五穀為養：與多酚類的關連

《黃帝內經》提出「毒藥攻邪，五穀為養，五果為助，五畜為益、五菜為充，氣味合而服之，以補精益氣。此五者，有辛酸甘苦鹹，各有所利，或散或收，或緩或急，或堅或軟，四時五臟，病隨五味所宜也」的膳食配伍原則。

- 五穀有補養的作用，五穀有五味，分別有不同的補養作用。
- 五果有輔助作用。
- 五畜是補益的作用，助長五臟精氣。
- 五菜為充養的作用。

- 穀肉果菜都有不同的味，作用也不同，在實踐當中也要調和這五味。
- 稻米、小米、小麥、豆類等五穀雜糧是補養五臟精氣最主要的養分，為諸營養分之首，加上適量水果、肉蛋類、蔬菜的補充，是補養人身體精氣神的主要來源。

Antioxidants Activity of Grains (J. Agric. Food Chem., 50:6182-6187, 2002)

綠原酸(ferulic acid)為主要酚類化合物，游離/可溶共軛物/結合態的比率約 0.1 : 1 : 100

Table 1. Ferulic Acid Contents of Grains and the Percentage Contribution of Each Fraction to the Total (μmol of ferulic acid/100 g of grain)

綠原酸含量		free	soluble conjugate	bound	total
corn	玉米	0.92 ± 0.02 (0.1%)[a]	8.95 ± 0.11 (1%)	896.27 ± 9.09 (98.9%)	906.13 ± 9.09
wheat	小麥	0.57 ± 0.02 (0.2%)	3.27 ± 0.27 (1%)	329.60 ± 16.20 (98.8%)	333.44 ± 16.20
oats	燕麥	0.65 ± 0.04 (0.4%)	3.4 ± 0.56 (1.84%)	180.61 ± 4.57 (97.8%)	184.66 ± 4.61
rice	米	0.7 ± 0.05 (0.5%)	9.9 ± 0.34 (6.5%)	142.80 ± 8.68 (93%)	153.39 ± 8.68

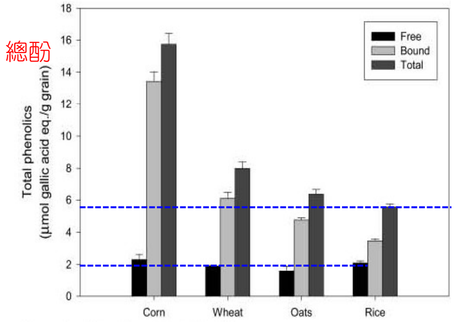


Figure 1. Phenolic content of grains.

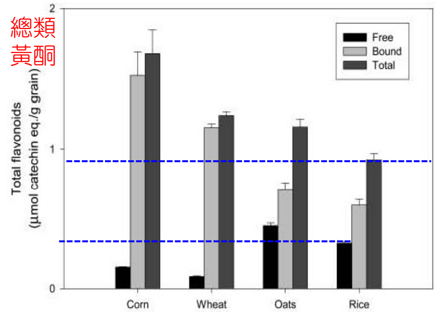


Figure 2. Flavonoid content of grains.

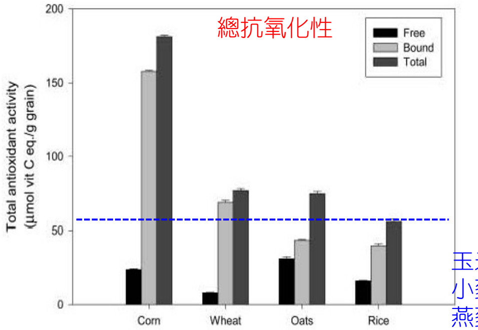


Figure 3. Total antioxidant activity of grains.

Table 2. Percentage Contributions of Free and Bound Fractions of Grains to Total Phenolics, Flavonoids, and Total Antioxidant Activity

		phenolic content (%)		flavonoid content (%)		total antioxidant activity (%)	
		free	bound	free	bound	free	bound
玉米	corn	15	85	9	91	13	87
小麥	wheat	25	75	7	93	10	90
燕麥	oats	25	75	39	61	42	58
米	rice	38	62	35	65	29	71

Table 3. Correlation Analysis of Phenolics and Total Antioxidant Activity

	free extracts		bound extracts		total	
	total antioxidant activity	phenolics	total antioxidant activity	phenolics	total antioxidant activity	phenolics
phenolics	0.076[a]		0.991**[b]		0.983**	
ferulic acid	0.0003[c]	0.695[c]	0.999**	0.994**	0.974*	0.998**
flavonoids	0.517	0.324	0.872	0.865	0.925*	0.933*

[a] Correlation coefficient R^2. [b] Significantly different: *, $p < 0.05$; **, $p < 0.01$; all others, $p > 0.05$. [c] Total of free and soluble conjugate ferulic acid.

Analysis of Phenolic Compounds in White Rice, Brown Rice, and Germinated Brown Rice (J. Agric. Food Chem., 52: 4808-4813, 2004)

Table 2. Soluble Phenolic Acid Content[a] of Germinated Brown Rice, Brown Rice, and White Rice (Milligrams per 100 g of Flour)

		白米 white rice	糙米 brown rice	發芽糙米 germinated brown rice
酚酸	protocatechuic acid	0.01 ± 0.00	0.04 ± 0.00	0.05 ± 0.00
	hydroxybenzoic acid	0.02 ± 0.00	0.04 ± 0.00	0.01 ± 0.00
	vanillic acid	0.03 ± 0.00	0.07 ± 0.00	0.06 ± 0.00
	syringic acid	0.01 ± 0.00	0.03 ± 0.00	0.03 ± 0.00
	chlorogenic acid	0.03 ± 0.00	0.03 ± 0.00	0.04 ± 0.00
	caffeic acid	0.02 ± 0.00	0.02 ± 0.00	0.05 ± 0.00
	p-coumaric acid	0.02 ± 0.00	0.10 ± 0.00	0.12 ± 0.00
	ferulic acid 綠原酸	0.07 ± 0.01	0.32 ± 0.01	0.48 ± 0.01
	sinapinic acid	0.01 ± 0.00	0.02 ± 0.00	0.21 ± 0.01
酚酸+糖基的酯	feruloylsucrose	0.03 ± 0.00	1.09 ± 0.01	0.27 ± 0.01
	sinapoylsucrose	0.03 ± 0.00	0.41 ± 0.01	0.13 ± 0.00
	total	0.28	2.17	1.45
	可溶性酚酸總量	1 :	7.8 :	5.2

[a] Mean value ± SD (n = 3).

Table 3. Insoluble Phenolic Acid Content[a] of Germinated Brown Rice, Brown Rice, and White Rice (Milligrams per 100 g of Flour)

	white rice	brown rice	germinated brown rice
protocatechuic acid	0.17 ± 0.00	0.17 ± 0.00	0.19 ± 0.01
hydroxybenzoic acid	nd[b]	0.16 ± 0.01	0.28 ± 0.02
vanillic acid	nd[b]	0.17 ± 0.01	0.20 ± 0.01
syringic acid	nd[b]	0.14 ± 0.00	0.16 ± 0.00
chlorogenic acid	nd[b]	nd[b]	nd[b]
caffeic acid	nd[b]	0.22 ± 0.00	0.22 ± 0.00
p-coumaric acid p-香豆酸	0.34 ± 0.01	2.10 ± 0.08	3.05 ± 0.02
ferulic acid 綠原酸	5.26 ± 0.14	15.19 ± 0.52	20.04 ± 0.77
sinapinic acid	nd[b]	0.32 ± 0.01	0.64 ± 0.01
feruloylsucrose	nd[b]	nd[b]	nd[b]
sinapoylsucrose	nd[b]	nd[b]	nd[b]
total	5.77	18.47	24.78
不溶性酚酸總量＝	1 :	3.2 :	4.3

[a] Mean value ± SD (n = 3). [b] Not detectable.

Table 4. Soluble Phenolic Acid and Insoluble Phenolic Acid Content[a] of Marketed Germinated Brown Rice (Milligrams per 100 g of Flour)

市售發芽造米	free	bound
protocatechuic acid	0.03 ± 0.00	nd[b]
hydroxybenzoic acid	0.12 ± 0.00	0.26 ± 0.01
vanillic acid	0.06 ± 0.00	0.18 ± 0.01
syringic acid	0.05 ± 0.00	0.15 ± 0.00
chlorogenic acid	0.03 ± 0.00	nd[b]
caffeic acid	0.05 ± 0.00	0.20 ± 0.00
p-coumaric acid	0.34 ± 0.01	3.00 ± 0.00
ferulic acid	0.28 ± 0.01	16.39 ± 0.65
sinapinic acid	0.11 ± 0.00	0.77 ± 0.04
feruloylsucrose	0.22 ± 0.01	nd[b]
sinapoylsucrose	0.10 ± 0.00	nd[b]
total	1.39	20.95

[a] Mean value ± SD (n = 3). [b] Not detectable.

