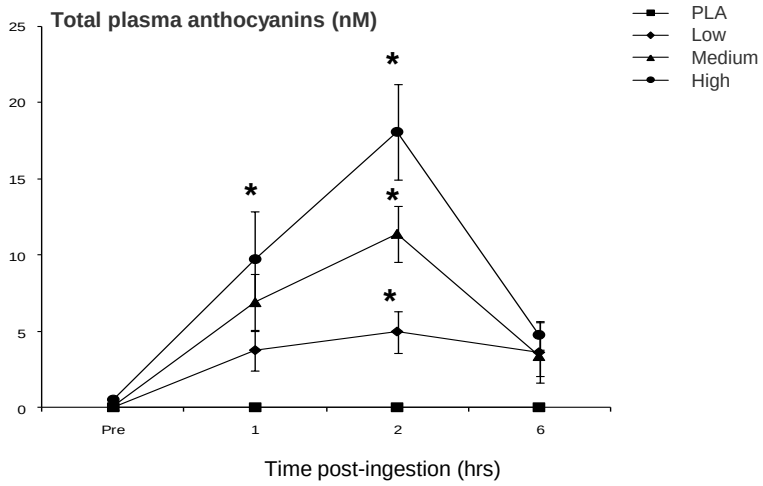
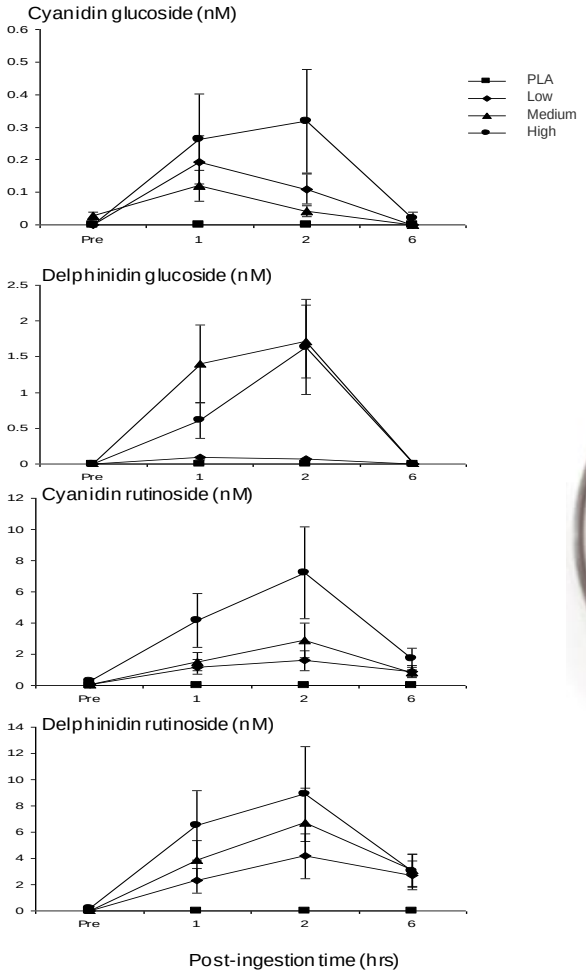
- Schrage,B., Stevenson, D., Wells, R., Lyall, K., Holmes, S., Deng, D., & Hurst, R. (2010) Evaluating the health benefits of fruits for physica fitness: A research platform. *J. Berry Res.* 1, 35-45.

Human Exercise Models

Rowing	Repeat quadriceps squats	Repeat leg extensions	High intensity training
			
30 mins, 80% max heart rate	**4 sets of 10 repeats – to failure -**	**3 sets of 100 repeats Resist arm**	**All out for 60 sec Ramping up repeats x3 /week over 4 weeks**
Oxidative Stress	***Muscle damage***	***Muscle damage***	***Fatigue/endurance/training***

