Table S1. LRM active ingredient extraction

Extract	Extraction method	Extraction parameters	Extraction rate	References
Polysaccharide	Hot water extraction	Solid-liquid ratio 1:6.7, Temperature 100℃, Time 4h, Frequency 5	3.11%	[8]
		Solid-liquid ratio 1:27, temperature 90℃, time 60min,	12.3%	
	Ultrasonic-assisted method	solid-liquid ratio 1:21, time 30min, power 200 W	16.1%	[9]
	Enzyme extraction method	Solid-liquid ratio 1:20, PH3.5, temperature 50℃, time 60 min, enzyme amount 0.48%,	20.3%	
	High hydrostatic pressure-assisted extraction	Solid-liquid ratio 1:25,Pressure 380MPa , time 8 min	(8.35±0.12)%	[11]
Proanthocyanidins	Ultrasonic-assisted dual-liquid phase extraction	Solid-liquid ratio 1:26, ammonium sulphate mass concentration of 0.24 g/mL, time 49 min, power 220 W.	6.113%.	[17]
Polyphenols	Solvent method	Solid-liquid ratio 1:50, 1:26Ethanol content was 70%, temperature 58°C, time 37 min.	3.59%	[18]
	Ultrasonic-assisted method	Solid-liquid ratio 1:50, ethanol volume fraction 60%, temperature 36°C, time 31 min, power 240 w.	3.96%	
Anthocyanins	Ultrasonic assisted pectinase extraction	Solid-liquid ratio 1:30, mperature 45 ℃, time 30 min, the enzyme content was 0.5%, power 360 W, pH 1.	19.4%	[19]
Flavonoids	Supercritical CO2 extraction	extraction pressure is 35 MPa, temperature 45℃, time 1h, outlet valve temperature is 110℃		[25]
Tannin	Homogenate method	Solid-liquid ratio 1:30, 70% acetone aqueous solution		[28]
Fatty acids	Soxhlet extraction	Extracted for 2 hours using n-hexane as a solvent		[29]
Phenylpropanoid Derivatives	Organic solvent extraction	Solid-liquid ratio 1:5，60% EtOH－H2O，time 2h, Frequency 3		[30]
Polyphenol glycosides	Organic solvent extraction	Solid-liquid ratio 1:8，80% EtOH－H2O，time 3Day.	20%	[31]

Table S2. LRM active ingredient determination

Determination of samples	Measurement method	Conditions	Analysis conditions	Measure advantages	References
Polysaccharide	1H-NMR	Solvent: heavy water	Relaxation time (D1): 1 s, pulse width (P1): 14.90 s, num-	Analysis is simple, fast, and accurate, with short meas-	[14]

