Higher extrusion temperature induces greater formation of less digestible type-V and retrograded starch in iron-fortified rice grains, but does not affect iron bioavailability: stable isotope studies in young women

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Supplementary table 1. Ingredients composition of fortified extruded rice samples used for starch structure and color measurement

Sampl	*Extrusion temperatures	% ingredient (dry weight) per extrusion batch					
		Rice flour	Iron	Zinc	Citric acid (CA)	Trisodium Citrate (TSC)	Monoglyceride
Non-fortified extruded rice	Cold, Warm, Hot	100.00	0.00	0.00	0.00	0.00	0.00
FeZn+CA/TSC+monoglyceride	Cold, Warm, Hot	93.76	1.58	0.74	0.12	3.56	0.25
FeZn+CA/TSC	Cold, Warm, Hot	93.99	1.58	0.74	0.12	3.57	0.00
FeZn+monoglyceride	Cold, Warm, Hot	97.34	1.64	0.76	0.00	0.00	0.26
Zn+CA/TSC+monoglyceride	Cold, Warm, Hot	95.29	0.00	0.76	0.12	3.57	0.26

* Extrusion temperature: cold temperature (40 ˚C), warm temperature (70 ˚C), and hot temperature (90 ˚C). Fe, ferric pyrophosphate; Zn, zinc oxide; CA, citric acid; TSC, trisodium citrate.

Supplementary table 2. Degree of crystallinity (χ) and percentage of Type-V starch for the different samples with different processing temperatures.

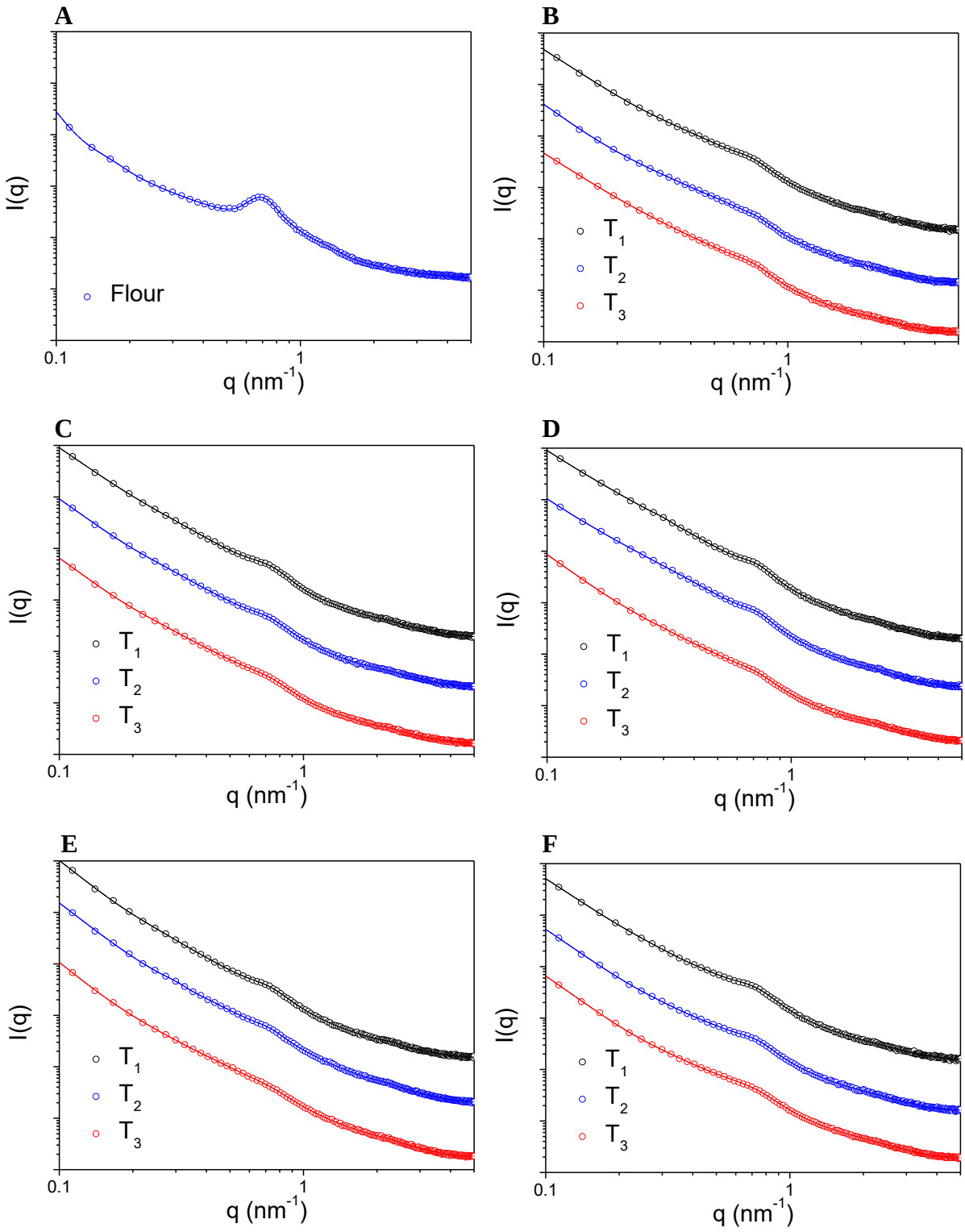
Sample	χ (%)			Type-V (%)		
	Cold	Warm	Hot	Cold	Warm	Hot
Non-fortified extruded rice	32	36	34	68	80	92
FeZn+CA/TSC+monoglyceride	46	46	46	45	55	85
FeZn+CA/TSC	53	53	47	26	36	75
FeZn+monoglyceride	40	40	45	57	70	89
Zn+CA/TSC+monoglyceride	39	34	39	49	69	79

