

## SUPPLEMENTARY MATERIALS

**Table S1** The gradient elution of free furan fatty acids

Time (min)	A(%)	B(%)	Flow(mL/min)
0	90	10	0.4
1	80	20	0.4
4	70	30	0.4
7	60	40	0.4
13	50	50	0.4
20	50	50	0.4
21	40	60	0.4
25	40	60	0.4
26	30	70	0.4
27	30	70	0.4
28	0	100	0.4
32	0	100	0.4
33	90	10	0.4

**Table S2** The gradient elution of CMPF

Time (min)	A(%)	B(%)	Flow(mL/min)
0	90	10	0.4
1	90	10	0.4
2	70	30	0.4
5	20	80	0.4
6	0	100	0.4
7	0	100	0.4
7	90	10	0.4
10	90	10	0.4

**Table S3** The gradient elution of astaxanthin

Time (min)	A(%)	B(%)	C(%)
0	81	15	4
15	66	30	4
23	16	80	4
27	16	80	4
30	81	15	4
35	81	15	4

**Table S4** Dietary intake in treatment groups.

	FO (n=4)	BMLE (n=5)	CO (n=4)	p
Energy (kcal)	1370.82±352.81	2150.64±701.88	1120.59±419.9 9	0.07
Protein (g)	69.39±15.65	101.42±26.54	63.16±22.61	0.10
Fat (g)	55.85±18.67	101.64±44.39	42.38±11.70	0.06
Carbohydrate (g)	147.64±44.02	204.96±57.77	121.48±60.36	0.17
Fibre (g)	13.04±2.87	22.63±14.73	13.15±4.94	0.36
Cholesterol (mg)	577.54±392.62	606.37±471.27	933.18±997.44	0.76
Saturated fatty acid (g)	8.75±3.21	18.03±13.66	8.57±4.07	0.32
Monounsaturated fatty acids (g)	7.91±4.49	13.37±8.93	6.58±3.25	0.36
Polyunsaturated fatty acids (g)	9.37±1.73	23.16±28.58	8.83±6.19	0.51
Total fatty acid (g)	26.41±9.13	55.21±41.17	24.42±12.88	0.28

Nutrients intake was calculated by Nutrition System of Traditional Chinese Medicine Combining with Western Medicine MX2 (V12.0).

**Table S5** Correlation between changes of furan fatty acids and CMPF and changes of abundance of inflammatory factor, blood glucose and lipid indicators and PUFA.

	11D3		11D5		CMPF	
	r	p	r	p	r	p
Erysipelotrichaceae.	-0.024	0.797	-0.131	0.164	-0.026	0.781
Turicibacter	0.089	0.164	0.006	0.946	0.021	0.824
TNF- $\alpha$	0.143	0.129	0.122	0.196	-0.092	0.329
IL-1 $\beta$	-0.138	0.144	0.116	0.220	0.075	0.428
HbA1c	0.051	0.587	0.059	0.530	0.145	0.125
Glucose	-0.028	0.766	0.024	0.800	<b>0.222</b>	<b>0.018</b>
Fasting insulin	0.032	0.733	-0.031	0.745	0.074	0.434
HOMA-IR	-0.024	0.797	0.008	0.933	0.137	0.146
Triglyceride	0.072	0.443	0.067	0.476	-0.095	0.313
Total cholesterol	-0.105	0.265	-0.022	0.816	0.103	0.276
High-density lipoprotein cholesterol	0.023	0.810	-0.030	0.753	0.073	0.440
Low-density lipoprotein cholesterol	-0.119	0.206	-0.063	0.504	0.173	0.065
C18:2n-6	-0.079	0.404	-0.145	0.124	0.039	0.679
C20:4n-6	<b>-0.249</b>	<b>0.008</b>	<b>-0.323</b>	<b>&lt;0.001</b>	-0.030	0.755
C20:5n-3	0.028	0.765	0.092	0.331	0.134	0.155
C22:5n-3	0.047	0.623	-0.041	0.668	-0.011	0.910
C22:6n-3	-0.095	0.313	-0.149	0.114	0.052	0.582
Total n-3 PUFA	-0.082	0.388	-0.097	0.403	0.031	0.744
Total n-6 PUFA	<b>-0.216</b>	<b>0.021</b>	<b>-0.342</b>	<b>&lt;0.001</b>	-0.013	0.895

