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LETTER TO THE EDITOR

Low *trans* Spread and Shortening Oils via Hydrogenation of Soybean Oil

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Sir
Hydrogenation has been the US Industry standard for many years because the technology allows the formulation of a wide variety of spreads, shortenings and frying fats from soybean and other liquid oils [1–3]. Typically, soybean oil hydrogenated from an iodine value of 135–110 serves as a salad orcooking oil, whereas, at IVs of 65–80, spread shortening basestocks result that, when blended with liquid oil or stearines, yield soft, stick spreads and baking/frying shortenings. Since soybean oil contains 7–8% linolenic acid that must be lowered or removed completely for oxidative stability, selective conditions are employed meaning high temperatures, low hydrogen pressures and moderate agitation. Selective conditions also produce considerable amounts of *trans* acids, thus raising the melting point and increasing functionality. Since the early 1990s, *trans* fatty acids have been implicated as cholesterol elevating agents and as risk factors in coronary heart disease [4]. These concerns have prompted changes in the Nutrition Education Act of 1990 such that *trans* fatty acids must be listed on nutrition labels effective Jan. 1, 2006 [5].

Consequently, there has been much effort on the part of oil processors and the food industry to meet the labeling requirements and reduce the *trans* fatty acid contents of packaged retail products [6]. The approaches taken to reduce *trans* fats include chemical/enzymatic interesterification, fractionation, use of naturally stable oils low in linolenic acid, blending of liquid oils with tropical fats and, to a lesser extent, modified hydrogenation technologies [7]. This letter describes the use of soybean oil hydrogenated to low iodine values (27–41) to formulate low *trans* spread and shortening oils.

A refined, bleached, deodorized soybean oil (ADM Corporation, Decatur, IL, USA) was used for the hydrogenations and had the following composition by gas chromatography: palmitic (10.4%), stearic (4.5%), oleic (22.4%), linoleic(54.1%) and linolenic (7.6%); calculated IV = 133.0. A commercially available catalyst (Nysosel 645) was obtained from Englehard Corporation (Now BASF Catalysts, LLC), Erie, PA. It is composed of nickel oxide, nickel and alumina (25–40%) suspended in hydrogenated vegetable oil (60–75%). A typical hydrogenation was carried out on one liter of soybean oil in a two liter, stirred autoclave as described previously [8]. Reaction conditions were 175 °C, 15 psi hydrogen pressure and moderate agitation. Reaction progress was monitored by refractive index taken at 70 °C. Once a target RI was reached, the bomb was purged with nitrogen and allowed to cool. The oil was then treated with 1.0 ml of an aqueous 50 wt% citric acid solution and 1.0 g Tonsil bleaching earth (Sud-Chemie, Puebla, Mexico). The oil was then filtered through a pad of Celite. Fatty acid compositions were determined by gas chromatography as described previously [6]. Mettler drop melting point and solid fat content (nmr) were determined according to official AOCS methods [9].

Names are necessary to report factually on available data: the USDA neither guarantees nor warrants the standard of the product, and the use of the name USDA implies no approval of the product to the exclusion of others that may also be suitable.

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Table 1 Composition of hydrogenated soybean oil

Iodine value	Percentage			Total monoene	Lo	Ln
	Stearic	Oleic (*cis*)	Elaidic (*trans*)			
133.0[a]	4.5	22.4	0.0	22.4	54.1	7.6
115.1	4.9	22.1	16.7	38.8	39.9	4.8
102.9	5.2	25.9	23.5	49.4	31.5	2.2
91.2	5.4	30.9	30.4	61.3	20.5	0.9
77.1	6.9	35.7	37.9	73.6	7.6	0.2
74.8	7.3	34.1	41.8	75.9	5.0	0.3
69.8	10.4	28.7	46.7	75.4	2.4	0.3
63.6	15.4	25.6	46.3	71.9	0.6	0.3
56.1	23.9	23.2	40.9	64.1	0.2	0.2
40.7	41.8	14.4	32.1	46.5	0.2	0.2
31.4	52.3	17.5	20.2	36.0	0.1	0.1
27.6	57.4	9.8	17.9	30.8	0.1	0.1