			ber of sample scans (NS): 32	urement time	
	UPLC-MS/MS	Chromatographic column: Acquity BEHC18 Mobile phase: 0.1% ammonia water, 0.1% ammonia water acetonitrile Electric spray ion source, negative ion mode scanning	Column temperature: 35 ℃, injection volume: 3.0 μ L. Flow rate: 0.3 m L/min Ion source temperature: 150 ℃, desolvent gas: 800 L/h, dry gas temperature: 400 ℃, cone hole gas: 50 L/h, capillary voltage: 2.5 kV	Simple and sensitive	[16]
	pH differential method	PH=3 phosphate buffer solution	2 mL sample solution+18 mL buffer solution	Fast, accurate, simple and easy to implement, without the need for standard samples	[20]
	HPLC-UV	Chromatographic column: Pntulips SBP-C18 Mobile phase: methanol, 0.5% formic acid aqueous solution Electrospray ionization, positive ion scanning	Column temperature: 30℃, injection volume: 10 μL, flow rate: 0.8 mL/min,, detection wavelength: 525 nm .	Simple, sensitive, and fast	[21]
Anthocyanins	UHPLC/FTL	Chromatographic column: Acquity UPLC BEHC18 Mobile phase: 0.1% trifluoroacetic acid -10% formic acid solution, formic acid water methanol acetonitrile (1:5:2:2, V/V) Electric spray ion source	Column temperature: 25 ℃; Injection volume: 2 μ L. Flow rate: 0.3 mL/min The primary mass spectrometry parameters are within the mass scanning range of m/z: 50 to 1700; Atomization gas pressure: 50 psi; Air curtain pressure: 35 psi; Ion source voltage: 5000 V; Ion source temperature: 500 ℃; Cluster removal voltage: 100 V; Collision energy: 10 eV. The secondary mass spectrometry parameters are within the mass scanning range of m/z: 50 to 1250; Cluster removal voltage: 100 V; Collision energy: 40 eV; Collision energy swing: 20 eV	Fast and efficient, with high accuracy	[22]
	NIR-HSI		Camera exposure time: 3500 μ s Height between lens and plate: 17.9 cm Moving speed of conveyor belt: 13.8 mm/s	Simultaneously measure total phenols, total flavonoids, and total anthocyanins.	[23]
	CIRs and Si-ACO-PLS		Initial population: 95, maximum iteration count: 50, maximum decay count: 0.6, maximum cycle count: 10, variable selection threshold probability: 0.4	Simple, fast, and economical	[24]
	UPLC-MS	Chromatographic column: Agilent ZORBAX-SBC Mobile phase: 0.1% formic acid, 0.1% formic acid acetonitrile Positive and negative ion scanning	Flow rate: 0.8 mL/min, column temperature: 35C, detection wavelength: 254nm, injection volume: 5L. M/z: 100-1500, atomization gas (GS1): 55 psi; Atomized gas (GS2): 55 psi; Curtain Air (CUR): 35 psi; Ion source temperature: 600 (positive)~550C (negative); Ion source	Simple operation	[25]

		mode	voltage: 5500 (positive)~4500 V (negative); Cluster removal voltage: 100 V; Focusing voltage: 10V		
Betaine	RP-HPLC	Chromatographic column: Hypersil NH2 Mobile phase: acetonitrile water (83:17, V/V);	Column temperature: 30℃, flow rate: 0.7 mL/min, detection wavelength: 195 nm	Good separation effect and strong reproducibility	[26]
	Ion-chromatography	Chromatographic column: Metrosep C cation analysis column Rinsing solution: methanesulfonic acid solution Detector: Conductivity detector	Column temperature: 38.5 ° C, flow rate: 0.8 mL/min;; Injection volume: 20 μL	Accurate and convenient	[27]
Tannin	UV	Ultraviolet spectrophotometer	670nm	Simple operation	[28]
Fatty acids	GC-MS	Dual flame ionization detector Chromatographic column: HP-88 column		Convenient detection, good separation effect, high sensitivity, and low detection limit	[29]
Phenylpropanoid Derivatives	HPLC	Chromatographic column: open silica gel CC Mobile phase: EtOH − H2O, CHCl3 − MeOH		High separation efficiency, fast speed, easy operation, and good detection sensitivity	[30]
Polyphenol glycosides	UPLC-QTOF-MS	Chromatographic column: COSMOSIL C18, reverse phase Kromasil 100-5C18, SH-Rxi-5Sil MS capillary Mobile phase: 0.1% (v/v) acetic acid	Column temperature: 35 ℃, flow rate: 0.8 mL/min, 2.0 mL/min.	Accurate detection, fast and efficient	[31]

Table S3. Biological activity of LRM extract

Activity	Plant extract/compound	Dose/concentration	Experimental model/results	References
Anti-tumor	homogeneous polysaccharide LRP1-S2	7.45 μM, 14.9 μM	It has obvious inhibitory effect on the proliferation of three pancreatic cancer cells AsPC-1, BxPC-3 and PANC-1	[8]
	Anthocyanins	200 μg/m L	Increase the apoptosis rate of human liver cancer HepG2 cells, significantly inhibit the mRNA expression of JAK2 and STAT3 (P<0.05), and significantly inhibit the protein expression of p-	[32]

