Assessment of *transesterified* palm olein and *Moringa oleifera* oil blends as vanaspati substitutes

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Revised: 31 December 2013 / Accepted: 24 January 2014 / Published online: 15 February 2014
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Abstract This study aimed to investigate the suitability of *Moringa oleifera* oil and palm olein blends as vanaspati substitutes on the basis of physico-chemical and sensory characteristics. Blends were prepared either by blending *Moringa oleifera* oil or palm olein at 25:75, 50:50, 75:25, and 100 ratios, transesterified by *Rhizopus miehei*, compared with market vanaspati, designated as T₁, T₂, T₃, T₄ and T₅, respectively. The blends were filled in 3-layer polyethylene pouch packs, stored at ambient temperature, sampled at every 0, 90 and 180-days for the assessment of storage stability. The melting point and iodine value of T₂ and control were 36.8, 37.2 °C and 62.2, 51.8, with no effect on free fatty acids content, peroxide, anisidine values and color of the deodorized stuffs. C18:1 content of T₂ was 59.7 % with no *trans* fatty acids. *Trans* fatty acid content of the market vanaspati was 22.9 %. The addition of *Moringa oleifera* oil improved the induction period of the blends strongly inhibited the formation of primary and secondary oxidation products. The overall acceptability score of French fries prepared in T₂ was 81 % of the total score (9). Blend containing 50 % palm olein and 50 % *Moringa oleifera* oil can be used in the formulation of a functional shelf stable fat that can be used as a vanaspati substitute.

Keywords *Moringa oleifera* oil · Palm olein · Vanaspati · Fatty acid composition

Introduction

The formulation of vanaspati is quite complicated, varies from a processor to the other, location, availability and cost of the edible oils. The major ingredients are either hydrogenated palm oil or palm olein or a combination of therefor; sometimes cotton seed oil, sunflower oil and other soft oils are blended. Vanaspati is the cheap alternate of ghee, used in all types of cooking, frying bakery products and traditional sweets. In the subcontinent vanaspati is manufactured from partially hydrogenated oils. The texture of vanaspati varies from pasty to coarse granular. Partial hydrogenation of edible oils produces undesirable *trans* fatty acids which have many health concerns (Erickson 1999). The harmful impact of *trans* isomers on the plasma lipid profile is two times worse than the saturated fatty acids (Lokuruka 2007). The American Heart Association advises the consumers to decrease the intake of *trans* and saturated fatty acids (USDA 2000). Cardio vascular disease is the biggest global cause of death; it is the biggest cause of death in the subcontinent as well. The National Health Survey of Pakistan reported that 21.5 % of the urban population over 15 years and one in every three persons over the age of 45 suffer from hypertension (Nishtar 2002). *Moringa oleifera* (MOO) is a promising tree widely grown in many tropical and sub-tropical regions of the world (Anwar and Bhanger 2003). It possesses a massive potential to become a new source of edible oil on a commercial level. 3,000 kg of seeds could be obtained from 1 ha; the oil ranges from 30 to 40 %, the oil is edible and closely resembles to olive oil in fatty acid composition. (Mohammed et al. 2003). The production of *Moringa oleifera* on commercial scale was started in USA in 2010 on Hawaii (Radovich 2010). With the production of 1.1 to 1.3 M. Tons India is the biggest producer of *Moringa oleifera* in the world with total area of 380 KM² under cultivation (Rajangam et al. 2001). According to an unreferenced source the average production cost of 1-kg seed

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is 0.15–0.2\$. The oils rich in monounsaturated fatty acids are generally more stable to oxidative rancidity, stable in deep frying and healthy friendly (Tsaknis et al. 1998). The massive economic and nutritional potential of *Moringa oleifera* oil as a source of edible oil has not been studied so far in the formulation of vanaspati. The present investigation planned to find out the suitability of interesterified *Moringa oleifera* oil, palm olein blends to develop a healthy fat that can be used as substitute for vanaspati ghee on the basis of certain chemical and sensory characteristics.

Materials and methods

Raw materials Refined bleached and deodorized palm olein was obtained from United Industries, Ltd. Faisalabad. Seeds of *Moringa oleifera* were purchased from a village of district Multan, Pakistan. *Moringa oleifera* oil was obtained by mechanical expression and solvent extraction with n-hexane in laboratory scale expeller.

Refining of *Moringa oleifera* oil The free fatty acids of *Moringa oleifera* oil was decreased by neutralizing with 14 % sodium hydroxide in an open conical shaped vessel, mixed, slowly heated to 70 °C (about 2° centigrade rise in 1 min) followed by soap removal and three hot water washings (90 °C). Blends were prepared either by blending *Moringa oleifera* oil or palm olein at 25:75, 50:50, 75:25, and 100 ratios, the detail of treatments is given in Table 1.