Antioxidant Activity and Nutrient Composition of Selected Cereals for Food Use (Food Chem., 98: 32-38, 2006)

全穀物產品(大麥、小米、裸麥及高粱)、商業全穀小麥粉比較

Table 1
Chemical composition (% dry basis) of wheat flours and whole grain cereals

	Cereal	Starch	Protein ($N\times$ factor)[a]	Total ash	Crude fat
硬質小麥	Hard wheat	77.4 ± 1.7	13.5 ± 0.3	0.56 ± 0.01	0.98 ± 0.03
軟質小麥	Soft wheat	77.9 ± 1.8	11.0 ± 0.2	0.71 ± 0.01	0.86 ± 0.03
大麥	Barley	53.6 ± 1.0	19.4 ± 0.4	2.88 ± 0.04	2.31 ± 0.1
小米	Millet	67.4 ± 1.3	8.8 ± 0.1	1.82 ± 0.03	4.22 ± 0.2
裸麥	Rye	58.0 ± 1.0	13.3 ± 0.2	1.96 ± 0.03	2.53 ± 0.1
高粱	Sorghum	67.7 ± 1.2	12.1 ± 0.1	1.87 ± 0.03	3.32 ± 0.1

Table 2
Dietary fibers composition (% dry basis) of wheat flours and whole grain cereals

Cereal	Soluble dietary fiber	Resistant starch	Insoluble dietary fiber	Total dietary fiber
Hard wheat	1.61 ± 0.01	0.20 ± 0.02	2.98 ± 0.01	4.59 ± 0.21
Soft wheat	1.78 ± 0.01	0.55 ± 0.01	1.87 ± 0.01	3.65 ± 0.11
Barley	2.56 ± 0.03	0.23 ± 0.01	22.07 ± 0.41	24.63 ± 0.52
Millet	1.45 ± 0.01	1.96 ± 0.01	13.50 ± 0.32	14.95 ± 0.41
Rye	3.70 ± 0.02	0.20 ± 0.01	14.07 ± 0.23	17.77 ± 0.53
Sorghum	1.42 ± 0.01	1.77 ± 0.02	19.59 ± 0.41	21.01 ± 0.41

Table 3
Mineral composition (mg/kg) of wheat flours and whole cereal grains

Mineral	Hard wheat	Soft wheat	Barley	Millet	Rye	Sorghum
P	3498	977.6	4570	2879	3620	349.9
K	826.2	1225	4572	2798	3570	239.9
Mg	301.2	306.5	1971	1488	1328	187.7
Ca	159.5	202.2	736.2	508.6	348.7	27.3
Na	46.0	38.4	238.4	60.89	67.2	4.6
Zn	30.8	7.6	74.2	65.9	30.6	3.1
Fe	13.2	13.9	128.4	199.8	44.0	10.6
Mn	5.2	8.1	9.2	8.1	24.4	1.2
Cu	1.4	1.6	5.7	3.4	2.9	0.2
Cr	0.1	0.001	0.9	7.7	0.7	0.8

Relative standard deviation of minerals ranged from 1.5% to 4.9%.

Table 4
Total phenols content and antioxidant properties of wheat flours and whole grain cereals

Cereal	Total phenols as gallic acid equivalent (μg/g)	DPPH scavenging capacity at 10 min (μmole/g)	ABTS scavenging capacity at 3 min (μmole/g)
Hard wheat	562 ± 28.8	4.33 ± 0.17	8.8 ± 0.39
Soft wheat	501 ± 25.5	4.17 ± 0.17	8.3 ± 0.31
Barley	879 ± 24.0	21.00 ± 0.83	14.9 ± 0.61
Millet	1387 ± 13.3	23.83 ± 0.67	21.4 ± 0.43
Rye	1026 ± 16.9	12.17 ± 0.50	13.0 ± 0.48
Sorghum	4128 ± 9.3	195.8 ± 8.82	51.7 ± 0.57

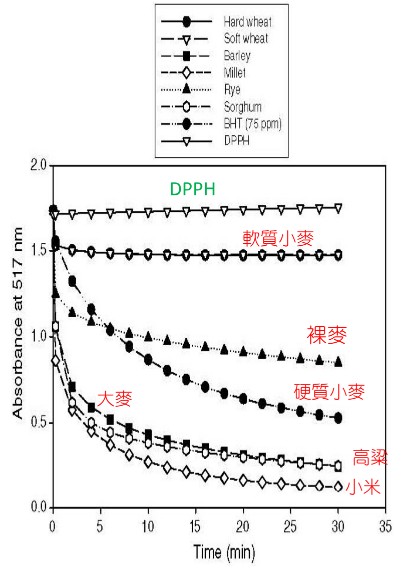


Fig. 1. Kinetics of DPPH radical with wheat flour extracts, cereal whole grain extracts and BHT.

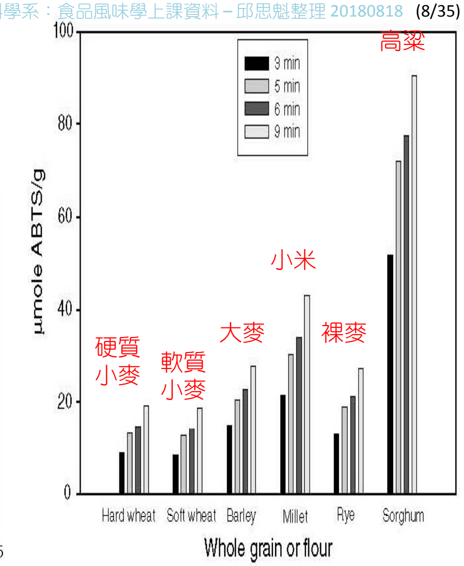


Fig. 2. Radical cation ABTS scavenging capacity of wheat flour and cereal whole grain extracts at different time.

Phenolic Compounds in Cereal Grains and Their Health Benefits

CEREAL FOODS WORLD, 52(3): 105-111, 2007

- 全穀類食品是酚類的很好來源。
- 黑高粱(black sorghums) 含高量的獨特的酚類：3-deoxyanthocyanidins。
- 燕麥是 avenanthramides 的唯一來源。
- 在穀物中，單寧高粱(tannin sorghum)和黑米(black rice)具有最高的抗氧化性(試管試驗)。

Table II. Phenolic acid content in cereal grains

Sample	酚類含量 (μg/g)	
Whole grains: 全穀物		
Barley	450–1346	大麥
Finger millet 小	612	龍爪稷
Foxtail millet 米	3907	狐尾粟
Maize	601	玉米
Oat	472	燕麥
Pearl millet	1478	珍珠粟
Rice	197–376	米
Rye	1362–1366	裸麥
Sorghum	385–746	高粱
Wheat	1342	小麥
Brans: 糠		
Oat	651	燕麥
Ryc	4190	裸麥
Wheat	4527	小麥

龍爪稷

狐尾粟

珍珠粟

Table IV. Anthocyanin content of pigmented cereal grains

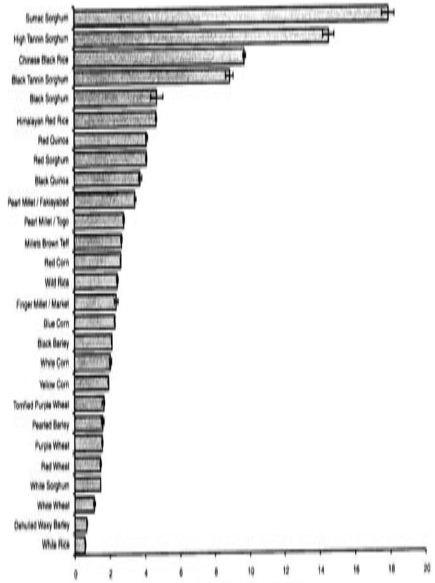
Sample	Amount (μg/g)
Blue barley[a]	4
Maize:[a]	
Pink	93
Red	558
Blue	225
Purple	965
Black rice[a]	2,283
Black sorghum[b]	944
Wheat:[a]	
Blue	106–153
Purple	13–139

[a] Data obtained from Abdel-Aal and coworkers (2).
[b] Rooney and coworkers (Cereal Quality Lab, Texas A&M University, College Station, TX, unpublished data).