Anthocyanin Bioavailability



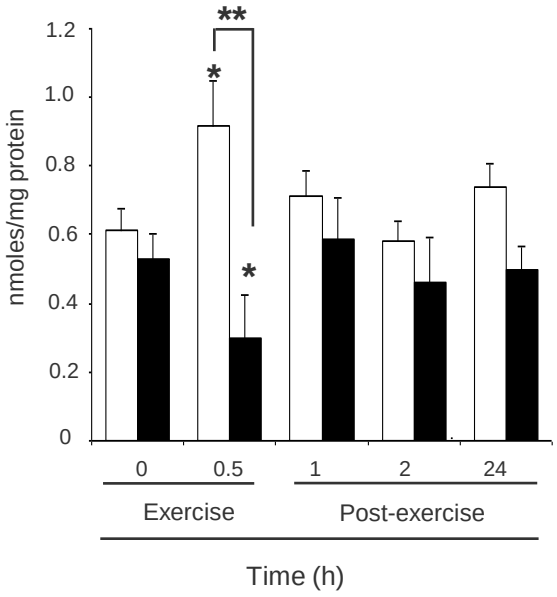


- Optimum dose determined
- Peak post consumption determined

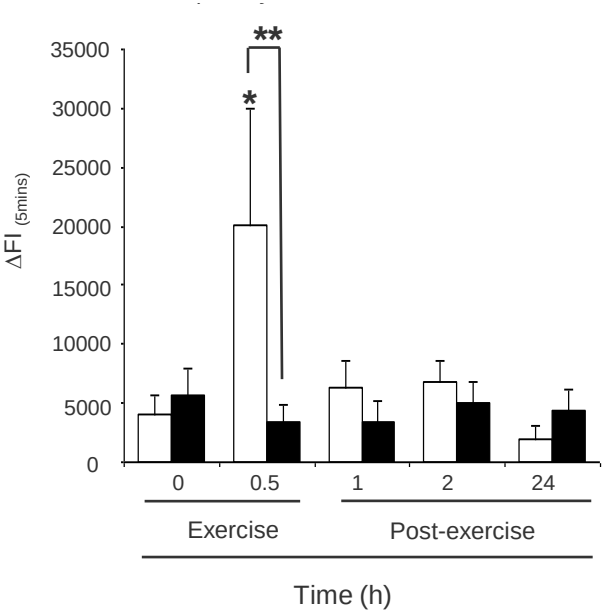
Human exercise – Blackcurrant - Oxidative stress model

- N=8 volunteers
- Double-blind, cross-over
- 30 min rowing exercise at 80% max ♥ rate
- 240 mg total anthocyanin
- Placebo – sugar control

