SUPPLEMENTARY INFORMATION

Supplementary Table 1. The standard curve and correlation coefficient of the internal standard in LC-MS/MS

Compounds	Retention time	Equation	r	Quantitative lower limit	Quantitative upper limit
Troxerutin	2.5802	y = 0.00462 x - 3.18765e-4	0.99171	5	1000

Supplementary Table 2. Primer information for PCR

Gene	Forward (5'-3')	Reverse (5'-3')
IRF6	TGGAGACCGGGAAGTATCAG	TCATGGGAACCTCTTTGGTC
IL-1β	GTACATCAGCACCTCACAAG	CACAGGCTCTCTTTGAACAG
IL-6	ACCACTCCCAACAGACCTGTCT	CAGATTGTTTTCTGCAAGTGCAT
TLR4	CTTTGCTTCCTTGGTGTTG	ATGATTCTCCTCTTCTTCACG
NF-κB	TCTGTTTCCCCTCATCTTT	TGGTATCTGTGCTTCTCTC
CYP2E1	GCTGTCAAGGAGGTGCTACT	CCAGTCACGGAGGATACTTAGG
CYP7A1	AGGCATTTGGACACAGAAG	ACAGATTGGAGGTTTTGCAT
AMPK	GCTGTGGCTCACCCAATTAT	TGTTGTACAGGCAGCTGAGG
GAPDH	ATTCAACGGCACAGTCAAGG	GCAGAAGGGGCGGAGATGA

Supplementary Table 3. Analysis of differential accumulated flavonoids in apple flesh between 'XJ4' and 'FJ'