Table V. Antioxidant activity (ORAC) of sorghum grains and brans compared to common fruits and vegetables[a]

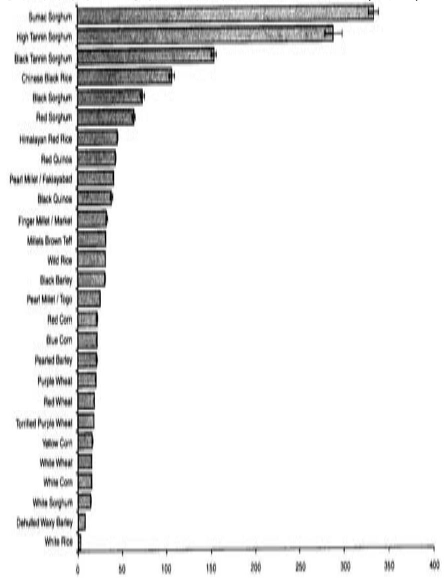
Commodity	ORAC (μmol TE/g, dry wt.)	
Tannin sorghum (grain)[b]	868	高粱穀物與糠
Tannin sorghum (bran)[b]	3124	
Black sorghum (grain)	219	
Black sorghum (bran)	1008	
Red sorghum (grain)	140	
Red sorghum (bran)	710	
White sorghum (grain)	22	
White sorghum (bran)	64	
Blueberry, lowbush	842	水果
Strawberry	402	
Plum	495	
Watermelon	18	
Apple, red delicious	295	
Orange, navel	137	
Broccoli	173	蔬菜
Carrot	108	
Onion, red	93	
Sweet pepper, green	105	
Radishes	217	
Potatoes, russet	63	

[a] Adapted from Dykes and Rooney [18].
[b] Sumac.



總酚含量(沒食子酸毫克當量/毫克)

Fig. 3. Total phenol levels of cereal grains. (Adapted from Guajardo-Flores and coworkers [25]).



抗氧化物活性(ABTS; Trolox毫當量/克)

Fig. 4. Antioxidant activity (ABTS) levels of cereal grains. (Adapted from Guajardo-Flores and coworkers [25]).

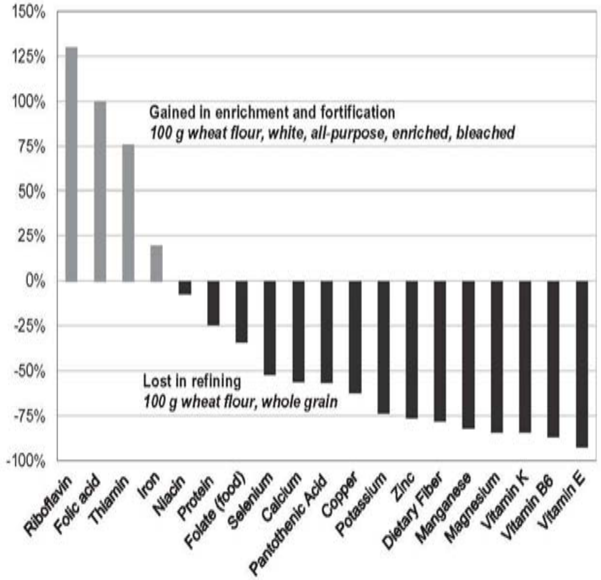


FIGURE 43.2 Percentage of nutrients lost or gained in the refining of wheat. Reprinted from McKeown et al. [62]. *Data source: U.S. Department of Agriculture* [117]. 小麥精製後營養素損失或增高的比率

常消費的全穀類16克中一些營養素的一般濃度

TABLE 43.1 Approximate Concentration of Selected Nutrients in One Serving (16g) of Commonly Consumed Whole Grains

	Wheat 小麥	Rye 裸麥	Oat 燕麥	Barley, Hulled 大麥脫殼	Corn, yellow 黃玉米	Rice, Long-Grain Brown 糙米長粒
Carbohydrate (g)	11.9	12.1	10.6	11.8	12.3	12.4
Fat (g)	0.3	0.3	1.1	0.4	0.6	0.5
Protein (g)	1.5	1.6	2.7	2.0	1.1	1.3
Total fiber (g)	2.1	2.4	1.7	2.8	1.2	0.6
Total fiber (% dry matter)	13.5	19.9	10.2	15.2	–	–
Arabinoxylan (% dry matter)	5.6	8.9	2.0	5.2	–	–
Cellulose (% dry matter)	2.5	2.9	1.3	1.9	–	–
β-glucan (% dry matter)	0.8	1.5	5.0	4.6	–	–
Fructan (% dry matter)	1.3	4.1	4.1	1.6	–	–
Thiamin (mg)	0.05	0.1	0.1	0.1	0.04	0.1
Riboflavin (mg)	0.03	0.04	0.02	0.05	0.01	0.01
Niacin (mg)	0.9	0.7	0.2	0.7	0.3	0.8
Vitamin B6 (mg)	0.03	0.05	0.02	0.1	0.1	0.1
Vitamin E (mg)	0.1	0.1	0.1	0.1	0.1	0.2
Magnesium (mg)	19	18	28	21	15	23
Iron (mg)	0.6	0.4	0.8	0.6	0.4	0.2

Sources: Frolich et al. [6] *and U.S. Department of Agriculture, Agricultural Research Service* [117].

from: *Food Chem., 152 (2014) 46-55*

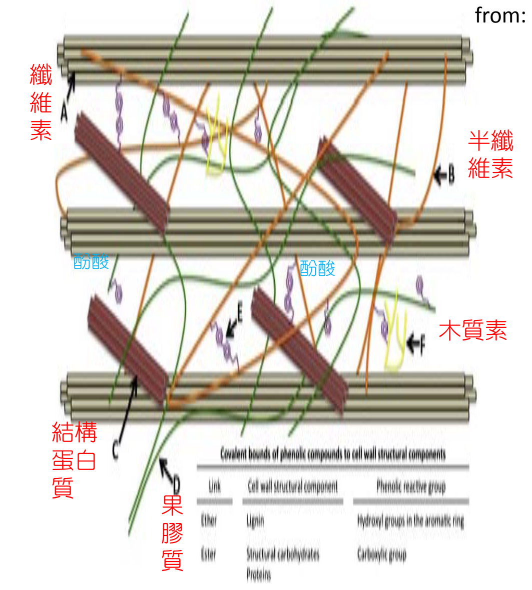
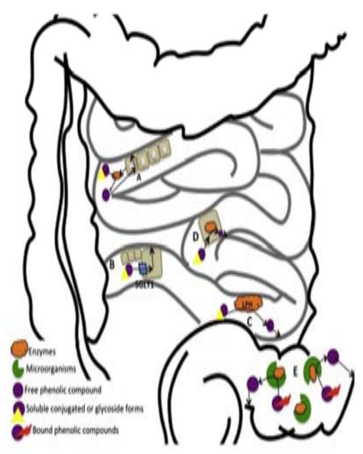


Fig. 1. Representations of primary cell wall structure of plant material and cross-linking between structural components and phenolic compounds. (A) Cellulose. (B) Hemicellulose. (C) Structural proteins. (D) Pectin. (E) Phenolic acids. (F) Lignin.



ig. 2. Absorption pathways of bound phenolic compounds in the gastrointestinal ract. (A) Hydrolysis of bound soluble conjugated forms by mucosa cells cinnamoyl esterases. (B) Soluble conjugated forms transport into enterocytes by the sodium-dependent glucose transporter SGLT1. (C) Lactase phloridzine hydrolase (LPH) (β-glycosidase) of the brush border hydrolysis soluble conjugated phenolic compounds. (D) Epithelial cells cytosolic β-glucosidase hydrolyzes glycosides, and aglycones are formed after absorption. (E) Esterase and xylanase activities of colon microorganism (e.g. *Clostridium spp., Eubacterium spp.,* and *Bifidobacterium adolescentis*).