**Table S6** Log<sub>2</sub> Fold Changes in Individual Family.

	BMLE			FO			CO		
	Log <sub>2</sub> FC	P	p-FDR	Log <sub>2</sub> FC	P	p-FDR	Log <sub>2</sub> FC	P	p-FDR
Methylophilaceae	-4.493	<0.001	0.000	-3.361	<0.001	0.000	-9.040	<0.001	0.000
Nitrospiraceae	-6.967	<0.001	0.000	-7.691	<0.001	0.000	-5.064	<0.001	0.005
Aeromonadaceae	-2.860	0.001	0.015	-3.721	0.001	0.015	-2.453	0.003	0.035
Selenomonadaceae	0.380	0.001	0.015	-2.188	0.001	0.009	-1.926	0.009	0.084
Coriobacteriales_Incertae_Sedis	-1.663	0.001	0.015	-2.081	0.002	0.020	-1.295	0.016	0.136
unclassified_Clostridia_UCG_014	-1.546	0.002	0.020	-0.785	0.034	0.128	0.564	0.291	0.572
unclassified_Bacteroidia	-2.468	0.002	0.021	-1.940	0.474	0.483	1.992	0.262	0.576
uncultured_Ruminococcaceae_bacterium	-1.348	0.003	0.029	-2.024	0.376	0.436	-1.196	0.151	0.535
Erysipelotrichaceae	-0.428	0.004	0.031	-1.187	0.361	0.432	-0.160	0.152	0.506
Bifidobacteriaceae	-0.466	0.012	0.067	-1.414	0.002	0.018	-0.777	0.032	0.248
Propionibacteriaceae	0.603	0.046	0.212	1.339	0.002	0.020	0.501	0.263	0.567
Akkermansiaceae	0.070	0.082	0.245	-1.347	0.005	0.046	0.034	0.271	0.563
Helicobacteraceae	1.359	0.194	0.374	0.440	0.007	0.052	6.046	<0.001	0.003
Lentimicrobiaceae	-0.140	0.012	0.071	1.228	0.282	0.373	2.123	0.001	0.012

\*Red mark means P < 0.05.

**Table S7** Log2 Fold Changes in Individual Genus.

	BMLE			FO			CO		
	Log <sub>2</sub> FC	P	p-FDR	Log <sub>2</sub> FC	P	p-FDR	Log <sub>2</sub> FC	P	p-FDR
Methylophilus	-4.493	<0.001	<0.001	-3.361	<0.001	<0.001	-3.204	<0.001	<0.001
Nitrospira	-6.967	<0.001	<0.001	-7.691	<0.001	<0.001	-5.064	<0.001	<0.001
Megamonas	0.380	0.001	0.028	-2.188	0.001	0.018	-1.926	0.009	0.116
Prevotella_7	-13.212	0.002	0.032	-7.340	0.001	0.026	-0.190	0.057	0.382
Aeromonas	-2.860	0.001	0.030	-3.721	0.001	0.024	-2.453	0.003	0.060
Turicibacter	-2.643	0.001	0.030	-2.531	0.024	0.130	-0.583	0.036	0.292
uncultured_Porphyrromonadaceae_b acterium	0.737	0.001	0.028	3.317	0.001	0.029	-3.467	0.001	0.020
unclassified_Coriobacteriales_Incer tae_Sedis	-1.663	0.001	0.029	-2.081	0.002	0.033	-1.295	0.016	0.163
unclassified_Clostridia_UCG_014	-1.546	0.002	0.033	-0.785	0.034	0.131	0.564	0.291	0.534
unclassified_Bacteroidia	-2.468	0.002	0.035	-1.940	0.474	0.486	1.992	0.262	0.561
unclassified_Christensenellaceae	-1.535	0.003	0.042	-3.022	0.001	0.024	0.759	0.263	0.554
uncultured_Ruminococcaceae_bact erium	-1.348	0.003	0.047	-2.024	0.376	0.433	-1.196	0.151	0.482
unclassified_Desulfovibrionaceae	-0.348	0.004	0.051	-1.249	0.001	0.023	-0.305	0.008	0.119
Propionibacterium	0.603	0.046	0.260	1.339	0.002	0.029	0.501	0.263	0.550
Hungatella	-3.943	0.054	0.275	-5.401	0.003	0.038	-0.897	0.117	0.421
Intestinibacter	-0.776	0.004	0.052	-1.299	0.002	0.039	-1.656	0.016	0.167
Clostridium_sensu_stricto_12	0.562	0.034	0.213	1.269	0.003	0.047	0.187	0.365	0.516
Helicobacter	1.359	0.194	0.389	0.440	0.007	0.077	0.500	0.000	0.006
Lentimicrobium	-0.140	0.012	0.098	1.228	0.282	0.353	-0.370	0.001	0.023
Megasphaera	0.880	0.021	0.151	-1.416	0.063	0.175	-0.136	0.001	0.031