Contains 10.5% palmitic acid

[a] Starting oil, no hydrogenation

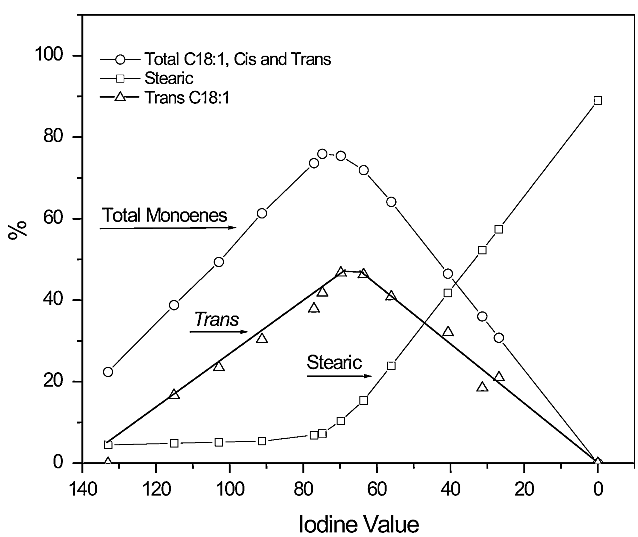

Fig. 1 Formation of *trans* and stearic acidsin hydrogenated soybean oil under selective conditions (175 °C, 15 psi, 0.02% nickel)

The composition of soybean oil, hydrogenated under selective conditions using a commercially available nickel catalyst, is shown in Table 1. Under selective conditions, i.e. high temperatures (175 °C), low hydrogen pressure (15 psi), moderate agitation and 0.02% nickel, reduction of polyunsaturates is favored with formation of high levels of *trans* fatty acids. A maximum of *trans* fatty acids is observed at an iodine value of approximately 70, after which trans bonds begin to hydrogenate. At IV 41, *trans* has been reduced from a maximum of 46% at IV 70 to about 32%. Under selective conditions, stearic acid levels increased slowly from IV 133 to about 80 and begins appreciable build up in hydrogenated oil at IV 70 and reaches 42% at an iodine value of about 40, as shown in Fig. 1. Under industrial conditions, soybean oil is typically hydrogenated under selective conditions to iodine values in the 65–80 range for margarines/spreads or shortenings, respectively. The blending of these basestocks with liquid oils and/or completely hydrogenated stearines forms the basis for most of the products found in the market place. Typically, spreads and baking shortenings contain 8–25% *trans* fatty acids [10].

The properties of soybean oil hydrogenated to low iodine values are shown in Table 2. At iodine values ranging from about 27–41, these oils show *trans* contents ranging from about 17–32% with saturated acids ranging from about 52–68%. Commercial margarine/spreads and shortening basestocks typically contain 32–40% *trans* acids and melting points ranging from 29–41 °C [11]. The NMR data shows that the IV 40.7 oil represents the lowest IV where relatively small amounts of high melting glycerides are present. At an IV of 27–31, 22–26% solids remain at temperatures of 55 °C or higher. Nonetheless, the low IV oils have physical properties comparable to hard structural fats prepared by the hydrogenation and interesterification of palm and palm kernel oils. These fats are capable of enmeshing large amounts of liquid oil and water in their crystal structure [12].

The physical properties of the low iodine value oils (27–41), blended with soybean oil, are shown in Table 3. Blending 5% of the IV 41 oil with 95% liquid soybean oil yields a product with 16.9% saturated acids and a *trans* fatty acid content of less than 2%. Increasing the IV 41 oil to 10% in the blend yields an oil with a dropping point of 36.7°C with sufficient solid fat needed for soft spreads. Blends of 25% IV 41 oil with soybean oil yields sufficient solid fat for all-purpose baking shortenings and the melting points are comparable. The *trans* fatty acid content is about 8%, which is considerably lower than commercially

Table 2 Properties of low iodine value soybean oil basestocks

Oil	IV	*Trans* (%)	Saturates (%)	Drop Pt. (°C)	SFC[a] @ temperature (°C)						
					10	21.1	26.7	33.3	40	50	55
Soybean	40.7	32.1	52.3	55.3	92.4	82.6	81.9	78.5	59.0	18.0	3.6
Soybean	31.4	20.2	62.8	60.6	95.5	92.8	93.0	91.7	86.8	41.7	21.9
Soybean	26.7	17.9	67.9	61.9	96.2	92.4	95.0	94.2	88.8	50.5	26.7