Analyses of Free and Bound Phenolics in Rice： 21品種日本米

(*Food Sci Techonl Res.*, 5: 74-79, 1999)

Table 2. Free phenolics in rice. 游離態酚類

	Total phenolics (mg/100 g)	Ferulic acid (μg/100 g)	p-Coumaric acid (μg/100 g)
米糠 Rice bran	160.2±195.2	561.1±575.7	429.5±277.9
coefficient of variation (%)	121.8	102.6	64.7
ratios (%)		56.6	43.4
精白米 Polished rice	8.19±3.05	65.3±62.2	23.7±46.6
coefficient of variation (%)	37.2	95.2	196.6
ratios (%)		73.4	26.6
糙米 Brown rice	23.39±19.49	114.9±81.4	64.3±53.2
coefficient of variation (%)	83.3	70.8	82.7
ratios (%)		64.1	35.9

Contents are shown as mean±standard deviation (n=21). Ratio is shown as each phenolic in ferulic acid plus *p*-coumaric acid. Contents in brown rice were calculated from values of rice bran and polished rice. Total phenolics were estimated by Folin-Dennis method and each phenolic was determined by HPLC.

Table 4. Bound phenolics in rice. 結合態酚類

	Total phenolics (mg/100 g)	Ferulic acid (mg/100 g)	p-Coumaric acid (mg/100 g)	5,5′-Diferulic acid (mg/100 g)
Rice bran	1223±346	154.9±52.6	115.7±46.1	9.80±4.39
coefficient of variation (%)	28.3	34.0	39.8	44.8
ratios (%)		55.2	41.3	3.5
Polished rice	286.2±100.8	7.08±2.63	1.81±0.97	0.261±0.094
coefficient of variation (%)	35.2	37.1	53.6	36.0
ratios (%)		77.4	19.8	2.9
Brown rice	257.7±90.7	21.86±5.87	13.20±4.56	1.21±0.47
coefficient of variation (%)	35.2	26.8	34.5	38.8
ratios (%)		60.3	36.4	3.3

Contents are shown as mean±standard deviation (n=21). Ratio is shown as each phenolic in ferulic acid plus *p*-coumaric acid plus 5,5′-diferulic acid. Contents in brown rice were calculated from values of rice bran and polished rice. Total phenolics were estimated by Folin-Dennis method and each phenolic was determined by HPLC.

The Distribution of Phenolic Acids in Rice (*Food Chem., 87: 401-406, 2004*)

Table 3
The contents of bound and total phenolic acids in brown and milled rice cv. Koshihikari 越光米(4及37°C貯藏6個月)

Phenolic acid	Phenolic acid content (mg kg⁻¹ dry grain)[a]											
	Brown rice 糙米						Milled rice 精白米					
	Fresh		Stored (six months, 4 °C)		Stored (six months, 37 °C)		Fresh		Stored (six months, 4 °C)		Stored (six months, 37 °C)	
	Bound	Total	Bound	Total	Bound	Total	Bound	Total	Bound	Total	Bound	Total
Ferulic acid	259	289	224	255	202	214	58	71	38	66	36	55
p-Coumaric acid	82	85	70	70	59	62	8.9	9.5	5.9	8.9	5.5	8.0
Gallic acid	16	19	11	16	11	14	3.2	4.0	0.11	3.8	0.2	3.8
Vanillic acid	11	15	2.1	12	3.0	13	0.3	0.6	Tr[c]	0.2	Tr	0.2
Caffeic acid	2.7	3.5	2.1	3.9	2.0	2.2	0.2	0.2	Tr	Tr	Tr	Tr
Syringic acid	2.0	2.8	1.4	2.6	1.5	2.4	Tr	Tr	Tr	Tr	Tr	Tr
Sum	373	415	311	360	279	308	71	86	44	79	42	67
Ratio[b]	0.32		0.31	87%	0.29	74%	0.15		0.15	92%	0.15	78%

[a] Standard error for measurement of individual acids 5%.
[b] Ratio = *p*-coumaric acid content/ferulic acid content.

Table 4
The contents of bound and total phenolic acids in brown and milled rice cv. Kyeema

Phenolic acid	Phenolic acid content (mg kg⁻¹ dry grain)[a]											
	Brown rice						Milled rice					
	Fresh		Stored (six months, 4 °C)		Stored (six months, 37 °C)		Fresh		Stored (six months, 4 °C)		Stored (six months, 37 °C)	
	Bound	Total	Bound	Total	Bound	Total	Bound	Total	Bound	Total	Bound	Total
Ferulic acid	330	362	287	350	270	333	76	84	61	74	60	68
p-Coumaric acid	117	121	107	113	101	103	9.1	10	6.0	8.2	5.7	7.5
Gallic acid	22	30	5.7	27	6.0	23	6.5	7.1	Tr[c]	5.6	Tr	5.0
Vanillic acid	4.3	6.1	3.3	4.9	3.1	5.0	3.0	3.2	Tr	2.5	Tr	1.5
Caffeic acid	5.1	5.8	3.9	4.6	3.1	3.5	0.10	0.10	Tr	0.03	Tr	0.10
Syringic acid	3.7	4.0	1.5	3.1	1.7	2.9	0.10	0.10	Tr	0.10	Tr	0.10
Sum	482	528	408	502	385	470	95	105	67	90	66	82
Ratio[b]	0.35		0.37	95%	0.37	89%	0.12		0.10	86%	0.10	78%

[a] Standard error for measurement of individual acids 5%.
[b] Ratio = *p*-coumaric acid content/ferulic acid content.
[c] Tr, Trace.

Antioxidant activity of methanolic extracts from some grains consumed in Korea

(Choi, Y., Jeong, H.S., Lee, J., Food Chem., 103:130-138, 2007)

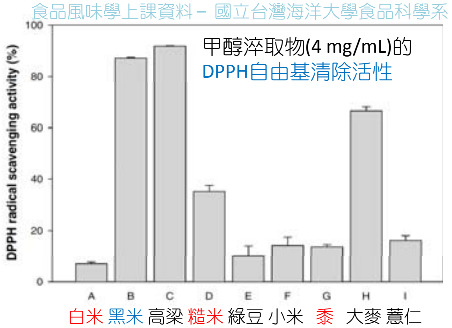
Table 1
Polyphenolics and total carotenoids contents of the methanolic extracts obtained from the grains and extraction yields

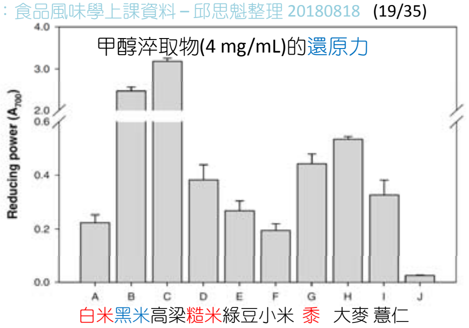
Source	Polyphenolics[a]	Total carotenoids[b]	Yield (%)
白米 White rice	18 ± 0.6	1 ± 0.5	2.3
Black rice 黑米	313 ± 31.5	77 ± 6.3	5.1
高粱 Sorghum	733 ± 48.4	22 ± 1.1	5.3
Brown rice 糙米	54 ± 2.2	14 ± 2.0	3.8
綠豆 Mungbean	45 ± 1.9	102 ± 3.7	6.1
Foxtail millet 狐尾粟	47 ± 1.4	80 ± 5.8	6.8
黍 Prosomillet	29 ± 1.2	74 ± 7.4	4.5
Barley 大麥	50 ± 2.9	15 ± 0.9	2.4
薏仁 Adlay	43 ± 2.0	10 ± 3.1	5.1

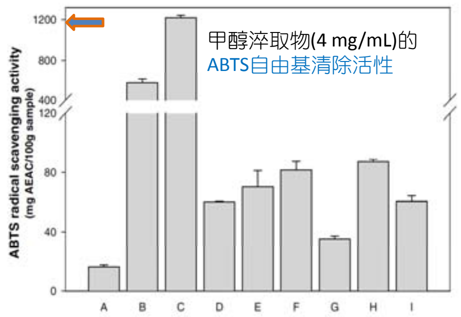
Table 2
Tocopherol and tocotrienol contents in the methanolic extracts obtained from the grains

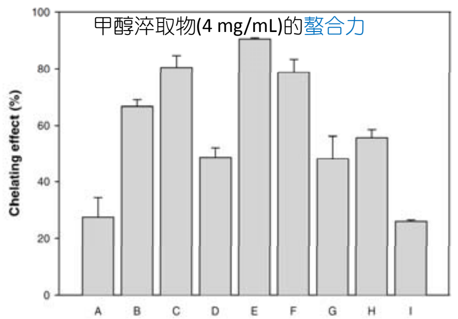
Sample[a]	α-T[b]	β-T	γ-T	δ-T	α-T3	β-T3	γ-T3	δ-T3	Total
White rice	0.07	–[c]	0.01	–	0.08	–	0.58	–	0.74
Black rice	1.24	–	0.25	3.86	1.38	–	2.64	–	9.37
Sorghum	0.14	–	1.33	0.02	0.21	–	0.08	0.01	1.79
Brown rice	0.42	–	0.12	0.00	0.56	–	1.54	–	2.64
Mungbean	0.05	–	9.78	0.70	0.04	–	0.32	0.03	10.92
Foxtail millet	0.06	–	2.62	0.04	0.05	–	0.57	–	3.34
Prosomillet	0.00	–	1.33	0.83	0.00	–	0.06	–	2.22
Barley	0.23	–	0.32	0.02	1.07	0.24	–	0.04	1.92
Adlay	0.02	–	1.67	0.16	0.09	–	1.31	0.17	3.42

[a] Mean of duplicate determinations expressed as mg per 100 g of grain (wet weight basis).
[b] Corresponding tocopherols and tocotrienols.
[c] Not detected.