\*Red mark means P &lt; 0.05.

**Table S8** Correlations between changes in inflammatory factor, blood glucose and lipid indicators and changes in abundance of Erysipelotrichaceae.

	BMLE		FO		CO	
	r	P	r	P	r	P
TNF- $\alpha$	0.010	0.951	-0.208	0.224	0.150	0.363
IL-1 $\beta$	0.159	0.335	-0.262	0.123	-0.096	0.560
HbA1c	0.024	0.884	0.040	0.817	-0.125	0.448
Glucose	0.171	0.297	0.245	0.149	-0.068	0.682
Fasting insulin	0.414	0.009	<0.001	0.998	-0.177	0.282
HOMA-IR	0.454	0.004	0.091	0.596	-0.146	0.377
Triglyceride	0.313	0.052	-0.138	0.423	-0.009	0.955
Total cholesterol	0.046	0.780	-0.003	0.985	-0.170	0.301
High-density lipoprotein cholesterol	-0.029	0.863	-0.056	0.746	-0.069	0.676
Low-density lipoprotein cholesterol	-0.070	0.670	0.069	0.689	-0.230	0.159

\*Red mark means  $P < 0.05$ .



**Table S9** Correlations between changes in inflammatory factor, blood glucose and lipid indicators and changes in abundance of Turicibacter.

	BMLE		FO		CO	
	r	P	r	P	r	P
TNF- $\alpha$	-0.020	0.902	-0.094	0.584	0.143	0.385
IL-1 $\beta$	-0.037	0.824	-0.243	0.154	-0.093	0.574
HbA1c	-0.062	0.709	<0.001	0.998	-0.081	0.624
Glucose	0.165	0.315	0.261	0.124	0.117	0.476
Fasting insulin	0.420	0.008	-0.285	0.063	-0.012	0.942
HOMA-IR	0.431	0.006	-0.040	0.816	-0.004	0.981
Triglyceride	0.393	0.013	0.144	0.403	-0.034	0.837
Total cholesterol	0.358	0.025	-0.135	0.432	0.160	0.331
High-density lipoprotein cholesterol	0.185	0.260	-0.105	0.541	0.169	0.305
Low-density lipoprotein cholesterol	0.170	0.301	-0.169	0.325	0.078	0.637

\*Red mark means  $P < 0.05$ .

**Table S10** Correlation between changes of PUFA in erythrocyte phospholipids and changes of abundance of Erysipelotrichaceae.

