Supplementary Information 1: LC-MS Analysis of Rice Samples

Chemicals and Standards

Fifteen compounds were using as reference standards in the LC-MS, along with their corresponding Chemical Abstracts Service (CAS) numbers presented in parentheses, as following; cyanidin-3-o-glucoside chloride (7084-24-4), cyanidin-3-o-rutinoside chloride (18719-76-1), peonidin-3-o-glucoside chloride (6909-39-4), delphinidin-3-o-glucoside chloride (6906-38-3), cyanidin chloride (528-58-5), peonidin chloride (134-01-0) (Biosynth Ltd, Comptom, UK), protocatechuic acid (99-50-3), 4 hydroxybenzoic acid (99-96-7), 2,4,6 trihydroxybenzaldehyde (487-70-7), vanillic acid (121-34-6), p-coumaric acid (501-98-4), sinapic acid (530-59-6), ferulic acid (1135-24-6), quercetin (117-39-5), and diosmin (520-27-4) (Sigma-Aldrich, Gillingham, UK). For extraction and analysis, LC-MS grade acetonitrile, methanol, water, hydrochloric acid, and formic acid were purchased from Fisher Chemical™ (Leicestershire, UK).

Sample extraction, preparation, and standard solutions

One hundred grams of raw rice was rinsed with cold tap water and drained using a strainer. The rinsed rice was then placed in a rice cooker, and 300 ml of water was added before giving the mixture a quick stir. The rice cooker was switched on, allowing the rice to cook for approximately 35 minutes at 100°C. After cooking, the rice was left to cool for five minutes. Cooked black and brown rice samples were lyophilized using a freeze dryer, ground using an electric grinder, and sieved through a 60-mesh.

For the extraction, 0.25 g of rice powder was extracted in triplicate with 4 mL of methanol acidified with 1.0 N HCl (85:15, v/v). The mixtures were vigorously mixed by vortex for 2 min, sonicated at 25 °C for 15 min, and then centrifuged at 3,500 × g for 15 min. The

supernatants were combined and divided equally into 10 Eppendorf tubes, then evaporated using a SpeedVac concentrator (Thermo Scientific/Savant, Model SPD131DDA) and stored at −20 °C for further analysis. For LC-MS analysis, A tube of crude extract was reconstituted by 1 mL of 70% methanol containing 5% formic acid (95:5, v/v) and filtered through a 0.45 μm PTFE syringe filter (Fisher Scientific, Loughborough, UK). The samples were freshly diluted on the day of analysis using 70% methanol containing 5% formic acid (95:5, v/v) to achieve concentration within a measurable range for an analytical assay, and replicates were prepared for each sample.

For standard preparation, each of the 15 reference compounds was dissolved in 80% methanol at a stock concentration of 200 μg/mL, except for vanillic acid and 3,4-dihydroxybenzoic acid, which were dissolved at concentration of 1 mg/mL concentration. The standard solutions were aliquoted into Eppendorf tubes and stored at -80 °C. Equal volumes of each standard solution were mixed and diluted with 70% methanol containing 5% formic acid (95:5, v/v) to create ten-point calibration curves covering concentrations from 0.0195 to 10 μg/mL, except for vanillic acid and 3,4-dihydroxybenzoic acid, which covered concentrations from 0.195 to 100 μg/mL.

Instrumental conditions

LC-MS analysis was performed on a Shimadzu Nexera X2 series UHPLC, coupled with an 8050 triple quadrupole mass spectrometer system (LCMS-8050; Shimadzu, Kyoto, Japan). Separation of standards and samples was achieved using an ACQUITY UPLC HSS T3 column (100 × 2.1 mm, 1.8 μm) with an ACQUITY in-line filter (Waters, Milford, MA, USA) at a column temperature of 40 °C, with a flow rate of 0.5 mL/min.