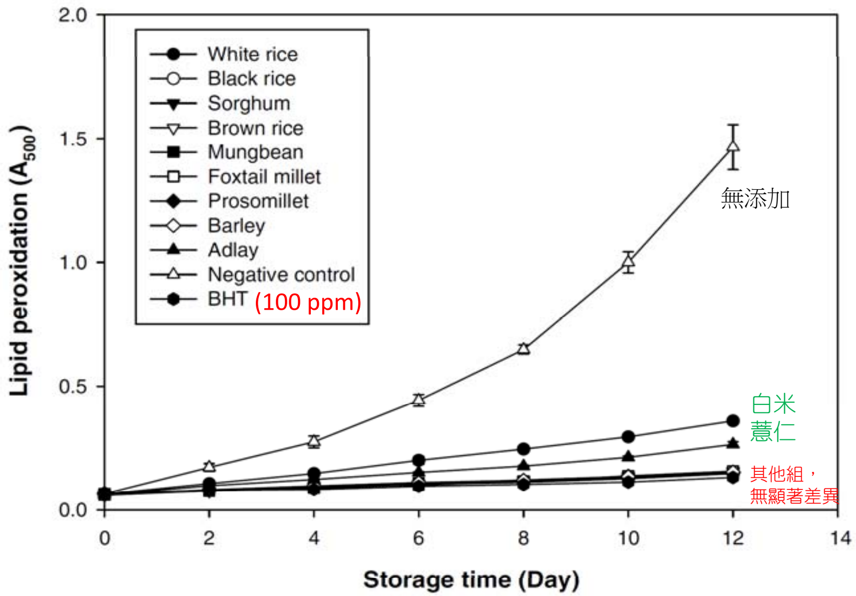
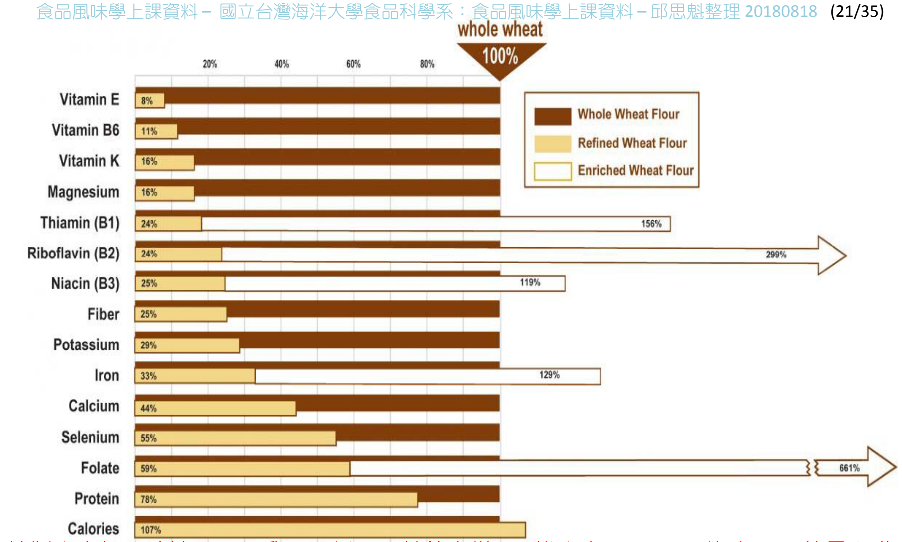


Fig. 5. Inhibition of lipid peroxidation of methanolic extracts (4 mg/ml) from grains.



精製小麥粉移除糠層及胚乳，降低必需營養素從8% (維生素E) 至59% (葉酸)，只熱量上升。

Refining wheat flour removes the bran and germ, decreasing essential nutrients to levels ranging from 8% (vitamin E) to 59% (folate) of the level naturally occurring in whole wheat. Only the calories increase!

Enriching wheat flour adds back five of these nutrients, in amounts different from their original levels in whole wheat flour. All other nutrients stay at the levels shown for refined flour above.

營養強化(enriched)小麥粉：回添5種營養素至全麥麵粉中的原存在量。

Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses.

Food Chem., 99 (2006) 191-203

Table 2
Phenolics content of selected fruits

Fruit	Total phenolics content	Reference
Apple	296.3 ± 6.4[a]	Sun et al. (2002)
Banana	90.4 ± 3.2[a]	Sun et al. (2002)
Banana	11.8 ± 0.4[a]	Luximon-Ramma et al. (2003)
Black plum	143.5 ± 40.6[b]	Karakaya et al. (2001).
Blackberry	417–555[a]	Sellappan et al. (2002)
Blackberry (*Rubus* species)	26.7–452.7[a]	Deighton et al. (2000).
Blueberry (rabbiteye)	270–930[a]	Sellappan et al. (2002)
Blueberry (Southern highbush)	261–585[a]	Sellappan et al. (2002)
Blueberry (*Vaccinium species*)	171–961[a]	Moyer et al. (2002)
Cherry	105.4 ± 27.0[b]	Karakaya et al. (2001).
Cranberry	527.2 ± 21.5[a]	Sun et al. (2002)
Guava (pink)	126.4 ± 6.0[a]	Luximon-Ramma et al. (2003)
Guava (white)	247.3 ± 4.5[a]	Luximon-Ramma et al. (2003)
Litchi (lichee)	3.35 ± 0.05[c]	Gorinstein et al. (1999)
Litchi (lichee)	28.8 ± 1.7[a]	Luximon-Ramma et al. (2003)
Mango	6.25 ± 0.05[c]	Gorinstein et al. (1999)
Mango	56.0 ± 2.1[a]	Luximon-Ramma et al. (2003)
Peach	84.6 ± 0.7[a]	Sun et al. (2002)
Papaya	57.6 ± 4.1[a]	Luximon-Ramma et al. (2003)
Persimmon	1.45[c]	Gorinstein et al. (1999)
Pineapple	94.3 ± 1.5[a]	Sun et al. (2002)
Pineapple	2.58 ± 0.05[c]	Gorinstein et al. (1999)
Plums	174–375[a]	Kim et al. (2003)
Prunes (pitted)	184.0 ± 85.5[a]	Donovan et al. (1998)
Raisins	399.4 ± 57.6[b]	Karakaya et al. (2001).
Rambutan	1.64 ± 0.04[c]	Gorinstein et al. (1999)
Raspberry	114–178[a]	de Ancos et al. (2000)
Red grape	220.6 ± 61.2[c]	Karakaya et al. (2001).
Red grape	201.0 ± 2.9[a]	Sun et al. (2002)
Starfruit (acidic)	142.9 ± 7.1[a]	Luximon-Ramma et al. (2003)
Starfruit (sweet)	209.9 ± 10.4[a]	Luximon-Ramma et al. (2003)
Strawberry	161–290[a]	Heinonen et al. (1998)
Strawberry	160 ± 1.2[a]	Sun et al. (2002)

[a] Gallic acid equivalents/100 g fresh weight.
[b] Catechin equivalents/100 g fresh weight.
[c] Chlorogenic acid equivalents/100 g fresh weight.