	BMLE		FO		CO		All	
	r	p	r	p	r	p	r	p
C18:2n-6	-0.202	0.217	0.208	0.224	-0.128	0.439	-0.024	0.803
C20:4n-6	0.243	0.137	0.044	0.799	0.032	0.847	0.092	0.332
C20:5n-3	0.215	0.188	0.145	0.398	0.263	0.106	0.172	0.068
C22:5n-3	0.120	0.467	-0.192	0.261	0.089	0.590	0.009	0.927
C22:6n-3	0.386	0.015	0.160	0.351	0.149	0.365	0.191	0.042
Total PUFA	0.371	0.020	0.118	0.492	0.035	0.832	0.145	0.124
Total n-3 PUFA	0.446	0.004	0.050	0.771	0.225	0.168	0.221	0.018
Total n-6 PUFA	0.126	0.444	0.165	0.337	-0.141	0.391	0.043	0.652

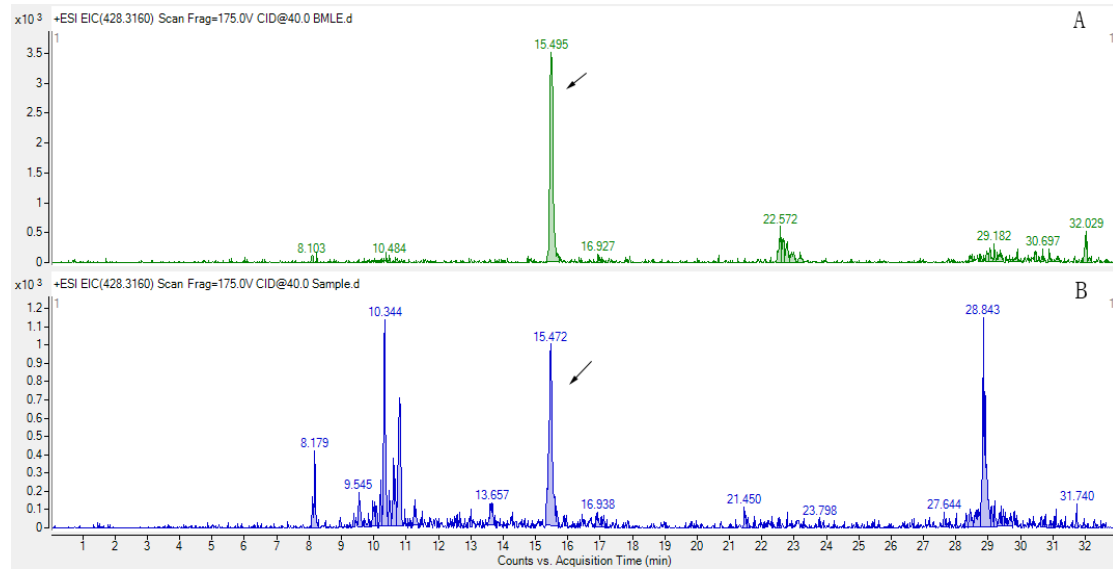
\*Red mark means  $P < 0.05$ .