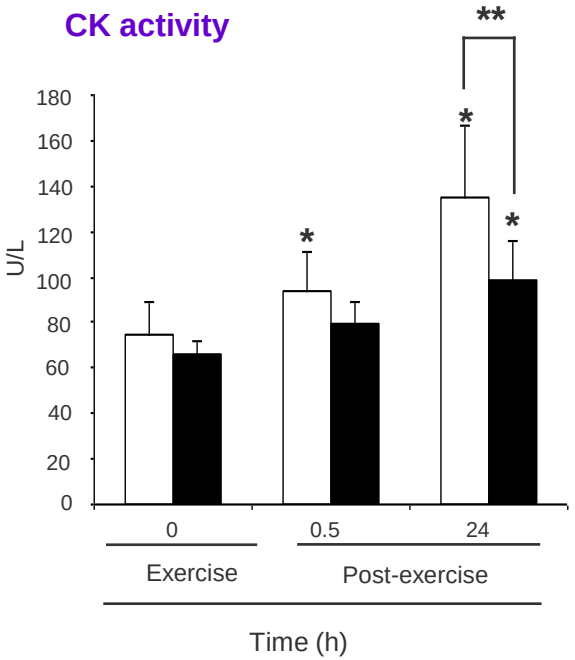
Protein carbonyls



Oxidative Capacity



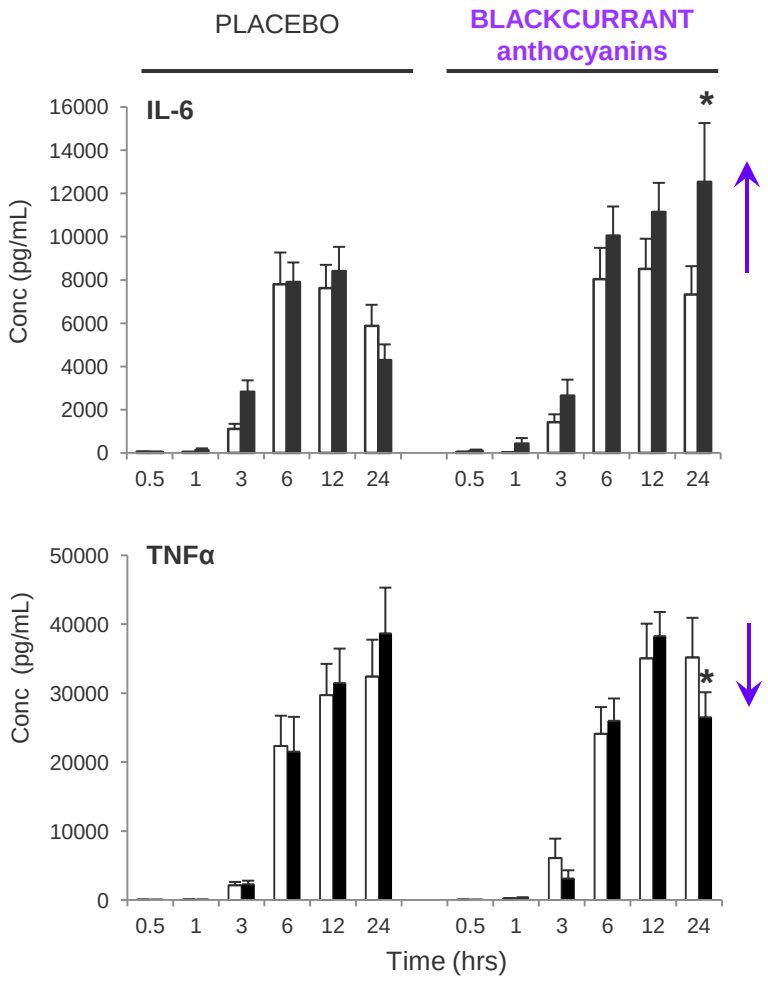
CK activity



Blackcurrant modulated exercise-induced oxidative stress and muscle damage

K.A. Lyall, et al., (2009) Short-term blackcurrant extract consumption modulates exercise-induced oxidative stress and lipopolysaccharide-stimulated inflammatory responses *Am. J. Physiol. Regul. Integr. Comp. Physiol.* 297, R70-81.

Human exercise – Blackcurrant - Immunity

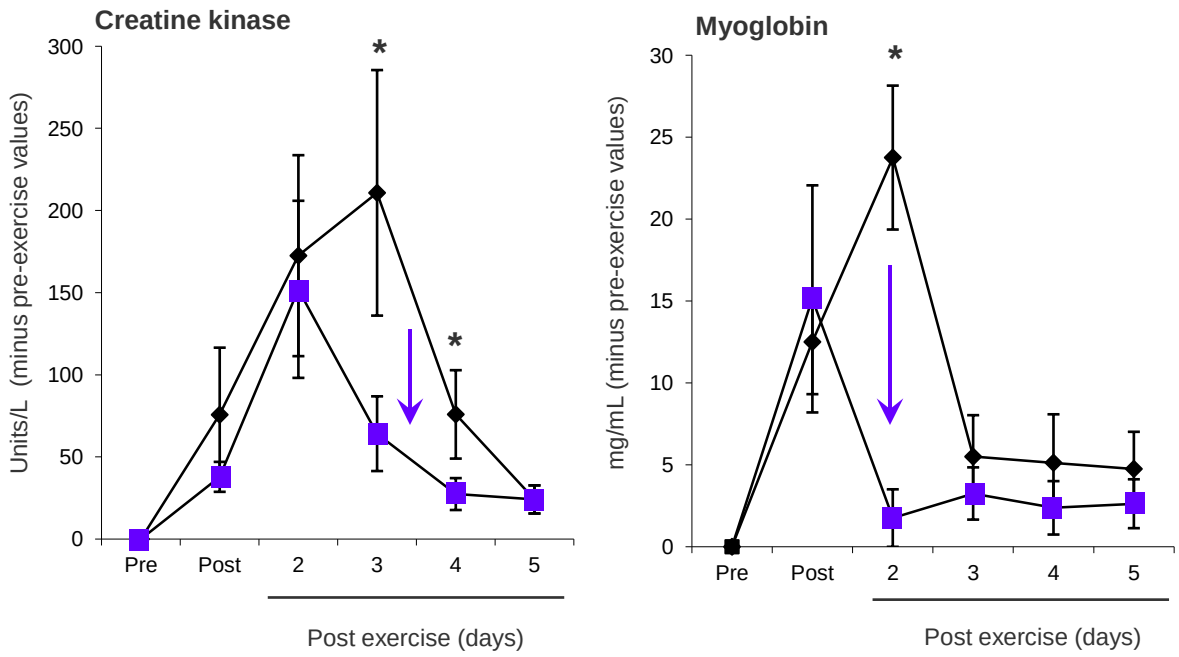


Blackcurrant assists immunity to aid tissue repair

S.M. Hurst & R.D. Hurst (2013) Anthocyanins, innate immunity and exercise. *In: Anthocyanins in Health & Disease.* Taylor C. Wallace (Ed), CRC Press.

K.A. Lyall, et al., (2009) Short-term blackcurrant extract consumption modulates exercise-induced oxidative stress and lipopolysaccharide-stimulated inflammatory responses. *Am. J. Physiol. Regul. Integr. Comp. Physiol.* 297, R70-81.