Table 3
Phenolics content of selected vegetables

Vegetable	Total phenolics content	Reference
Broccoli	101.6 ± 1.24[a]	Chu et al. (2002)
	87.5 ± 8.1[b]	Kaur and Kapoor (2002)
Brussel sprouts	68.8 ± 1.3[b]	Kaur and Kapoor (2002)
Cabbage	54.6 ± 7.0[a]	Chu et al. (2002)
	92.5 ± 2.4[b]	Kaur and Kapoor (2002)
Carrot	56.4 ± 5.1[a]	Chu et al. (2002)
	55.0 ± 0.9[b]	Kaur and Kapoor (2002)
Cucumber	19.5 ± 1.6[a]	Chu et al. (2002)
	48.0 ± 0.9[b]	Kaur and Kapoor (2002)
Mint	399.8 ± 3.2[b]	Kaur and Kapoor (2002)
Spinach	91.0 ± 8.5[a]	Chu et al. (2002)
Tomato	25.9 – 50.0[c]	Martínez-Valverde et al. (2002)
	68.0 ± 1.6[b]	Kaur and Kapoor (2002)
Vidalia onion varieties	73.3–180.8[a]	Sellappan and Akoh (2002)
Yellow onion	76.3 ± 1.9[a]	Chu et al. (2002)

[a] Gallic acid equivalents/100 g fresh weight.
[b] Catechin equivalents/100 g fresh weight.
[c] Ferulic acid equivalents/100 g fresh weight.

Table 4
Phenolic content of some fruit juices

Juice	Total phenolics content	Reference
Commercial juices		
Apple	339 ± 43[a]	Gardner et al. (2000)
Grapefruit	535 ± 11[a]	Gardner et al. (2000)
Orange	755 ± 18[a]	Gardner et al. (2000)
Pineapple	358 ± 3[a]	Gardner et al., 2000
Prune	441 ± 59[b]	Donovan et al. (1998)
Fresh juices		
Grape (red)	1728[a]	Sánchez-Moreno et al. (1999)
Grape (white)	519[a]	Sánchez-Moreno et al. (1999)
Orange	382–1147[b]	Rapisarda et al. (1999)

[a] mg gallic acid equivalents/ L.
[b] mg ferulic acid equivalents/L.

Table 5
Phenolic content of teas and coffee

Beverage, type	Total phenolics content[a]	Reference
Tea		
Black tea	80.5–134.9	Khokhar and Magnusdottir (2002)
Black tea	154.9–162.9	Lakenbrink et al. (2000)
Black tea	62–107	Luximon-Ramma et al. (2005)
Green tea	65.8–106.2	Khokhar and Magnusdottir (2002)
Green tea	117.3	Samman et al. (2001)
Green tea	61–200	Schulz et al. (1999)
Coffee		
Instant coffee	146–151	Lakenbrink et al. (2000)
Ground coffee	52.5–57.0	Lakenbrink et al. (2000)

[a] mg gallic acid equivalents/g dry matter.

Table 6
Phenolic content of different wines

Colour, region, country	Total phenolics content[a]	Reference
Red wines		
Argentine	1593–1637	Sánchez-Moreno et al. (2003)
Brazilian	1947–1984	Minussi et al. (2003)
Californian	1800–4059	Frankel et al. (1995)
Chilean	2133	Minussi et al. (2003)
French	1847–2600	Teissedre and Landrault (2000)
French	1018–3545	Landrault et al. (2001)
Greek	1217–3722	Arnous et al. (2001)
Italian	3314–4177	Minussi et al. (2003)
Japanese	1810–2151	Sato et al. (1996)
Portuguese	1615	Minussi et al. (2003)
Spanish	1869	Sánchez-Moreno et al. (1999)
White wines		
Argentine	216	Minussi et al. (2003)
Brazilian	256–353	Minussi et al. (2003)
Californian	165–331	Frankel et al. (1995)
Californian	220–306	Sánchez-Moreno et al. (2003)
French	245	Teissedre and Landrault (2000)
French	262–1425	Landrault et al. (2001)
Italian	439–854	Minussi et al. (2003)
Italian	191–296	Sánchez-Moreno et al. (2003)
Japanese	295–556	Sato et al. (1996)
Spanish	292	Sánchez-Moreno et al. (1999)
Rose wines		
Italian	1304	Minussi et al. (2003)
Japanese	340	Sato et al. (1996)

[a] mg gallic acid equivalents/L.

Table 7
Phenolic compounds from agricultural by-products

By-product	Phenolic compounds	Levels[a]	Reference
Almond [*Prunus dulcis* (Mill.) D.A. Webb] hulls	Chlorogenic acid	42.52 ± 4.50 mg/100 g fw	Takeoka and Dao (2002)
	4-*O*-Caffeoylquinic acid	7.90 mg/100 g fw	
	3-*O*-Caffeoylquinic acid	3.04 mg/100 g fw	
Apple peels	Flavonoids	2299 mg CE/100 g dw	Wolfe and Liu (2003)
	Anthocyanin	169 mg CGE/100 g dw	
Artichoke blanching waters	Neochlorogenic acid	11.3 g phenolics/100 mL	Llorach et al. (2002)
	Cryptochlorogenic acid		
	Chlorogenic acid		
	Cynarin		
	Caffeic acid derivatives		
Buckwheat (*Fagopyrum esculentum* Möench) hulls	Protocatechuic acid	13.4 mg/100 mg dw	Watanabe et al. (1997)
	3,4-Dihydroxybenzaldehyde	6.1 mg/100 g dw	
	Hyperin	5.0 mg/100 g dw	
	Rutin	4.3 mg/100 g dw	
	Quercetin	2.5 mg/100 g dw	
Dried apple pomace	Flavonols	673 mg/kg dw	Schieber et al. (2003)
	Flavanols	318 mg/kg dw	
	Dihydrochalcones	861 mg/kg dw	
	Hydroxycinnamates	562 mg/kg dw	
Dried coconut husk	4-Hydroxybenzoic acid ferulic acid	13.0 mg phenolics/g dry weight	Dey et al. (2003)

[a] Expressed on fresh weight (fw) or dry weight (dw) basis.

Antioxidant activities of extracts from selected culinary herbs and spices (*Food Chem., 97: 122-129*)

Table 1

Characterization of the plant material and extraction yield for hydrodistilled extracts 水萃取

Spice 乾燥原料	Botanical family	Extraction yield (mg/g)	Total phenols (mg GA/g)
Basil (*Ocimum basilicum*) 羅勒(九層塔)	Lamiaceae	246	➡ 147 ± 1.60a
Parsley (*Petroselinum crispum*) 荷蘭芹	Apiaceae	196	29.2 ± 0.44b,c
Laurel (*Laurum nobilis*) 月桂	Lauraceae	258	➡ 92.0 ± 2.45d
Juniper (*Juniperus communis*) 杜松	Cupressaceae	422	18.5 ± 0.62e
Cardamom (*Elettaria cardamomum*) 荳蔻	Zingiberaceae	88	24.2 ± 0.29b,f
Ginger (*Zingiber officinalis*) 薑	Zingiberaceae	302	23.5 ± 1.26b,e
Aniseed (*Pimpinella anisum*) 八角	Apiaceae	230	20.8 ± 0.62e,f
Fennel (*Foeniculum vulgare*) 茴香	Apiaceae	216	30.3 ± 0.76c
Cumin (*Carum carvi*) 孜然	Apiaceae	242	37.4 ± 0.32g

Lines with the same lowercase letter are not significantly different for total phenols ($P > 0.05$).

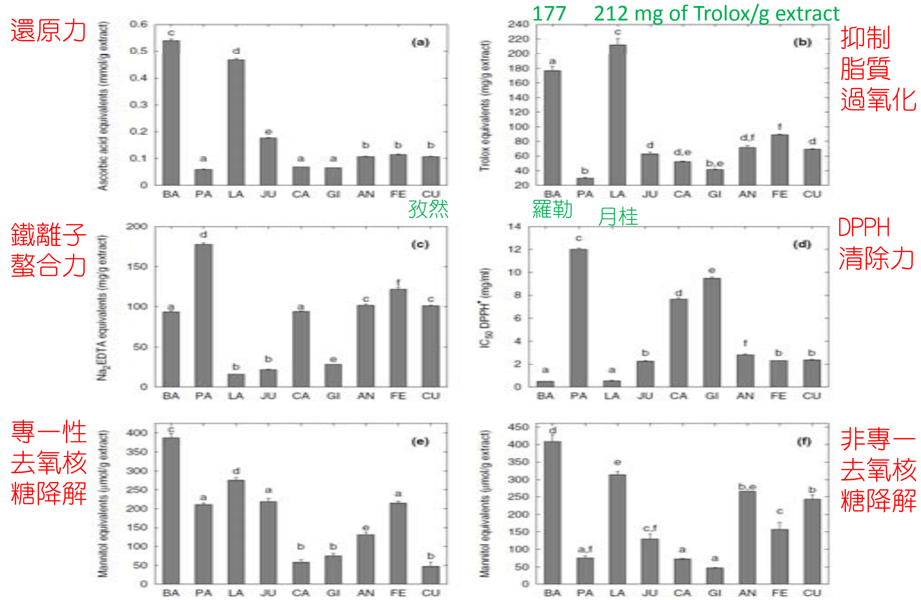


Fig. 1. Antioxidant activity of spice extracts in iron reduction (a), in lipid peroxidation (b), in iron chelation (c), against DPPH· (d), in site-specific (e) as well as nonsite-specific (f) deoxyribose degradation assay. BA, basil; PA, parsley; LA, laurel; JU, juniper; CA, cardamom; GI, ginger; AN, aniseed; FE, fennel; CU, cumin. Bars with the same lowercase letter are not significantly different ($P > 0.05$).