**Table S11** Correlation between changes of PUFA in erythrocyte phospholipids and changes of abundance of Turicibacter.

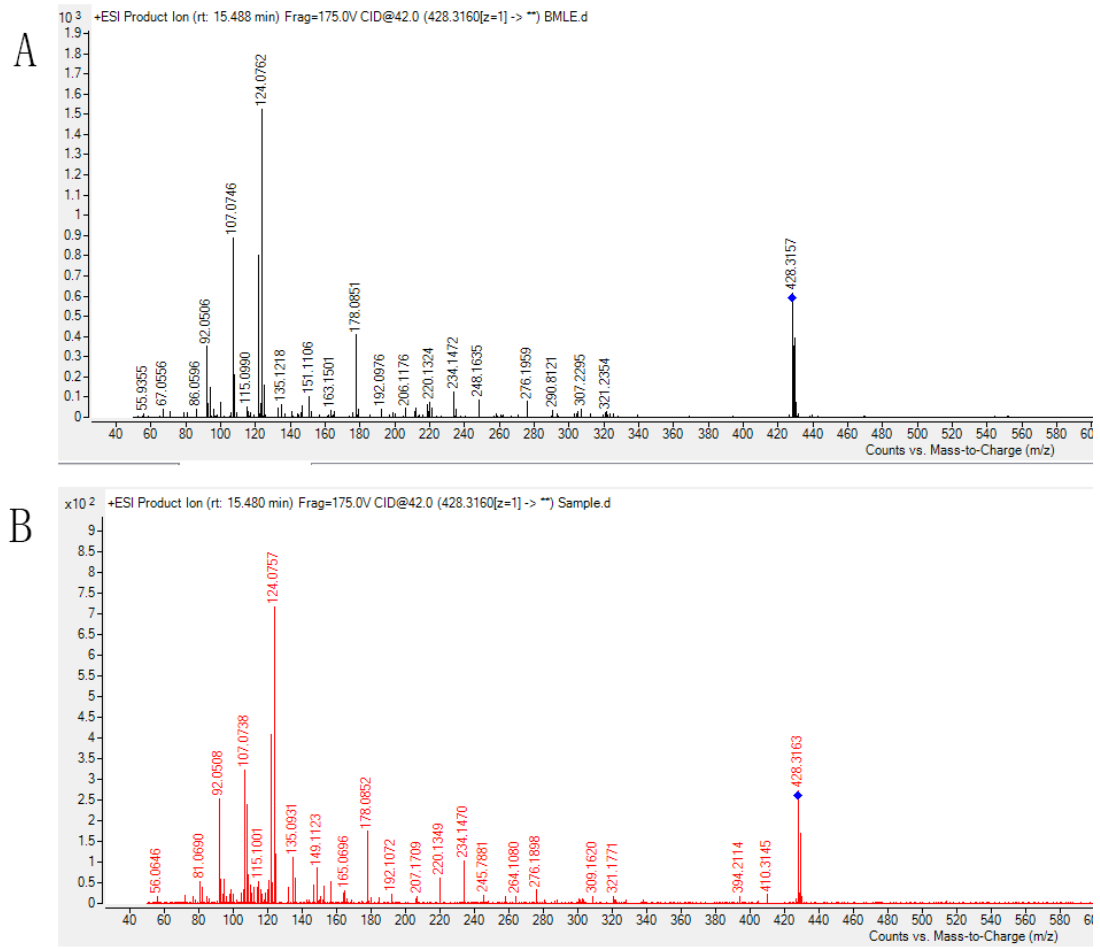
	BMLE		FO		CO		All	
	r	p	r	p	r	p	r	p
C18:2n-6	-0.342	0.033	0.191	0.263	0.044	0.792	-0.045	0.637
C20:4n-6	0.210	0.199	-0.021	0.905	0.161	0.328	0.103	0.277
C20:5n-3	0.277	0.087	0.350	0.036	0.267	0.100	0.250	0.007
C22:5n-3	0.136	0.409	-0.024	0.887	0.050	0.761	0.051	0.591
C22:6n-3	0.142	0.387	0.166	0.333	0.185	0.259	0.120	0.202
C24:1	-0.142	0.387	-0.049	0.779	-0.093	0.572	-0.089	0.346
Total PUFA	-0.305	0.059	0.140	0.416	0.245	0.133	0.178	0.058
Total n-3 PUFA	0.338	0.035	0.164	0.340	0.232	0.155	0.205	0.029
Total n-6 PUFA	0.075	0.648	0.138	0.421	0.223	0.172	0.108	0.255

\*Red mark means  $P < 0.05$ .