* Extrusion temperature: cold temperature (40 ˚C), warm temperature (70 ˚C), and hot temperature (90 ˚C). Fe, ferric pyrophosphate; Zn, zinc oxide; CA, citric acid; TSC, trisodium citrate. The degree of crystallinity for native basmati rice and rice flour was 53% and 42%, respectively, and the percentage of type-A starch for both reference samples was 95% (5% of Type-B) and 87% (13% of Type-V), respectively.

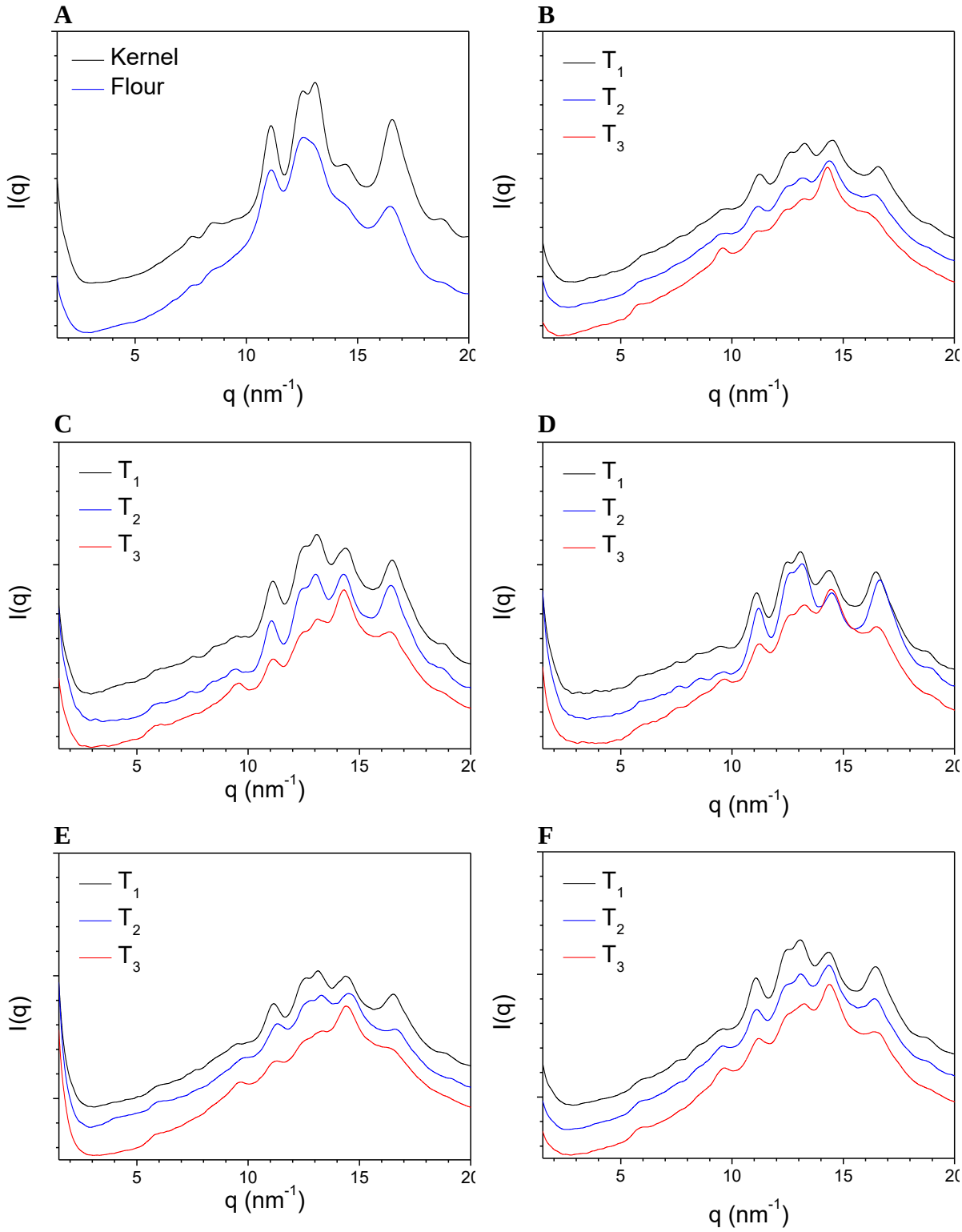
Supplementary table 3. Endothermic peak maxima (T_m) and enthalpy (ΔH_m) upon heating and exothermic peak minimum (T_r) and enthalpy (ΔH_r) upon cooling obtained from differential scanning calorimetry (DSC).

Sample	*Extrusion temperature (°C)	Endothermic peaks				Exothermic peak	