Flavors of the future: Health benefits of flavor precursors and volatile compounds in plant foods- Review

(Trends in Food Sci. & Technol., 48: 69-77, 2016)

背景：Consumers' food production requirements have changed considerably during the last decade. This includes growing interest in the use of aroma compounds to develop functional foods for providing health benefits and reducing chemically synthesized additives. More recently, beyond their flavoring properties, various reports have shown the potential role of volatile compounds in human health, including their antioxidant, anti-inflammatory, anti-cancer and anti-obesity activities. Thus, investigation into the pharmacological activities of flavor and volatile compounds has been increased.

Table 1

Promising health benefits of volatile and non-volatile compounds.

Compounds	Example sources	Taste/odor description	Promising health benefits	References
Chlorogenic acids 綠原酸	Coffee, blueberry, papaya, mango, wine, grape, yerba mate, apple juice, arnica flower	Bitter	Anti-obesity, anti-diabetic, antimicrobial activity, natural phytoestrogen	Allred et al. (2009); Flanagan et al. (2014); Ozçelik et al. (2011); Rempe et al. (2015); Shin et al. (2015); Van Dam (2006)
Trigonelline 葫蘆巴鹼	Coffee, fenugreek 咖啡 葫蘆巴	Bitter	Anti-cancer, memory enhancer, antimicrobial activity	Antonio et al. (2010); Meghwal and Goswami (2012); Ozçelik et al. (2011); Tohda et al. (2005)
6-Gingerol 6-薑酚	Ginger 薑	Pungent	Anti-obesity	Tzeng, Chang, and Liu (2014)
8-Prenylnaringenin 8-異戊烯基柚皮素	Hops 啤酒花	Bitter	Reducing hot flushes during menapouse	Keiler et al. (2013)
Naringin 柚皮苷	Citrus	Bitter	Inhibits bone loss, improves bone density	Fan, Ji, and Fan (2015)
Picrocrocin 番紅花苦苷	Saffron 番紅花	Bitter	Antioxidant, neurodegenerative disease	Akowuah and Htar (2014); Rahaiee et al. (2015)
白藜蘆醇 Resveratrol	Red grape	Astringent	Cardivascular, anti-obesity	Singh, Liu, and Ahmad (2015)
Geraniol 香葉醇	Rose flowers, apricot, peach, hops, bergamot 佛手柑	Floral	Neurodegenerative disease anti-inflammatory	Rekha et al. (2013)
Raspberry ketone 覆盆子酮 稀酮素	Raspberry 覆盆子	Raspberry	Anti-obesity, bone formation, liver protection	Lopez et al. (2013); Park (2015); Takata and Morimoto (2014); Wang, Meng, and Zhang (2012)
Linalol 芳樟醇	Orange, hops	Citrus, floral	Anti-inflammatory	Li et al. (2015)

□英國科學家最近發現，啤酒中含有一種**8-prenylnaringenin**化學物質，會限制精子的繁殖力。

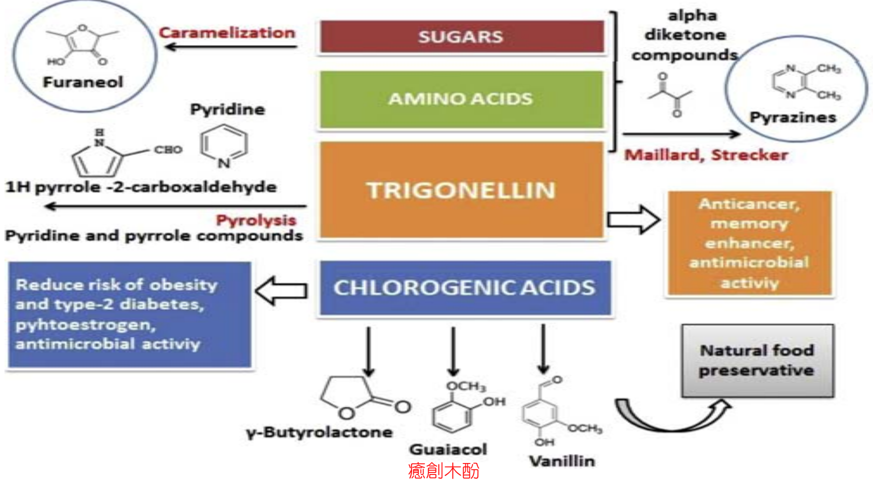


圖1 ：烘焙咖啡的風味形成與健康益處。風味前驅物如綠原酸及葫蘆巴鹼顯著貢獻於咖啡的風味，兩成分的攝取和疾病的低發生率也有關連，譬如第二型糖尿病、癌症、肥胖與其他慢性病。另外，為解決細菌的抵抗性，尋找新抗菌物質愈形重要，有趣的是，綠原酸及葫蘆巴鹼都具有抗菌性。

除了營養上的益處，類胡蘿蔔素carotenoids 是水果和蔬菜例如番茄、西瓜和番紅花中的重要風味前驅物。

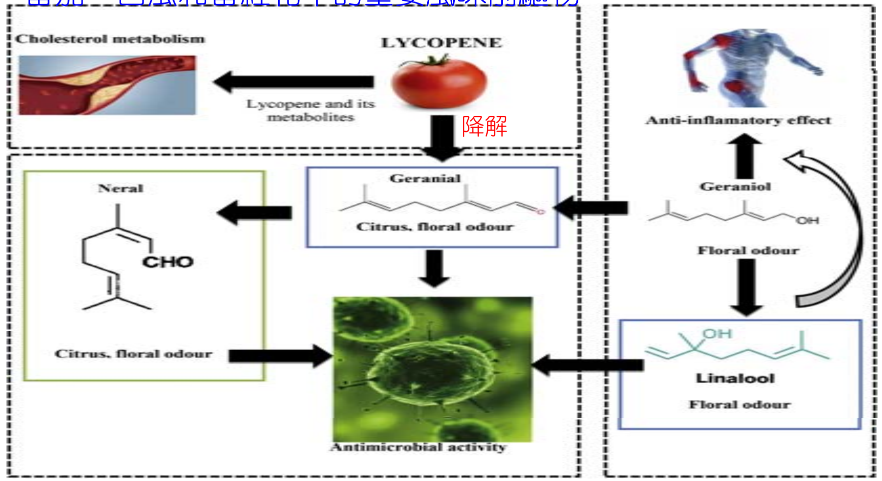


Fig. 3. Overview of aroma compounds formation in tomato and their benefits as natural antimicrobial agents. (Arathi et al., 2015; Davidovich-Rikanati et al., 2007; Keiler et al., 2013; Li et al., 2015; Selli et al., 2014).

Table 2 植物食品中揮發性化合物的氣味描述和抗菌性質

Antimicrobial properties and odor decriptions of volatile compounds in plant foods.