The mobile phase consisted of two components: 0.1% formic acid in water (Mobile Phase A) and 0.1% formic acid in acetonitrile (Mobile Phase B). The system operated under a back pressure of 710 bars to maintain a steady flow rate and efficient separation. A fifteen-minute run was the following gradient timetable: at 2.00, 12.00,14.50 min, the B concentration was 5%, 64% and 95%, respectively and it returned to 5% at 17.00 min, which also marked the stop command. This gradient ensured the proper elution of polyphenols from the column within the specified run time. The LC stop time was set at 17.00 min for all acquisition times to ensure consistent data collection across all samples. The analysis was performed using an Electrospray Ionization (ESI) interface under the following conditions: nebulizing gas flow of 3 L/min, heating gas flow of 10 L/min, interface temperature of 400 °C, desolvation temperature of 550 °C, DL temperature of 150 °C, and drying gas flow of 10 L/min. The autosampler pretreatment was disabled, with no overlap time applied. The column oven was maintained at 30 °C, with a maximum allowable temperature of 90 °C to ensure optimal separation. Prior to each run, the column was checked to ensure system reliability and the accuracy of the data. The system operated in binary gradient mode with a total flow rate of 0.6000 mL/min, a Pump B starting concentration of 5.0%, and a Pump B curve set to 0. The setup included Pump A and Pump B (both LC-30AD models) and a solenoid valve FCV-11ALS (Valve A: 1). Pressure limits for both pumps were maintained with a maximum of 1200 bar and a minimum of 50 bar. The retention times and LC-MS analytical profile of anthocyanins and phenolic acids in samples are presented in Table S1.

Compound	RT (min)	Content (mg/100 g DW)		Content (mg/100g DW)	
		Raw black rice	Raw brown rice	Cooked black rice	Cooked brown rice
Cyanidin-3-O-glucoside	4.725	445.98 ± 9.91	ND	212.94 ± 13.33	ND
Cyanidin-3-O-rutinoside	4.84	1.33 ± 0.09	ND	0.53 ± 0.04	ND
Peonidin-3-O-glucoside	5.135	31.44 ± 3.81	ND	16.42 ± 1.93	ND
Delphinidin-3-glucoside	4.372	ND	ND	ND	ND
Cyanidin chloride	5.72	2.27 ± 0.13	ND	2.47 ±0.10	ND
Peonidin chloride	6.228	ND	ND	ND	ND
Protocatechuic acid	2.962	15.84 ± 1.17	ND	49.02 ± 3.96	ND
Vanilic acid	4.846	3.60 ± 0.37	ND	8.83 ± 0.57	ND
4 hydroxybenzoic acid	4.1	ND	ND	ND	ND
Ferulic acid	6.119	ND	ND	ND	ND
P-coumaric acid	5.784	ND	ND	ND	ND
Sinapic acid	6.16	ND	ND	ND	ND
Quercetin	7.904	1.60 ± 0.03	ND	0.84 ± 0.07	ND
2,4,6 trihydroxybenzaldehyde	5.520	ND	ND	ND	ND
Diosmin	6.602	ND	ND	ND	ND

Table S1 LC-MS analytical profile of anthocyanins and phenolic acids in black and brown rice samples.

ND = not detected.

Supplementary Information 2: cognitive task description and scoring

The standardized cognitive assessments were administered using computerized versions via the online Gorilla platform, with the exception of the Digit Symbol Substitution Task (DSST), which was conducted using a paper-based format as detailed below.

1. **Rey Auditory Verbal Learning Test (RAVLT):** this task was used for measuring short-term, episodic memory through immediate and delayed recalls of a list of 15 words. RAVLT consists of 5 consecutive free recalls of the same 15 nouns presented as an auditory list (list A), followed by recall of a further 15 nouns presented as an interference list (list B), which is recalled only once. For immediate recall, the volunteers listened to an auditory list of 15 words (list A). After 15 words were presented, participants were asked to say aloud as many words as they could recall in any order. This session was repeated five times, with participants typically taking approximately one minute for each repetition. Then, the participants listened to an auditory list of 15 words (list B) and were asked to say aloud each word as many times as they could recall in any order. After this, they were asked again to repeat as many words in list A as they could recall, and the participants completed other cognitive tasks in the test battery. For delayed recall, this session was set as the final assessment (at least 30 min from immediate recall). The task will involve an attempt to orally recall the words presented during Immediate Word Recall (list A). The volunteers were asked again to recall as many words as they can remember in any order. The primary dependent variable for each recall task was the number of words correctly recalled, including immediate recall (recall after the 1st trial), final recall (recall after the 5th trial), total recall (averaged number of correct words of five trials), amount learned (difference between final and immediate recall), proactive interference (difference between recall of interfering words and immediate recall), retroactive interference (difference between final recall and recall after

interference), and delayed recall (recall after 20 minutes). Due to the crossover nature of the study design, multiple word lists were presented across different test sessions.