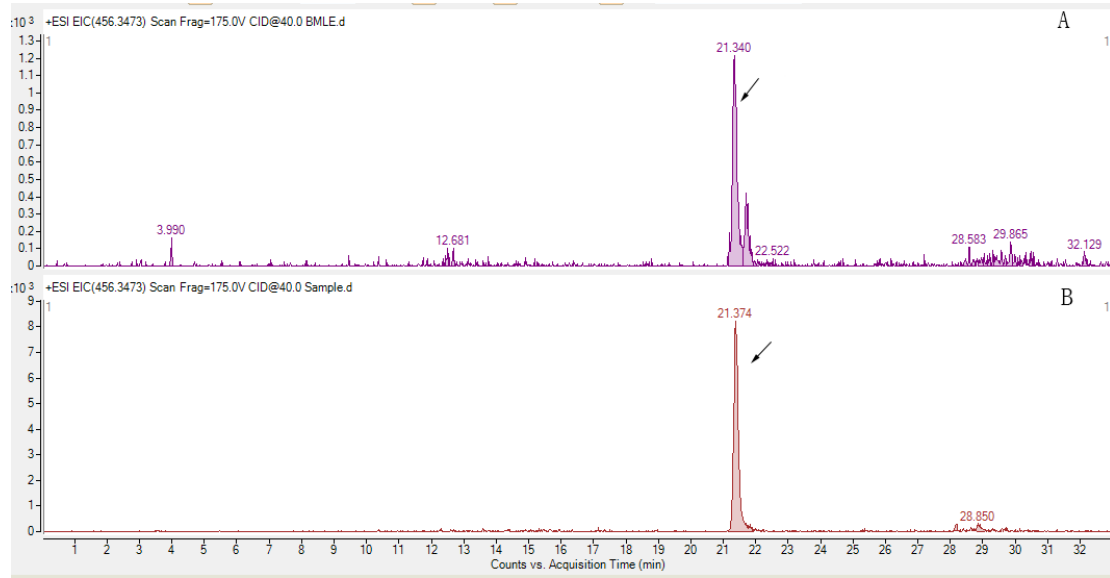
**Figure S1** The MS spectrum of 11D3-AMMP. BMLE (A) and Serum (B)



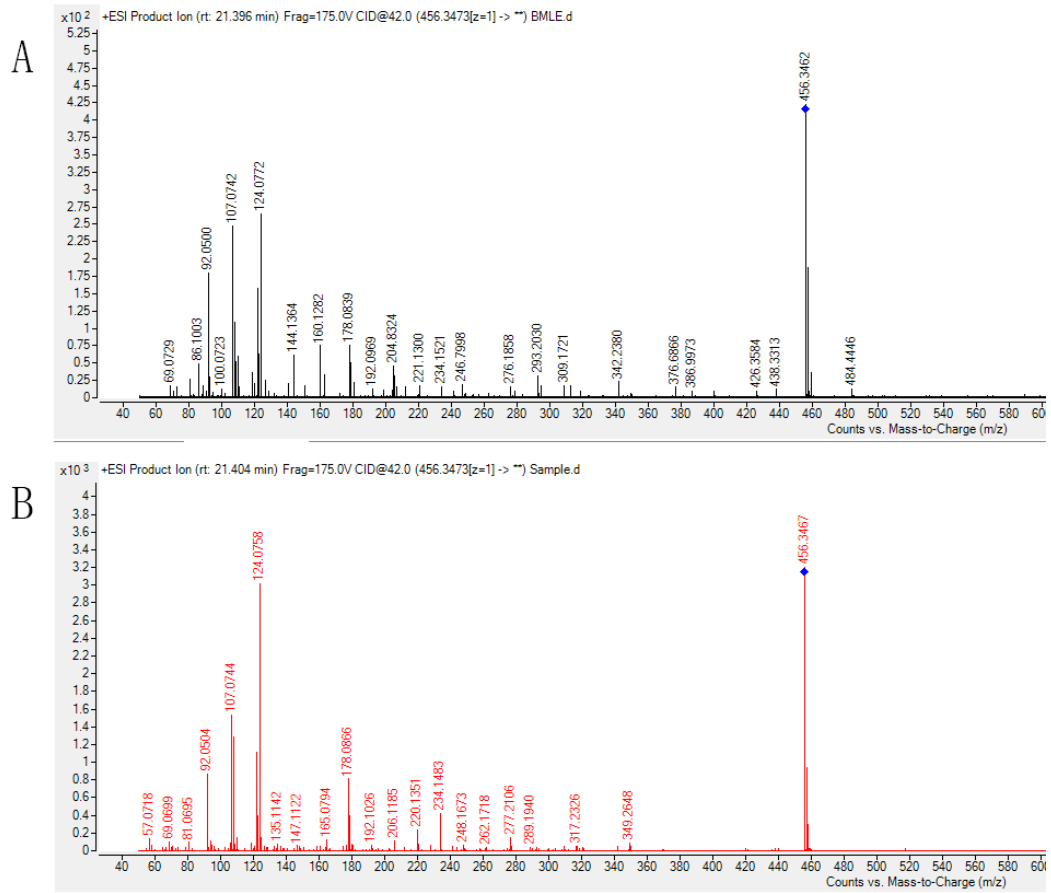
**Figure S2** The MS/MS spectrum of 11D3-AMMP. BMLE(A) and Serum (B).