			JAK2 and p-STAT3 (P<0.05); Significantly increased mRNA expression of LC3 and protein expression of LC3- Ⅱ (P<0. 05)	
		12.5, 25, 50 , 100 μg/m L	The activity of human liver cancer HepG2 cells was significantly reduced (P<0.05)	[33]
		LRP (150 μg/ml), LRAC (20 μg/ml)	The mixture of LRP and LRAC can significantly inhibit the proliferation of tumor cells within 24 hours	[34]
		IC50 = 601.97 μg/mL IC50 =445.79 μg/mL	LRM anthocyanin pt3g can inhibit the proliferation of prostate cancer LNCaP and PC-3 cells and promote cell apoptosis	[35]
		IC50 =361.58 μg/mL、IC50 =601.97 μg/mL 、 IC50 =445.79 μg/mL	LRM anthocyanin Pt3G can inhibit the proliferation of prostate cancer DU-145, LNCaP, and PC-3 cells by inducing cell apoptosis(p<0.05)	[36]
	Flavonoids	IC50 =110.49 μg/mL	Inhibition of Hep G-2 cell growth(P<0.05)	[37]
Prebiotics	LRP	100 mg/kg	The weight of mice was lower than that of the CT group (P<0.05), The number of Lactobacillus and Bifidobacterium in the gut of HFA mice increased compared to the CT group, while the number of Enterobacterium and Enterococcus decreased (P<0.01) The sIgA content in the intestinal mucosa of HFA mice was significantly higher than that of the CT group (P<0.01)	[40]
		6 mg/mL	The number of live bacteria in the experimental group was lower than that in the positive control group (P<0.01) and better than that in the blank group (P<0.05)	[38]
		0.5 g/L	Significantly promoted the growth of G2 (P<0.05)	[39]
		1.5 g/L	The free radical scavenging rates of G2 DPPH increased by 300.0% and 243.6%, respectively, and the reducing power increased by 6.7% and 4.7%; The free radical scavenging rates of L9 DPPH increased by 18.7% and 116.7%, respectively, and the reducing power increased by 4.1% and 4.1%	
	Anthocyanins	0.8% aqueous solution of anthocyanins	Increased diversity of gut microbiota in mice and altered the community structure of gut microbiota(P<0.05)	[41]
Anti-fatigue	LRP	0.5 g/mL	Can significantly increase the exhaustion time of swimming(p < 0.05) LDH, IL-6, IL-1β, IL-2 were significantly decreased(p < 0.05)	[43]
		0.05 g/mL	Can significantly increase the exhaustion time of swimming(p < 0.01) LDH(p < 0.05), TNF-α(p < 0.05), IL-6, IL-1β, IL-2 were significantly decreased, and SOD was significantly increased(p < 0.01)	
		0.10 g/mL	Can significantly increase the exhaustion time of swimming(p < 0.001) LDH(p < 0.01), TNF-α(p < 0.05), IL-6, IL-1β, IL-2 were significantly decreased, and SOD was significantly increased(p < 0.001)	