		1st endothermic peak		2nd endothermic peak			
		T_m (°C)	ΔH_m (J/g)	T_m (°C)	ΔH_m (J/g)	T_r (°C)	ΔH_r (J/g)
Basmati rice	n/a	76	8.60	96	0.54	76	-1.57
Long-grain rice flour	n/a	68	7.92	94	0.78	73	-1.61
non fortified-extruded rice	T1	66	1.20	97	1.05	77	-1.21
	T2	70	0.78	98	0.97	77	-1.04
	T3	71	0.49	99	0.68	76	-0.77
FeZn+CA/TSC+monoglyceride	T1	69	1.36	99	2.01	74	-1.24
	T2	70	0.94	99	1.68	77	-0.96
	T3	72	0.59	101	0.67	75	-0.52
FeZn+CA/TSC	T1	69	1.51	100	0.72	72	-1.02
	T2	70	1.02	98	1.30	72	-0.94
	T3	72	0.79	99	0.83	73	-0.82
FeZn+monoglyceride	T1	67	1.87	98	1.17	66	-0.55
	T2	69	0.90	97	1.32	63	-0.74
	T3	72	0.59	98	0.77	64	-0.81
Zn+CA/TSC+monoglyceride	T1	69	1.27	98	1.95	78	-1.79
	T2	71	1.00	99	1.56	78	-1.74
	T3	73	0.75	98	1.33	78	-1.51