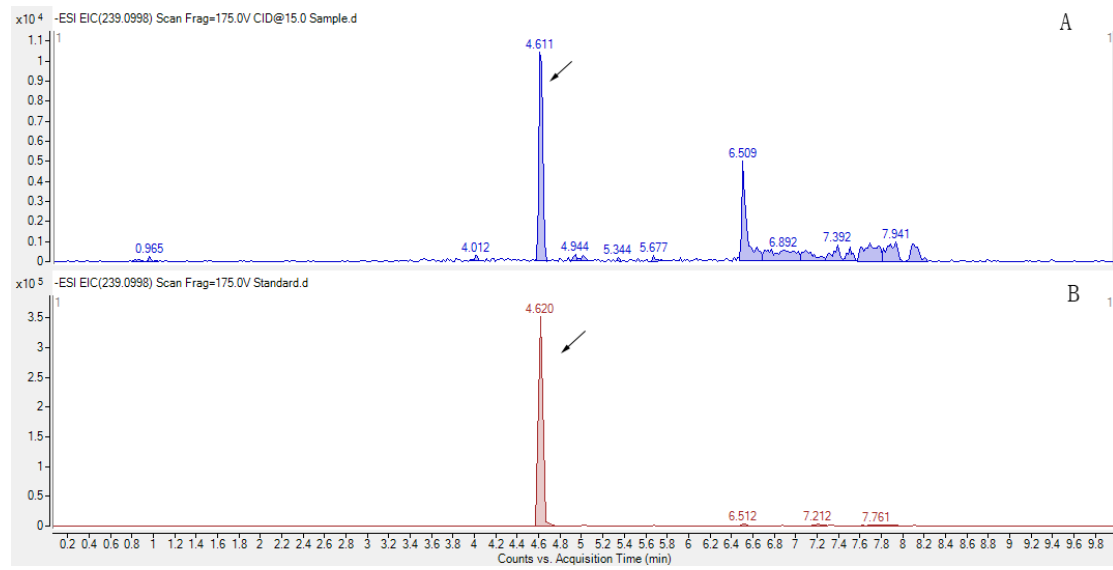
**Figure S3** The MS spectrum of 11D5-AMMP. BMLE (A) and Serum (B)