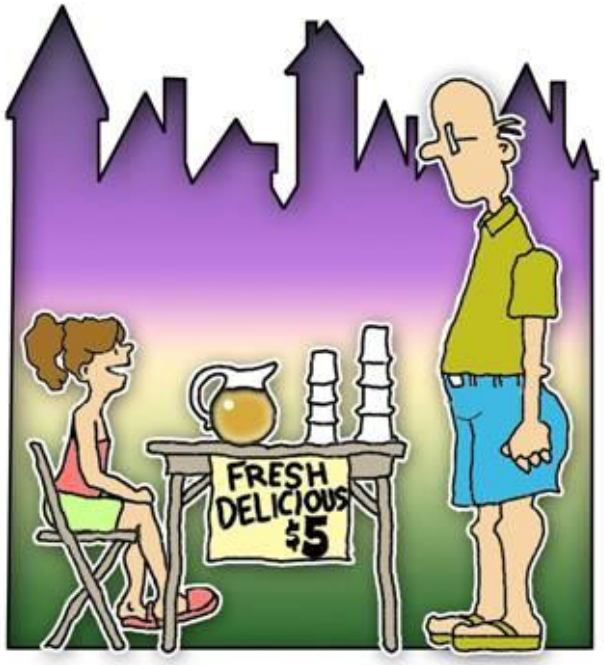
Human exercise – Muscle damage model



Muscle damage prevention by blackcurrant – long term action

S.M. Hurst & R.D. Hurst (2013) Anthocyanins, innate immunity and exercise. *In: Anthocyanins in Health & Disease.* Taylor C. Wallace (Ed), CRC Press.

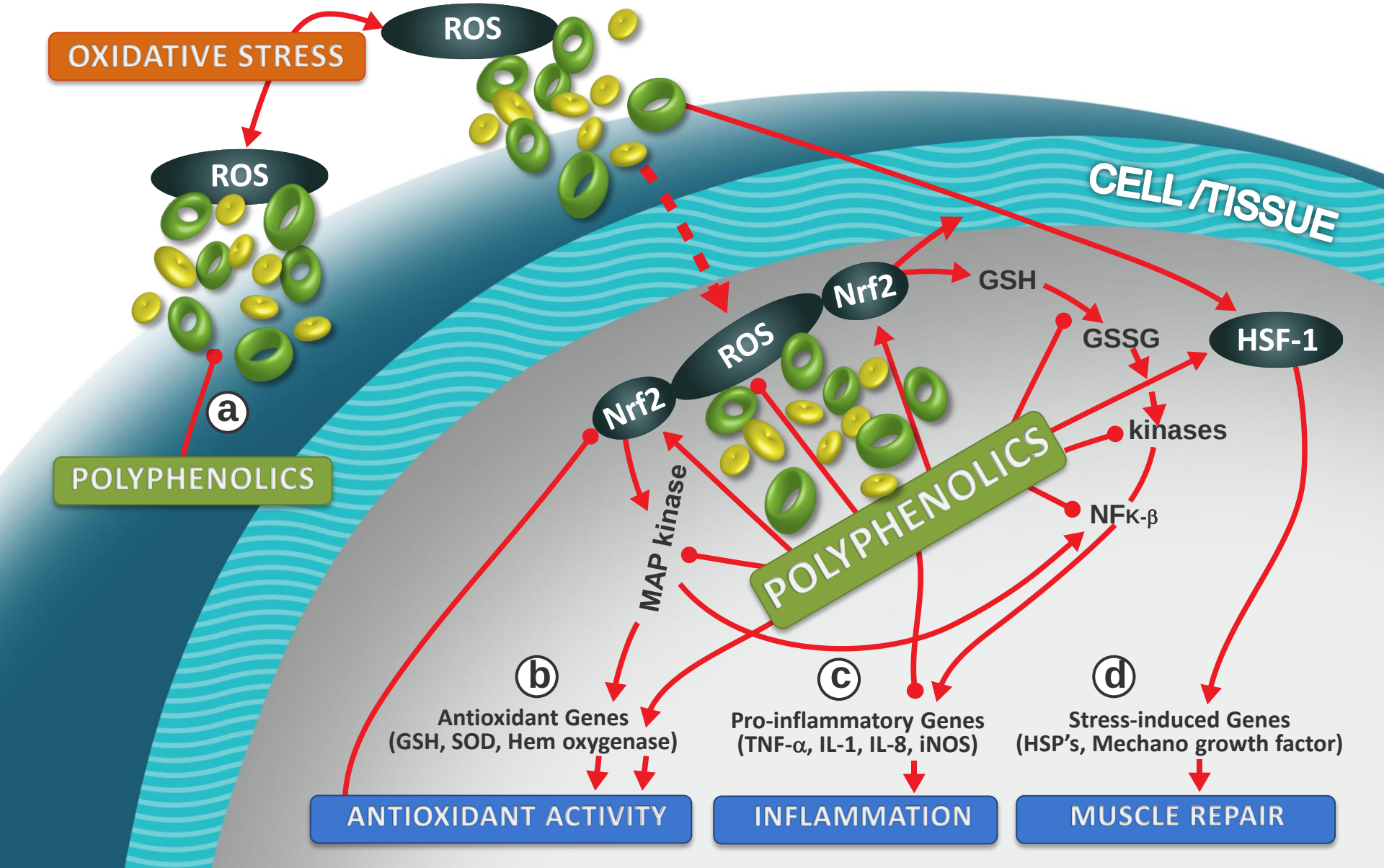
What is the Mechanism of Action?