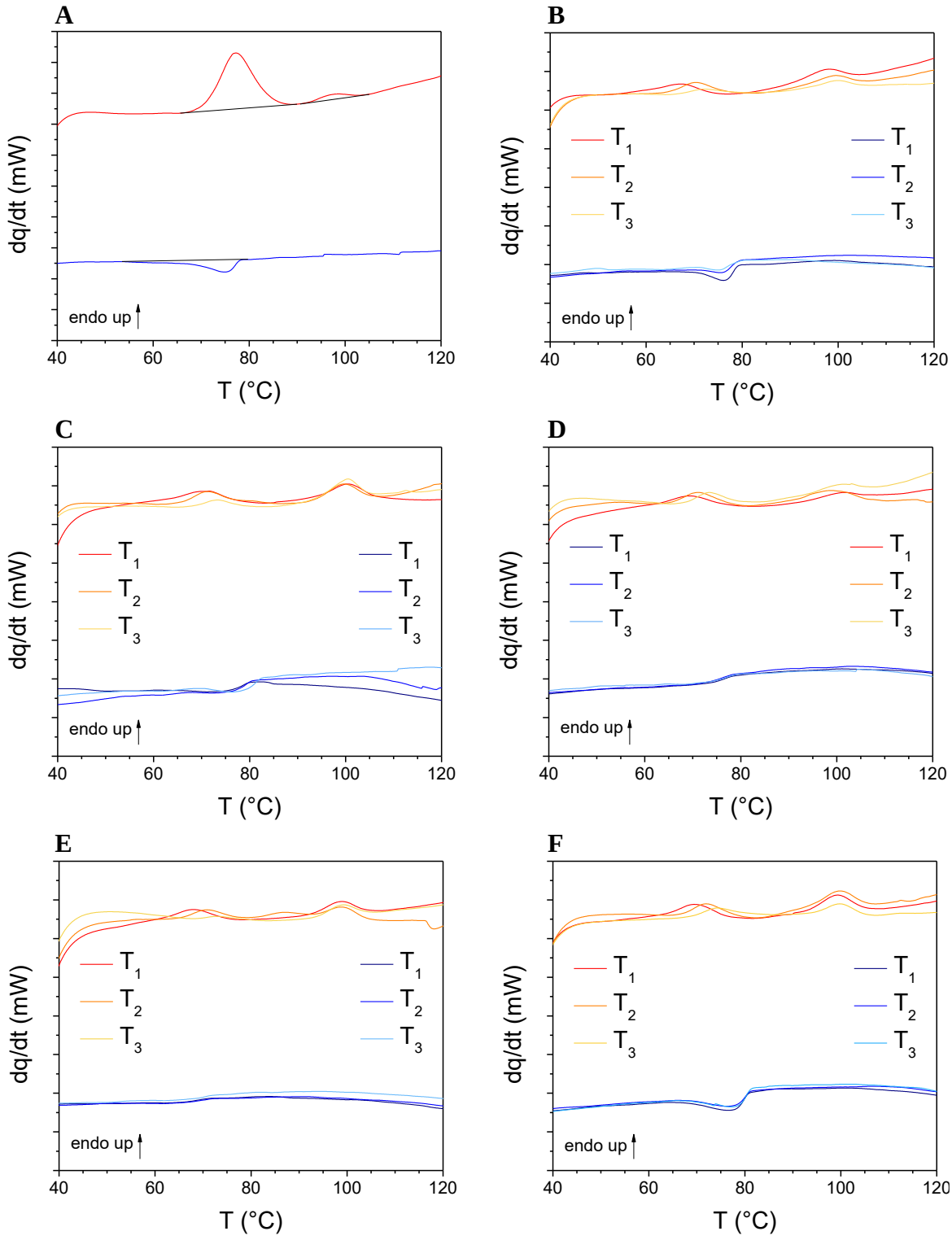
* Basmati rice served as a control. Extruded samples were produced from long-grain rice flour with or without the following ingredients: Fe, ferric pyrophosphate; Zn, zinc oxide; CA, citric acid; TSC, trisodium citrate. Extrusion temperature: T_1, cold temperature (40 ˚C); T_2, warm temperature (70 ˚C); and T_3, hot temperature (90 ˚C).