[a] Solid fat content by pulsed NMR

Table 3 Properties of low iodine-value soybean oils

IV	Percentage of Low IV oil	Percentage of soy oil	Percentage of *Trans*	Drop Pt. °C	Solids by NMR (percent @ °C)									
					10	21.1	26.7	33.3	40	45	50	55	60	65
40.7	100	0	32.1	55.3	92.4	82.6	81.9	78.5	59.0	–	18.0	3.6	0.0	0.0
	5	95	1.6	30.5	4.4	2.5	2.2	1.7	0.4	0.0	0.0	0.0	0.0	0.0
	10	90	3.2	36.7	6.9	4.5	4.7	2.8	0.8	0.2	0.0	0.0	0.0	0.0
	15	85	4.8	42.2	12.4	9.5	9.4	6.7	3.6	1.3	0.0	0.0	0.0	0.0
	25	75	8.0	46.7	20.2	17.4	16.6	10.5	7.5	3.8	0.0	0.0	0.0	0.0
31.4	100	0	20.2	60.6	95.5	92.8	93.0	91.7	86.8	–	41.7	21.9	–	–
	5	95	1.0	37.0	5.1	4.4	3.2	3.1	2.0	1.1	0.2	0.0	0.0	0.0
	10	90	2.1	46.3	10.5	8.9	7.7	7.0	5.3	3.4	1.8	0.6	0.0	0.0
	15	85	3.2	49.2	15.0	14.5	13.0	11.8	9.5	6.1	3.9	2.0	0.0	0.0
	20	80	4.2	51.2	19.1	18.1	16.3	15.9	13.0	9.0	5.6	3.0	0.0	0.0
	25	75	5.3	53.1	23.8	22.9	21	19.1	17.5	11.9	7.6	4.3	0.2	0.0
	50	50	10.5	57.9	46.9	46.2	44.9	42.4	39.0	29.5	21.3	15.5	6.7	0.0
26.9	100	0	17.9	61.9	96.2	92.4	95.0	94.2	88.8	–	50.5	26.7	–	–
	5	95	0.9	35.6	3.4	4.8	3.9	3.4	2.8	1.5	0.7	0.2	0.0	0.0
	10	90	1.9	43.8	11.4	10.3	8.8	8.7	7.6	4.4	2.6	0.4	0.0	0.0
	15	85	2.8	48.1	15.0	14.2	12.8	12.0	10.3	7.0	4.2	2.4	0.0	0.0
	20	80	3.7	49.9	19.2	17.9	16.3	15.8	14.3	9.3	5.9	4.0	0.3	0.0
	25	75	4.7	51.4	24.3	23.6	21.5	21.1	19.0	13.6	9.3	6.4	1.9	0.0
	50	50	9.4	56.5	47.4	47.4	44.5	43.5	39.1	33.5	23.8	17.2	8.8	0.7

Table 4 Properties of commercial spreads/shortenings—soy based

	Percentage of *Trans*	Drop Pt. °C	Solids by NMR (percent @ °C)					
			10	21.1	26.7	33.3	40	45
Spreads	10–13	31–32	11–15	5–6	3–4	1–2	0.0	0.0
Shortenings	12–25	41–48	23–37	16–23	13–27	9–16	3–9	0.0
Low Trans shortenings	6	48–52	16–24	13–18	12–18	12–16	9.5–13.5	0.0
Crisco/all purpose Hyd.	10.6	45.0	21.4	15.6	14.5	11.5	6.2	0.0
Crisco zero trans	0.0	50.1	15.2	15.3	15.0	14.0	11.8	0.0

See Refs. [10,11]

available products (Table 4). A shortening prepared by blending low IV soybean and liquid oil contains 24.4% total saturates plus *trans*. Although the use of lower IV 27–31 bases in blends results in lowered trans contents, some increase in saturates occurs and more highly melting triglycerides are introduced that may affect the functionality of the product. The results indicate that significant reductions in *trans* fats can be achieved by hydrogenation of soybean oil to low Iodine Values under conditions well within current commercial practices with commercially available catalysts.

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