		0.15 g/mL	Can significantly increase the exhaustion time of swimming($p < 0.001$) LDH($p < 0.01$), TNF-α, IL-6, IL-1β, IL-2 were significantly decreased, and SOD was significantly increased($p < 0.001$)	
Eye care	LRP	LMP: 500 μg/mL	Cell activity inhibited (P<0.05)	[44-45]
		LMP-1-1, LMP-3-1, LMP-4-1,the concentration of 25, 50, 100 μg/mL	Compared with the blank control group, the activities of SOD and GSH Px in ARPE-19 cells significantly decreased (P<0.01), while MDA significantly increased (P<0.01); Compared with the model control group, the activity of GSH Px and SOD significantly increased (P<0.01, P<0.05), while the content of MDA significantly decreased (P<0.05, P<0.01)	
		LMP-2-1: 25, 50, 100μg/mL	Compared with the blank control group, the activities of SOD and GSH Px in ARPE-19 cells significantly decreased (P<0.01), while MDA significantly increased (P<0.01); Compared with the model control group, the activity of GSH Px and SOD significantly increased (P<0.01, P<0.05), while the content of MDA significantly decreased (P<0.05, P<0.01) The total apoptosis rate of ARPE-19 in the low and medium dose groups of LMP-2-1 was significantly reduced (P<0.05) Compared with the blank control group, the model control group showed NLRP3, Caspase-1, IL-1 β Significant increase in expression (P<0.01, P<0.05); Compared with the model control group, the low and medium dose groups of LMP-2-1 showed NLRP3, Caspase-1, and IL-1 β Significant decrease in protein expression (P<0.01), NLRP3 and IL-1 in the high-dose LMP-2-1 group β The protein expression significantly decreased (P<0.01, P<0.05).	
Skincare effect	Anthocyanins	100ug/mL, 500ug/mL, 1000ug/mL	Compared with the blank group, the number of aging cells in HSFs significantly increased, with SA- β- The positive rate of Gal staining significantly increased (P<0.01). Compared with the UVB irradiation group, SA- β- The positive rate of Gal staining decreased (P<0.05) The expression of aging genes p53 and p21 decreased with increasing drug concentration (P<0.05).	[47]
		0.1，0.5，1.0 mg/mL	Can significantly reduce HSFs and TNF- α The expression of ($p<0.01$). TNF group treated with 1.0 mg/mL anthocyanins- α The most significant decrease in expression was observed ($p<0.01$). Caspase-7 expression decreased while Survivin expression increased ($p>0.05$)	[48]
Nerve protection	LRP	5, 10, and 20 μM	Not causing significant cytotoxic effects	[50]
	Anthocyanins	50, 100, 200 μg/mL	Not causing significant cytotoxic effects The significant decrease in ROS levels significantly increased the activity of CAT, SOD, and GPx (P<0.05) Significantly reduced the activities of caspase-3 and bax, and significantly increased the activity of bcl-2 (P<0.05)	[51]
	Pn3G5G	100 mg/kg	Significant improvement effect on cognitive impairment in rats (P<0.01) Significantly reduces neuronal apoptosis	[52]

			Significantly reduce AGEs, MDA, NF in D-galactose-treated rats- κ B. P65, TNF- α (P<0.05), COX-2 and IL-6 (P<0.01)	
Anti-inflammation	Anthocyanins	50mg/L	Compared with the normoxic group, the normoxic+AC group of rats had MDA and TNF in myocardial cells- α、 The content of IL-6 was significantly reduced (P<0.05), while the activities of CAT, HO-1, Na+- K+- ATPase, and Ca2+- ATPase were significantly increased (P<0.05). The activities of GSH Px, SOD, and IL-10 were all significantly increased (P<0.01); Compared with the hypoxic group, the MDA and TNF in myocardial cells of rats in the hypoxic+AC group- α、 The content of IL-6 was significantly reduced (P<0.01), while the activities of CAT, GSH Px, SOD, HO-1, Na+- K+- ATPase, Ca2+- ATPase, and IL-10 content were significantly increased (P<0.01)	[53]
		238 mg / kg 59. 5 mg / kg	It can significantly reduce ankle joint swelling in rats at 6 and 24 hours after modeling (P<0.05) 01. P<0 05) Significantly improved the limping gait of rats after 6 hours of modeling (P<0 05) High doses of AEL can continuously improve the limping gait of rats after 24 hours of modeling (P<0 05)	[54]
		100,, 200, 400 μg/ml	RASFS was significantly inhibited at 24 and 48 h (P<0.01).	[55]
Liver protection	LRP	30, 50, 150,200 mg/kg	The activities of SOD, CAT, and GSH Px were significantly increased, while the contents of MDA, AST, and ALT in liver tissue were significantly reduced (P<0.05)	[56]
	Proanthocyanins	140 mg/kg/d	Significantly reduced the accumulation of triglycerides in the liver, reduced inflammation, increased GSH Px activity, and decreased MDA levels. The expression of the fatty acid oxidation related gene Scd 1 significantly increased, and the fatty acid synthesis related gene Ppar γ The expression of was significantly downregulated.	[57]
Bacteriostasis	Anthocyanins	MIC: 3.125 mg/mL	The best antibacterial effect on S.aureus	[58-59]
Protecting myocardial cells	Anthocyanins	50 μg/mL	LDH activity significantly decreased (P<0.05), cell density increased, cell boundaries were clear, and cell morphology was relatively normal The fluorescence intensity of blue and red cells was significantly reduced, and the ROS content and apoptosis rate were significantly reduced (P<0.01). The mRNA and protein expression of Bax were significantly reduced (P<0.01), while the mRNA and protein expression of Bcl2 and Bcl2/Bax ratio were significantly increased (P<0.01) The number of G0/G1 phase cells significantly decreased (P<0.05), while the number of S phase and G2/M phase cells significantly increased (P<0.05). The mRNA and protein expressions of CCNT2, CDK9, and FOXP1 were also significantly increased (P<0.01)	[62]
		50 μg/mL	The differentially expressed RNAs include 2980 mRNA (2365 upregulated, 615 downregulated), 101 miRNAs (62 upregulated, 39 downregulated), and 35 circRNAs (15 upregulated, 20 downregulated)	[63]
Hypoglycemic and hypolipemic	Anthocyanins	IC50=1.35 μg/mL	right α- Glucosidase activity has a significant inhibitory effect.	[65]