Volatile compounds	Odor descriptions	Example sources	Antimicrobial effect agnist	References
(*E*)-2-hexenal, hexanal	Green-grass like	Tomato fruit and leaf, hops, raspberry, guava, pomegranate	*B. subtilis, B. ammoniagenes, E. aerogenes, E. coli, C. utilis, P. acnes, P. aeruginosa, P. vulgaris, P. chrysogenum, S. aurew, S. mutans, T. mentagrophytes*	Belletti et al. (2007); Fadida et al. (2015); Lanciotti et al. (2004)
Hexyl acetate	Green	Raspberry, tomato	*E. coli, L. monocytogenes, S. enteritidis,*	Lanciotti et al. (2004)
Neral, geranial	Floral, citrus	Citrus, tomato, hops, lemon balm	*E. coli, P. aeruginosa, S. aureus, C. albicans*	Belletti et al. (2007); Boulogne et al. (2012)
Vanillin	Vanillin like	Vanilla, coffee, cherry tomato	*E. coli, L. plantarum, L. innocua,*	Ayala-Zavala et al. (2009); Fitzgerald et al. (2004); Xavier et al. (2015)
Terpinen-4-ol	Musty	Hops, ginger, tea tree	*E. faecalis, P. aeruginosa, E. coli, H. influenzae, S. pyogenes, S. pneumoniae*	Ayala-Zavala et al. (2009); Boulogne et al. (2012); Carson et al. (2006)
Linalool, α-terpineol	Citrus, floral	Hops, beer, tea olive, citrus essential oil, raspberry, coffee	*A. flavus, A. niger, A. actinomycetemcomitans, B. cereus, E. faecalis, E. coli, E. faecalis, F. nucleatum, K. pneumoniae, L. monocytogenes, P. corylophilum, P. aeruginosa, P. gingivalis, P. intermedia, S. aureus,*	Ayala-Zavala et al. (2009); Boulogne et al. (2012); Park et al. (2012); Schwab et al. (2008)

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Trends in Food Science & Technology 16 (2005) 407–415

TRENDS IN FOOD SCIENCE & TECHNOLOGY

Review

Not just colors—carotenoid degradation as a link between pigmentation and aroma in tomato and watermelon fruit

Efraim Lewinsohn[a]*, Yaron Sitrit[b], Einat Bar[a], Yaniv Azulay[a], Mwafaq Ibdah[a], Ayala Meir[a], Emanuel Yosef[bc], Dani Zamir[d] and Yaakov Tadmor[a]

Several lines of evidence indicate that important fruit aroma volatiles are derived from the degradation of carotenoid pigments. One such compound, lycopene, the major pigment in the red varieties of tomato and watermelon, gives rise, to a number of aroma volatiles including geranial, a lemon-scented monoterpene aldehyde. Various tomato and watermelon varieties and transgenic and near-isogenic tomato lines that range in color from yellow through orange to pink and red differ markedly in their carotenoid profiles. These variations are accompanied by differences in the compositions of terpenoid volatiles and hence in their taste.

Fruit color

Carotenoids are among the most important pigments that accumulate in fruits. In addition to their key role as accessory photosynthetic pigments harvesting light and preventing photo-oxidative damage, carotenoids serve as coloring agents in fruits and flowers. It is now generally accepted that carotenoids, being antioxidants and vitamin A precursors, exhibit many health-promoting activities, including lowering blood pressure and preventing heart disease (Baker & Gunther, 2004; Smidt & Burke, 2004; Zhang, Nara, Ono, & Nagao, 2003). The carotenoid lycopene does not normally accumulate in plant tissues,

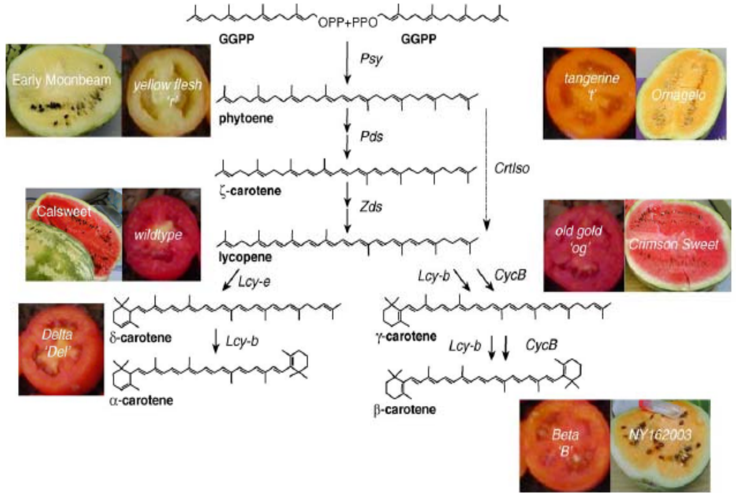

Fig. 2. Tomato and watermelon fruit color mutants and their biosynthetic pathways. Adapted from Hirschberg (2001) and Tadmor *et al.* (submitted).

野生種番茄的類胡蘿蔔素，非環狀的 lycopene 約85%，雙環狀的 β –carotene ＜10%；植物分類上不同，典型的紅西瓜(類胡蘿蔔素組成 lycopene 95%及 β –carotene 5%) 類似於野生種番茄。

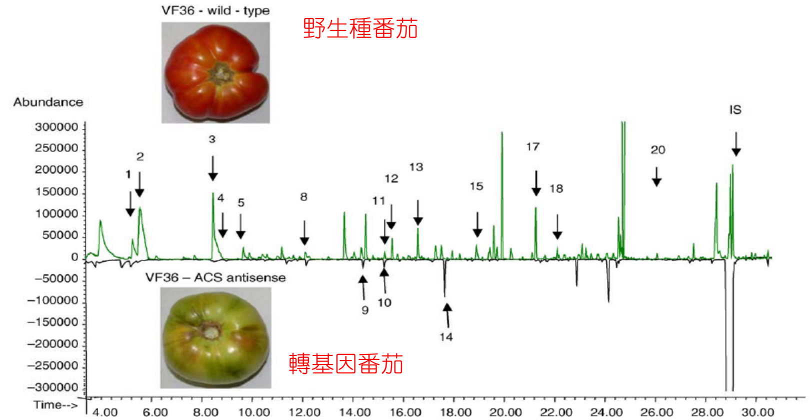

Fig. 1. Analysis of volatiles from VF36 (wild-type) and ACS-silenced transgenic tomatoes. Tomato fruits were extracted with methyl-*tert*-butyl ether and analyzed by GC–MS as described in Lewinsohn *et al.* (2001). The following compounds were identified: (1) *cis*-3-hexen-1-ol; (2) 1-hexanol; (3) 6 methyl-5-hepten-2-one; (4) furan; (5) limonene; (6) guaiacol (7) 2-isobutyl thiazole; (8) phenyl ethyl alcohol; (9) methyl salicylate; (10) 4 vinylphenol; (11) neral; (12) 2,3 epoxy geranial; (13) geranial; (14) 2-methoxy-4-vinylphenol; (15) eugenol; (16) 4-hydroxy benzeneethanol; (17) geranyl acetone; (18) β-ionone; (19) homovanillic acid and (20) farnesyl acetone. (IS) Internal standard–ethyl myristate.

- 轉基因番茄：乙烯合成少，保持綠色，無法正常熟成如野生種，香氣亦受影響。野生種存在的大部分揮發物在轉基因種都不存在，包括 norisoprene 及 monoterpene 化合物，反之，綠色未熟野生種存在的 guaiacol 及 methyl salicylate，是成熟轉基因種的主要成分。部份歸因於欠缺類胡蘿蔔素。

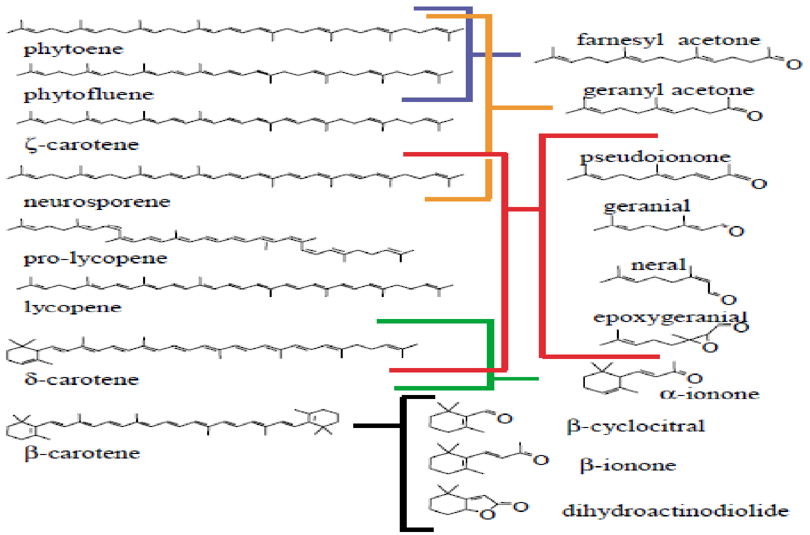

Fig. 4. Tomato and watermelon norisoprenes and their putative precursors. Genetic evidence indicates that carotenoids (left) are degraded into their respective norisoprene and monoterpene aroma volatiles (right). (Modified from Lewinsohn *et al.*, 2005.)