2. Digit span forward: this task was used to assess working memory. Briefly, participants were presented with a sequence of digits (0–9) on a screen at a rate of one per 1.5 seconds and were required to recall them in the same order by pressing numbers on the keyboard. The sequence starts with a two-digit span length, and each digit span length has two trials. The span size increased in length after completing responses from two to nine digits in span length. The score is the maximum number of correct digits in both trials, prior to failing two consecutive trials at any one span size.

3. Digit span backward: this task was used to assess working memory and executive function. Briefly, participants were presented with a sequence of digits (0–9) on a screen at a rate of one per 1.5 seconds and were required to recall them in reverse order by pressing numbers on the keyboard. The sequence starts with a two-digit span length, and each digit span length has two trials. The span size increased in length after completed responses from two eight-digit span lengths. The score is the maximum number of correct digits in both trials, prior to failing two consecutive trials at any one span size.

4. Stoop Task: this task was used to assess attention and executive function. The volunteers were presented with the words 'GREEN,' 'BLUE,' 'RED,' and 'YELLOW,' which were displayed either in the same color ink as the meaning of the word (congruent trials) or in a color inconsistent with the meaning of the word (incongruent trials). The participants were instructed to respond to the color in which the word is presented rather than the meaning of the word by pressing a corresponding key on the keyboard. There were 96 trials in total, and the task lasted for approximately four minutes. The outcome was reported as the Stroop Effect, which means retention time (RT) incongruent − mean RT congruent

5. Word Recognition: This task was used to assess delayed memory or recognition. Volunteers were shown a sequential list of 50 nouns consisting of words from List A and List B (previously presented in the RAVLT task), plus 20 additional novel words not previously heard. Participants were instructed to indicate whether they had encountered each word previously by pressing a key corresponding to "Yes" for words from List A (previously learned) or "No" for words from List B and the new (unseen) words. Each word remained on the screen until a response was made. Performance was measured as the total number of correct responses, reflecting the participant's ability to distinguish between previously learned and novel words.

6. Digit Symbol Substitution Task (DSST): This task was used to assess processing speed. Participants were presented with a key at the top of the page that paired digits 1 through 9 with nine distinct symbols. Below the key, there were four rows of 25 boxes, each containing a digit (1–9) in random order, with a blank space directly beneath each digit. Starting at the beginning of the first row and proceeding left to right, top to bottom, participants were instructed to fill in the corresponding symbol in the blank box using the digit-symbol key. Participants were given 90 seconds to complete as many items as possible in sequence. The total number of correctly completed boxes was recorded and used as an indicator of processing speed.

Supplementary Information 3: Baseline dietary intake assessed using the EPIC Food Frequency Questionnaire (FFQ).

Table S2 Macro- and micronutrient intake of participants as assessed by FFQ prior to the commencement of the study visit.

Nutrients	**Average intake (mean ± SD)**	**Range**
Energy (kcal)	1,912.04 ± 533.03	1,041.99 – 2,939.32
Total CHO (g)	206.30 ± 70.04	105.98 – 376.56
CHO-starch (g)	104.81 ± 40.25	42.91 – 200.01
CHO-sugar (g)	98.07 ± 33.60	57.68 -179.87
CHO-fructose (g)	21.41 ± 8.78	9.23 – 45.47
CHO-galactose (g)	0.89 ± 0.56	0 -1.70
CHO-glucose (g)	19.23 ± 8.23	9.90 – 49.42
CHO-lactose (g)	17.34 ± 9.15	3.18 – 38.48
CHO-maltose (g)	1.95 ± 1.10	0.80 – 5.64
CHO-sucrose (g)	34.50 ± 11.91	17.69 – 65.35
Protein (g)	84.39 ± 23.99	35.80 -125.65
Total Fat (g)	83.45 ± 23.08	42.54 – 128.53
Saturated fatty acid (g)	27.86 ± 7.37	16.00 -40-68
Monounsaturated fatty acid (g)	32.64 ± 10.47	14.65 -55.74
Polyunsaturated fatty acid (g)	16.00 ± 5.43	6.55 -29.45
Cholesterol (mg)	271.99 ± 71.77	108.06 – 406.64
Fiber (g)	20.45 ±8.30	8.18 – 36.12