		IC50= 25.26 μg/mL	For Caco-2 cells α- Glucosidase activity also has a significant inhibitory effect	
		50 mg/kg 100 mg/kg	TG, TC, and LDL-C values significantly decreased, while HDL-C values increased (P<0.01). The weight gain rate and liver index of SD rats were significantly reduced (P<0.05). The concentrations of SOD and GSH Px both increased, while the concentrations of MDA decreased (P<0.01)	[66]
Anti-influenza	LRP	CC50=409.11 μg/mL IC50=17.58 ± 0.38 μg/mL	It can inhibit the activity of A/H3 N2 virus	[67]
Anti-anxiety	Anthocyanins	3g/kg	The Conditioned place preference scores in the treatment group were significantly lower than those in the model group (P < 0.01).	[68]
Prolong life	LRM extracts	5、10 mg/mL	the middle (5 mg/mL) and high doses (10 mg/mL) of LRM extracts significantly prolonged the average lifespan of C. elegans by 24.28% and25.19% (p< 0.05）	[69]
	LRP-S2	100, 500 mg/kg	LRP-S2 increased Alkaline phosphatase activity by 94.3% and showed the highest potential to stimulate osteoblast differentiation	[70]
	Anthocyanins	200, 400 mg/kg	Inhibition of ankle joint edema in mice began at 36 and 24 hours (both p<0.05), and showed the best inhibitory activity at 72 hours (all p<0.01).	[71]
Protecting mitochondria	Anthocyanins	50 , 100 μg/mL	Improved the vitality of DF-1 cells	[72]

Table S4. Product development of LRM extract

Product name	Sample	Process parameters	Advantage	References
Intelligent active packaging film	Anthocyanins, cassava starch, polyvinyl alcohol (PVA)	2% gelatinous starch solution, 2% PVA solution, 2% LRM anthocyaninss, 30% glycerol, temperature: 30 ℃, drying time: 30 minutes	Reduce the increasing environmental and health issues caused by traditional plastic packaging, and monitor food quality in real-time	[73]
Fibrous Membrane	Procyanidin	10% (W/V) gelatin acetic acid solution, 10% (W/V) polyethylene oxide acetic acid solution, 3% LRM procyanidin, spinning voltage: 40 kV, spinning rate: 100 mm/s; Spinning distance: 15cm; Environmental temperature: 20-30 ℃, relative humidity: 40%~60%	There is no heat involved in the spinning process, and the impact on bioactive substances is relatively small	[74]
Food packaging film	Cassava starch, Polyvinyl alcohol (PVA), LRM polyphenols	Cassava starch (20 g/L), PVA(20 g/L), starch and PVA solution: 1:1, 2% LRM polyphenols, 25% glycerol, temperature: 30 ℃, drying time: 48 hours.	It has antioxidant and antibacterial properties, as well as strong mechanical and barrier properties of the film.	[75]