"This is no ordinary lemonade. It's a tart blend of fruit and green tea that is not only refreshing but sufficiently high in antioxidants. Plus it grows hair."

Mechanisms

- Stevenson D. Scheepens A. & Hurst RD (2009) Bioavailability and metabolism of dietary flavonoids – much known – much more to discover. International *J. Medi. Biol. Front.* 6: 3–4.
- Hurst, RD. & Hurst SM (2011) Fruits and vegetables for physical fitness and inflammation. In: *Bioactive Foods for Chronic Disease States.* Eds R. Watson. Elsevier Press, Oxford UK.



Platform of Health Support - Sports

<u>Platform of science evidence</u> that NZ blackcurrant

'Assists the Natural Benefits of Exercise & Sports'

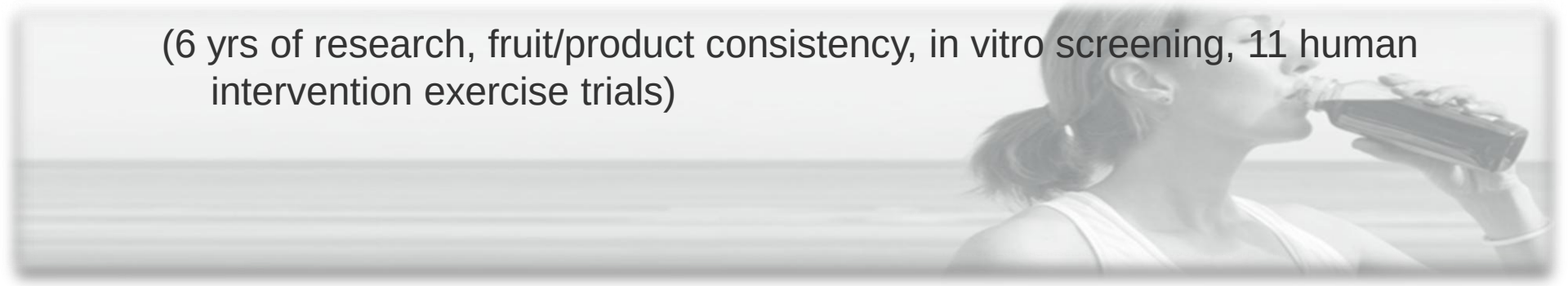
Evidence = Specific fruit ; Dose ; Timing ; Actives ; Mode of Action

Marketing backed by science:

- Controlled oxidative stress and inflammation
- Controlled muscle damage and soreness
- Assisted immune protection - enhanced immunity
- Speedier tissue repair, recovery and performance in exercise
- Train/work harder …….again, and for longer

- Health Claim in NZ

(6 yrs of research, fruit/product consistency, in vitro screening, 11 human intervention exercise trials)



Acknowledgements

Plant & Food RESEARCH
RANGAHAU AHUMĀRA KAI

Sue Hurst
Birgit Ha
Kirsty Lyall
Dominic Lomiwes
Jeff Greenwood
Harry Martin
Robyn Wells
Jing Yuan
David Stevenson
Dawei Deng
Janine Cooney
Dwayne Jensen
Greg Sawyer
Geoff Langford
Jo Stephens
Jessica Scalzo
Cath Snelling
Shanthi Parkar
Jingli Zhang
Selena Holmes
Tafa Nyanhanda
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APPALACHIAN STATE UNIVERSITY
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David Nieman
Mary-Pat Meaney

NZ Govt, NZ Blackcurrant Industries

And a big thank you for listening