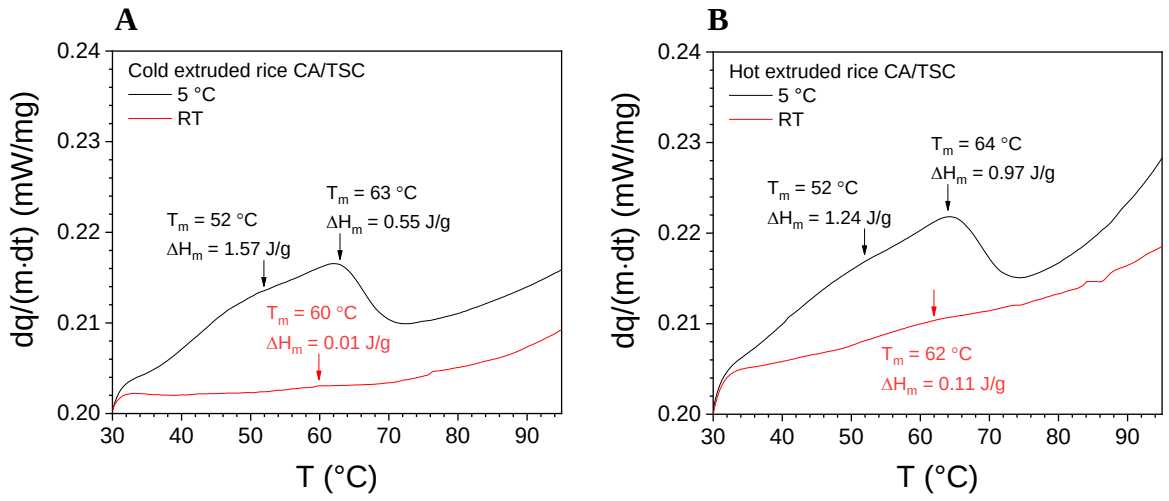
Supplementary figure 1. SAXS intensity profiles for a) Basmati flour, and b) non fortified extruded rice, c) fortified extruded rice with ferric pyrophosphate and zinc oxide (FeZn), citric and trisodium citrate (CA/TSC) and monoglyceride [FeZn+CA/TSC+monoglyceride], d) fortified extruded rice with FeZn+CA/TSC, e) fortified extruded rice with FeZn+monoglyceride, and f) fortified extruded rice with Zn+CA/TSC+monoglyceride. T_1, cold temperature (40 ˚C); T_2, warm temperature (70 ˚C); and T_3, hot temperature (90 ˚C).



Supplementary figure 2. WAXS intensity profiles for A) Basmati rice and long-grain rice flour, and B) non fortified extruded rice, C) fortified extruded rice with ferric pyrophosphate and zinc oxide (FeZn), citric and trisodium citrate (CA/TSC) and monoglyceride [FeZn+CA/TSC+monoglyceride], D) fortified extruded rice with FeZn+CA/TSC, E) fortified extruded rice with FeZn+monoglyceride, and F) fortified extruded rice with Zn+CA/TSC+monoglyceride. T_1, cold temperature (40 ˚C); T_2, warm temperature (70 ˚C); and T_3, hot temperature (90 ˚C).



Supplementary figure 3. DSC thermograms for A) Basmati flour, and B) non fortified extruded rice, C) fortified extruded rice with ferric pyrophosphate and zinc oxide (FeZn), citric and trisodium citrate (CA/TSC) and monoglyceride [FeZn+CA/TSC+monoglyceride], D) fortified extruded rice with FeZn+CA/TSC, E) fortified extruded rice with FeZn+monoglyceride, and F) fortified extruded rice with Zn+CA/TSC+monoglyceride. T_1, cold temperature (40 ˚C); T_2, warm temperature (70 ˚C); and T_3, hot temperature (90 ˚C).



Supplementary figure 4. DSC thermograms for A) cold extruded rice with CA/TSC (extruded at 40 ˚C), and B) hot extruded rice with CA/TSC (extruded at 90 ˚C). Both samples were cooked and stored at 5 ˚C and room temperature (RT) for 24 h before being analyzed. The arrows indicate the endothermic peak maxima (T_m) and the corresponding enthalpy (ΔH_m) upon heating.