Smart tags	Anthocyanins	LRM anthocyanins: 10mg/mL, soaking time: 2 minutes	Can provide real-time and accurate feedback on freshness information	[77]
PH sensitive membrane		ASKG solution and SPI solution: 1:1, 40% glycerol, room temperature drying time: 12 hours, hot air drying temperature: 50 ℃, drying time: 12 hours. 1%, 2%, 3%, and 4% (g/mL) acidified ethanol solution of LRM anthocyanins.	The pH sensitive membrane prepared has the advantages of high sensitivity, non toxicity, low cost, and biodegradability, and can be used for real-time monitoring of meat freshness.	[78]
Colorant		LRM anthocyanins: 25 μ Mol/L 0.06 M metal ion solution (Al 3+or Fe 3+), then in a pH 3-9 buffer (i.e., metal ion concentrations of 2.5, 12.5, 25, 50, 125, 250, 750, and 1500) μ Mix specific target anthocyanins and metal ion molar ratios (1:0.1, 1:0.5, 1:1, 1:2, 1:5, 1:10, 1:30, 1:60) with LRM anthocyanin extract in mol/L.	Has strong stability.	[79]
Accelerator		LRM anthocyanin addition amount: 0.06 mg/mL	Significantly enhance the antioxidant capacity of mycelium cells, increase biomass and polysaccharide production.	[80-81]
Chewable	Procyanidin	LRM procyanidin 40%, microcrystalline cellulose 15%, dextrin 20%, xylitol 10%, mannitol 10%, malic acid 2.5%	Smooth surface, uniform and consistent color, sweet and sour taste, smooth entrance, moderate hardness and brittleness.	[82]
	LRM	Crystal cellulose: 15 g, xylitol: 12.5 g, carboxymethyl cellulose sodium: 15 g, LRM: 41 g, water: 9 g, magnesium stearate: 13 g	Smooth surface, delicate and compact cross-sectional organization, refreshing and delicious, with a harmonious sour and sweet taste, and a smooth entrance	[83]
		Material water ratio: 1:30 (g: mL), inoculation amount of 3% (volume fraction), fermentation temperature: 37 ℃, fermentation time: 15 hours	It has the unique flavor of LRM and the unique aroma of lactic acid fermentation, with a sweet and sour taste and a delicate taste; Organizational form: The product is clear and transparent, with good fluidity and no visible impurities or precipitates	[84]
Beverage	LRM	Pure milk: 77%, passion fruit juice: 5%, LRM juice: 11%, sucrose: 7%, thickener: 0.06%, bacterial inoculation amount: 0.003%, fermentation time: 6.5 hours	It has certain antioxidant properties, good organizational state, no whey precipitation, no layering, and has the fragrance of passion fruit and LRM, as well as the unique flavor of dairy beverages. The sour sweet ratio is appropriate	[85]
		Aronia melanocarpa (Michx.) Elliott: 20%, LRM40%, white sugar: 10%, citric acid: 0.10%, xanthan gum: 0.08%, carboxymethyl cellulose sodium: 0.06%, pectin: 0.04%	Rich in nutrients, unique in flavor, with antioxidant and other functions	[86]
		LRM: 1%, salt: 0.2%, citric acid: 0.1%, xylitol: 6%	The beverage is purple in color, clear liquid, sweet and sour, and has the aroma that LRM should have	[87]
		LRM: 8.20%, white sugar: 9%, bacterial powder: 0.91%, temperature: 42 ℃, fermentation time: 4.94 hours	Suitable color, well organized, uniform texture, sour and sweet taste, with a unique taste and aroma of LRM	[88]
Fruit vinegar	LRM	Strain: Winecoideryeast, LRM: 15%, initial sugar content: 17%, fer-	Maximizing the preservation of LRM's original flavor, nutrition,	[89]

		mentation temperature: 32 ℃, inoculation amount: 4%; Strain: Shanghai Brewing 1.01 Acetobacter, fermentation temperature: 30 ℃, inoculation amount: 7%, liquid content: 42mL/250mL.	and health benefits, adding the unique mellow flavor to fruit vinegar	
Microcapsule	Anthocyanins	Embedding time: 66 min, CS: 0.2 mg/mL, HP- β- CD: 1.93 mg/mL.	Improving the pH and thermal stability of LRM anthocyanins	[90]
Dyeing agents	LRM pigment	80% ethanol/water mixed solution, solid-liquid ratio: 1:10, staining temperature: 80 ° C, pH=2	Dyed wool fabrics can achieve higher surface depth, and their antioxidant and antibacterial properties are stronger.	[91]