Compounds	Test material	Mean ± SD(μg/g)	P-value	Log_2FC	VIP	Type
Phlorizin	XJ4	137.344±10.1498	0.002332	2.936124	1.022079	up
	FJ	12.1361±10.5153				
Quercitrin	XJ4	117.6824±5.6565	0.000804	3.241174	1.025083	up
	FJ	8.2355±7.1689				
Chlorogenic acid	XJ4	108.1946±10.7077	0.004887	2.356672	1.016598	up
	FJ	14.3232±12.4				
Cryptochlorogenic acid	XJ4	108.1946±10.7077	0.004887	2.356672	1.016598	up
	FJ	14.3232±12.4				
Reynoutrin	XJ4	68.9412±0.9139	0.000043	4.839827	1.027188	up
	FJ	1.5991±1.392				
Guaijaverin	XJ4	68.9412±0.9139	0.000043	4.839827	1.027188	up
	FJ	1.5991±1.392				
Avicularin	XJ4	35.3221±2.6831	0.002003	5.450059	1.023073	up
	FJ	0.5575±0.4812				
Hyperoside	XJ4	21.1245±2.5598	0.005130	5.165810	1.017650	up
	FJ	0.3782±0.3232				
Isorhamnetin 3-O-glucoside	XJ4	12.2575±1	0.002282	5.971067	1.022763	up
	FJ	0.1309±0.1116				
Tamarixin	XJ4	12.2575±1	0.002282	5.971067	1.022763	up
	FJ	0.1309±0.1116				
Cacticin	XJ4	12.2575±1	0.002282	5.971067	1.022763	up
	FJ	0.1309±0.1116				
Caftaric acid	XJ4	6.0657±0.156	0.000063	2.137927	1.026193	up
	FJ	0.9167±0.7962				
Protocatechuic acid	XJ4	4.0614±0.0878	0.000159	4.547501	1.027041	up
	FJ	0.116±0.1005				
Astragalin	XJ4	4.0196±0.0765	0.000055	3.209692	1.027073	up
	FJ	0.2977±0.2577				
Luteolin-4'-O-glucoside	XJ4	4.0196±0.0765	0.000055	3.209692	1.027073	up
	FJ	0.2977±0.2577				
kaempferol 7-O-glucoside	XJ4	4.0196±0.0765	0.000055	3.209692	1.027073	up
	FJ	0.2977±0.2577				
Hesperetin 5-O-glucoside	XJ4	3.7527±0.0565	0.000001	4.000174	1.027092	up
	FJ	0.1439±0.1247				
trans-Piceid	XJ4	2.604±0.1588	0.000787	3.235266	1.024429	up
	FJ	0.1985±0.173				
Cynaroside	XJ4	1.6989±0.0198	0.000000	2.502108	1.026934	up
	FJ	0.1973±0.1718				
Ononin	XJ4	1.348±0.0556	0.000594	5.369836	1.026316	up
	FJ	0.0217±0.0183				
4-Hydroxycinnamic acid	XJ4	1.1865±0.0918	0.004665	1.175923	1.014343	up
	FJ	0.352±0.3015				
Diosmetol 7-glucoside	XJ4	0.9406±0.0802	0.003261	2.553362	1.020671	up
	FJ	0.105±0.0881				
Thermopsoside	XJ4	0.9406±0.0802	0.003261	2.553362	1.020671	up
	FJ	0.105±0.0881				
carlinoside	XJ4	0.7482±0.0555	0.004680	-1.384529	1.011313	down
	FJ	1.2473±1.0821				
Caffeic acid	XJ4	0.6783±0.052	0.001732	3.729345	1.022754	up
	FJ	0.0329±0.0282				
3,4-Dihydroxybenzaldehyde	XJ4	0.6014±0.0215	0.000061	1.445900	1.020902	up
	FJ	0.1519±0.1337				
Afzelin	XJ4	0.4975±0.0254	0.000416	2.377352	1.023655	up
	FJ	0.065±0.0566				
Coniferaldehyde	XJ4	0.3772±0.0378	0.003466	4.334086	1.020062	up
	FJ	0.0126±0.0081				
Astilbin	XJ4	0.3228±0.0113	0.000401	2.858654	1.025909	up
	FJ	0.0292±0.0249				
Taxifolin	XJ4	0.1997±0.0118	0.001045	3.346045	1.023777	up
	FJ	0.0126±0.01				
(-)-Catechin gallate	XJ4	0.1908±0.0374	0.001964	-2.660136	1.017967	down
	FJ	0.7614±0.6579				
(-)-Epicatechin gallate	XJ4	0.1908±0.0374	0.001964	-2.660136	1.017967	down
	FJ	0.7614±0.6579				
Apigenin 5-O-beta-D-glucopyranoside	XJ4	0.1767±0.023	0.008613	1.994824	1.007371	up
	FJ	0.031±0.0194				
Homoplantaginin	XJ4	0.1626±0.0044	0.000003	2.705654	1.026101	up
	FJ	0.0158±0.014				
Sinapaldehyde	XJ4	0.1397±0.0097	0.001571	4.770186	1.023798	up
	FJ	0.004±0.0023				
Aesculin	XJ4	0.1234±0.0018	0.000000	4.356227	1.026994	up
	FJ	0.0037±0.0033				
Engeletin	XJ4	0.1202±0.0024	0.000001	2.122838	1.026061	up
	FJ	0.0176±0.0153				
Dihydrokaempferol	XJ4	0.118±0.0023	0.000002	2.944492	1.025962	up
	FJ	0.0095±0.0085				
(-)-Epiafzelechin	XJ4	0.118±0.0106	0.004050	1.509232	1.013899	up
	FJ	0.0283±0.0212				
Eriodictyol	XJ4	0.0893±0.0105	0.005523	2.418358	1.011946	up
	FJ	0.0122±0.0058				
Scutellarin	XJ4	0.058±0.0037	0.000309	1.612728	1.018009	up
	FJ	0.0123±0.0106				
Phloretin	XJ4	0.0544±0.0062	0.006562	2.217713	1.012132	up
	FJ	0.0098±0.0028				