**Figure S4** The MS/MS spectrum of 11D5-AMMP. BMLE(A) and Serum (B).

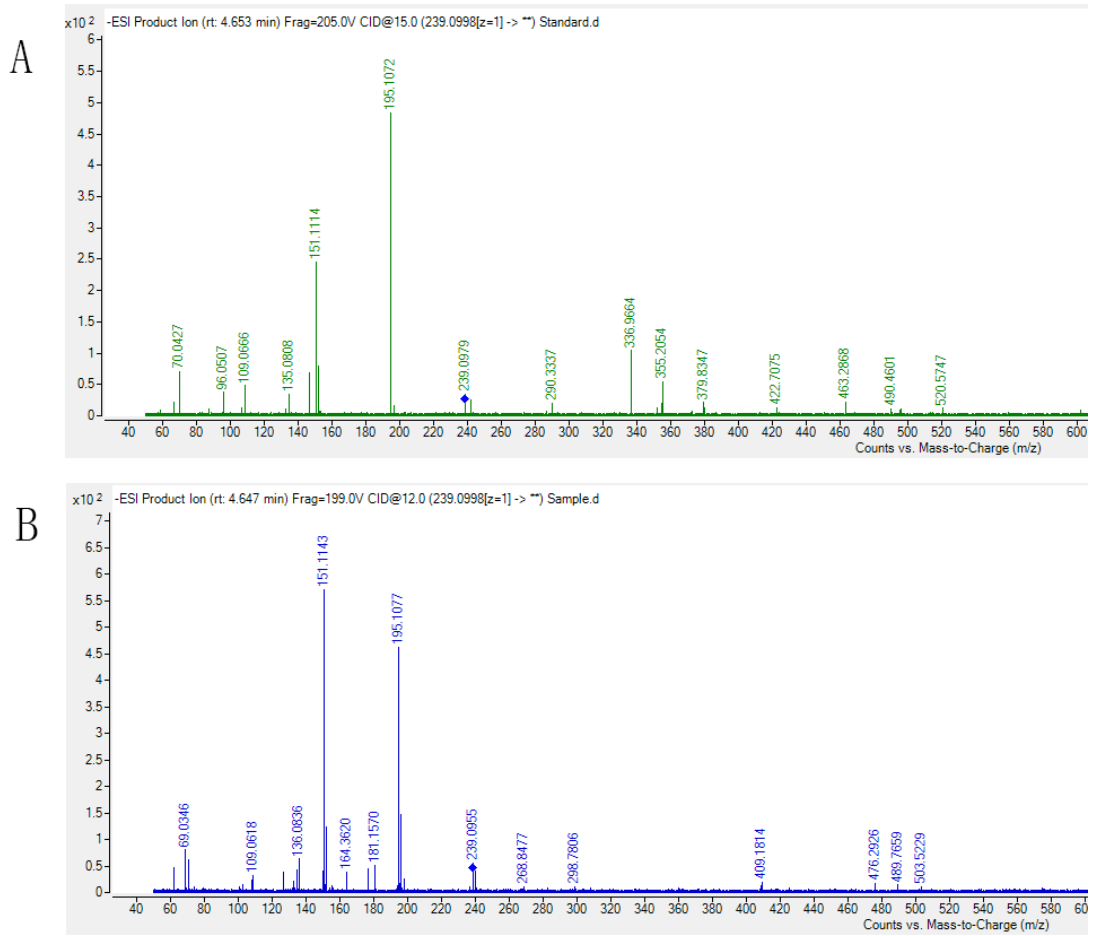


**Figure S5** The MS spectrum of CMPF. Serum (A) and Standard (B)

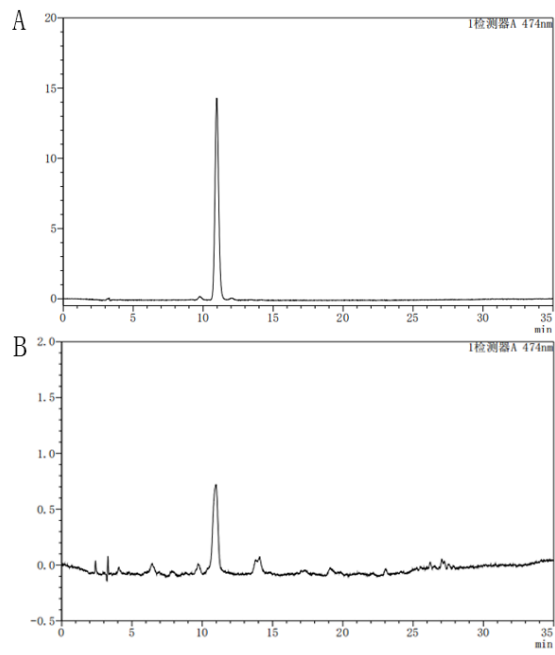




**Figure S6** The MS/MS spectrum of CMPF. Standard(A) and Serum (B).



**Figure S7** HPLC spectrum of astaxanthin. Standard (A) and BMLE (B)



**Figure S8** Sensitivity analysis of the correlations between changes in relative abundance of Erysipelotrichaceae and glycemic traits and blood lipids. (A) HOMA-IR. (B) Insulin. (C) TC. (D) TG. (E) Glucose. (F) HbA1c. (G) HDL-C. (H) LDL-C.