Alpha carotene (mcg)	574.24 ± 324.08	92-64 – 1,253.61
Beta carotene (mcg)	3,755.65 ± 1,777.58	1,228.12 – 7,466.94
Carotene - total (carotene equiv.) (mcg)	4, 215.21 ± 1950.37	1,527.10 – 8254.92
Vitamin A- retinol (mcg)	610.21 ± 424.89	217.17 – 1,753.81
Vitamin B1- thiamin (mg)	1.58 ± 0.53	0.62 -2.76
Vitamin B2- riboflavin (mg)	2.13 ± 0.64	0.89 – 3.32
Vitamin B6- pyridoxine (mg)	2.24 ± 0.71	0.97 – 3.54
Vitamin B12- cobalamin (mcg)	7.33 ± 3.02	1.23 – 15.84
Vitamin C -ascorbic acid (mg)	118.03 ± 56.34	52.70 -310.03
Vitamin D (mcg)	3.49 ± 1.79	0.63 -6.70
Vitamin E–alpha tocopherol equiv. (mg)	13.89 ± 5.03	5.92 – 28.16
Calcium (mg)	979.31 ± 333.80	487.67 – 1792.87
Chloride (mg)	4040.39 ± 1370.06	1,371.17 – 6,546.00
Copper (mg)	1.43 ± 0.49	0.59 – 2.83
Iron (mg)	12.28 ± 4.32	5.58 – 21.40
Folate (mcg)	329.85 ± 107.59	142.95 – 527.36
Iodine (mcg)	151.87 ± 46.14	74.19 – 248.58
Potassium (mg)	3,964.04 ± 1061.91	1,881.51 – 6,098.51
Magnesium (mg)	362.46 ± 113.81	158.32 – 606.94
Manganese (mg)	4.46 ± 1.07	1.91 – 8.74
Sodium (mg)	2,681.36 ± 909.11	880.49 – 4,315.26
Niacin (mg)	23.72 ± 7.81	6.48 – 36.86
Phosphorus (mg)	1,530.68 ± 435.09	729.08 - 2,353.66

Selenium (mcg)	69.88 ± 27.34	20.19 – 131.74
Nitrogen (g)	13.72 ± 3.92	5.80 – 20.55
Zinc (mg)	9.76 ± 2.88	4.63 – 15.00
Alcohol (g)	7.55 ± 6.77	0.76 – 28.49
Cereals and cereal products (g)	244.39 ± 94.56	93.1 - 456.09
Eggs and egg dishes (g)	25.17 ± 12.50	3.50 -50.00
Fat and oils (g)	18.04 ± 11.49	2.30 – 53.8
Fish and fish products (g)	57.91 ± 30.12	0 – 134.60
Fruit (g)	240.45 ± 139.20	79.10 – 569.35
Vegetable (g)	319.45 ± 146.62	142.91 – 158.84
Meat and meat products (g)	79.64 ± 39.61	32.83 – 157.00
Milk and milk products (g)	369.92 ± 167.60	176.66 – 735.62
Alcoholic beverages (g)	120.18 ± 113.79	0 - 344.97
Non-alcoholic beverages (g)	843.83 ± 350.98	406.44 – 1529.68
Nuts and seeds (g)	27.02 ± 21.26	4.76 – 76.33
Potatoes (g)	67.21 ± 35.66	17.5 – 160.28
Soups and sauces (g)	70.94 ± 60.35	19.25 – 241.16
Sugar; preserves and snacks (g)	26.82 ± 20.36	11.13 -89.68