Supplementary Table 4. Feed and fat intake across experimental groups

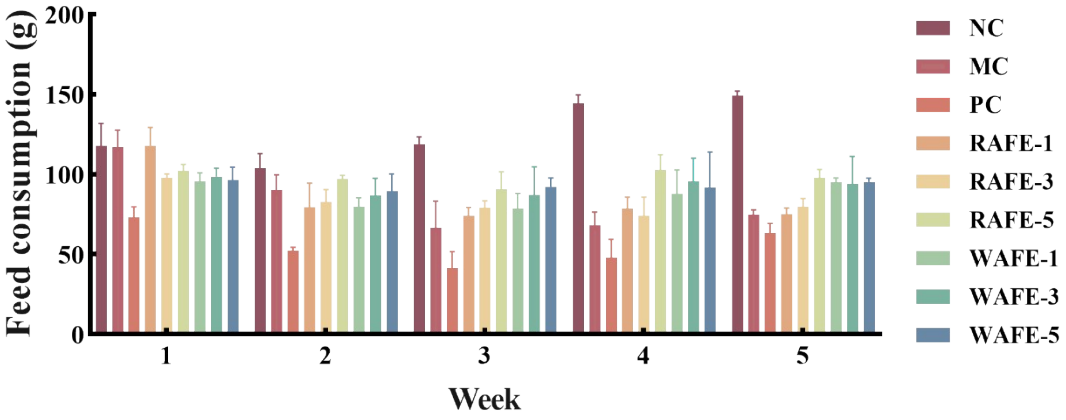
Group	Average Daily Feed Intake (g/day)	Daily Fat Intake (g/day)	Weekly Feed Intake Pattern
NC	3.5 ± 0.2^{a}	0.18 ± 0.02^{a}	Stable throughout study
MC	3.8 ± 0.2^{b}	1.33 ± 0.11^{b}	Initially elevated, then stabilized
PC	3.7 ± 0.3^{ab}	1.30 ± 0.13^{b}	Similar to MC group
L-RAFE	3.9 ± 0.3^{b}	1.37 ± 0.12^{b}	Similar to MC group
M-RAFE	3.7 ± 0.2^{ab}	1.30 ± 0.10^{b}	Similar to MC group
H-RAFE	3.8 ± 0.3^{b}	1.33 ± 0.14^{b}	Similar to MC group
L-WAFE	4.0 ± 0.3^{b}	1.40 ± 0.13^{b}	Similar to MC group
M-WAFE	3.8 ± 0.2^{b}	1.33 ± 0.11^{b}	Similar to MC group
H-WAFE	3.9 ± 0.3^{b}	1.37 ± 0.12^{b}	Similar to MC group

Data are expressed as mean ± SEM (n=10). Different superscript letters indicate significant differences between groups ($p < 0.05$). Fat intake was calculated based on diet composition: normal diet (5% fat by weight), high-fat diet (35% fat by weight).

Supplementary Table 5. Detailed hepatic steatosis assessment

Group	Steatosis Grade	Macrovesicular (%)	Microvesicular (%)
NC	0.2 ± 0.1^{a}	5.2 ± 2.1^{a}	2.1 ± 1.2^{a}
MC	2.8 ± 0.3^{d}	68.5 ± 5.3^{d}	15.2 ± 3.1^{c}
PC	1.3 ± 0.2^{b}	28.3 ± 4.2^{b}	8.5 ± 2.3^{b}
L-RAFE	2.1 ± 0.2^{c}	45.2 ± 4.8^{c}	12.3 ± 2.8^{c}
M-RAFE	1.2 ± 0.2^{b}	25.8 ± 3.9^{b}	7.8 ± 2.1^{b}
H-RAFE	1.5 ± 0.3^{bc}	32.5 ± 4.5^{bc}	9.2 ± 2.5^{b}
L-WAFE	2.3 ± 0.3^{c}	52.1 ± 5.1^{c}	13.5 ± 3.0^{c}
M-WAFE	1.8 ± 0.2^{bc}	38.7 ± 4.6^{bc}	10.8 ± 2.6^{bc}
H-WAFE	1.9 ± 0.3^{bc}	41.3 ± 4.9^{c}	11.2 ± 2.7^{bc}

Data are expressed as mean ± SEM (n=10). Different superscript letters indicate significant differences between groups ($p < 0.05$).



Supplementary Figure 1. Weekly feed intake of mice in different treatment groups