Bleaching and transesterification Oils were dried at 110 °C under vacuum (600-mmHg) in MS fabricated bleacher for 30-min with 1 % bleaching earth (Sony) cooled to 50 °C and filtered by passing the slurry through the plate and frame filter press (Erickson 1999). The same vessel was used for transesterification; 10-l stuff was treated with 1 % Lipozyme IM-60 (*Rhizopus miehei*) reacted for 24 h at 60 °C at 200-rpm, after the completion of reaction, the samples were filtered to remove enzymes (Abdulkarim et al. 2007).

Table 1 Experimental plan

Treatments	Palm olein%	<i>Moringa oleifera</i> oil%
T ₁	75	25
T ₂	50	50
T ₃	25	75
T ₄	100	—
T ₅	—	100
Control	Hydrogenated product	

Deodorization Deodorization was performed in a batch type deodorizer (10-l capacity) a welded vessel fabricated of mild steel equipped with steam heating coils, circular ring (with holes facing the bottom) for the injection of live steam from the bottom and fat catcher assembly. The vessel was connected with vacuum pump (Siemens) capable of establishing 760 mmHg vacuum. Oil was heated to 150 °C by circulating steam in the coils and live steam was injected from the bottom at 2.5-kg/cm² pressure for 2-h till negative kries test (Erickson 1999).

Analysis Melting point, iodine, peroxide and anisidine values were determined as per standard methods (AOCS 1995). Colour was checked by Lovibond Tintometer by combining the red and yellow slides (Tintometer Corporation Salisbury, England). Fatty acids were converted into respective fatty acid methyl esters by methyl transesterification technique. 2 µ-liter was injected to a Thermo Electronic (Austin, TX) gas chromatography (model TRACE GA Ultra) by an automatic injection system (model AS-3000, Thermo Electronic Co.) separated with a 0.25-mm i.d. (0.25 µm film thickness) × 30-m long fuse silica DB-FFAP capillary column (Agilent Technologies, Wilmington, DE) and detected by a flame ionization detector (Model 650-FID). The injection and detector temperature were 250 and 280 °C, respectively. The column temperature was programmed from 50 °C (5 min) to 250 °C (20 min) at 5 °C/min. Helium was the carrier gas with a flow rate of 2.5 mL/min. Chrome Quest 5.0 version 3.2.1 software (Thermo Fisher Scientific Inc., Pittsburgh, PA) was used for data analysis. Identification was achieved by comparing the retention time of unknown FFA with known FAME standard mixture (Alltech Associates, Inc., Deerfield, IL; Sigma-Aldrich Corp., Bellefonte, PA). For the measurement of induction period, 2.5-g samples were weighed in the reaction vessels, exposed to 120°C and 22-l air/h. The break point in the curve was used as an indication of induction period on a Metrohm Rancimat 679 as per protocol described in the instruction manual of Metrohm Corporation, Switzerland (Metrohm 1993). Sensory evaluation was performed on a 9-point scale by a panel of 10-trained judges (1; the worst 9; the best) as prescribed by Larmond (1987). The samples were evaluated for taste, texture, smell and overall acceptability. The data was analyzed through one way and two way analysis of variance techniques (Steel et al. (1997). Significant difference among the treatments was determined by using Duncan's Multiple Range Test (DMRT).

Results and discussion

The results of chemical characteristics of deodorized palm olein and *Moringa oleifera* oil blends are given in Table 2.

Table 2 Chemical characteristics of deodorized palm olein and *Moringa oleifera* oil blends

Treatments	Free fatty acids %	Peroxide value (meqO ₂ /kg)	Anisidine value	Color (5.25" cell) red + yellow	Melting point °C	Iodine value (Wijs) cg/g
T ₁	0.08±0.01a	0.20±0.03a	4.56±0.16a	R+Y 2.5+25a	32.4±0.1b	59.12±0.93d
T ₂	0.08±0.01a	0.18±0.02a	5.72±0.42a	R+Y 2.6+25a	36.8±0.2a	62.25±0.45c
T ₃	0.09±0.01a	0.19±0.02a	4.36±0.19a	R+Y 2.0+20a	36.6±0.3a	65.37±0.74b
T ₄	0.08±0.01a	0.26±0.04a	4.67±0.23a	R+Y 2.7+26a	26.3±0.2c	56.8±0.69d
T ₅	0.11±0.02a	0.21±0.03a	4.45±0.27a	R+Y 1.8+20a	29.3±0.1c	68.5±1.12a
Control	0.11±0.01a	0.22±0.02a	4.39±0.21a	R+Y 2.7+28a	37.2±0.2a	51.1±0.97e

Within a column means denoted by a similar letter are not different

R+Y: Red+Yellow

Refer Table 1 for the detail of treatments

Free fatty acid of substrate oils and their blends were virtually comparable to the hydrogenated product (control). The resemblance in free fatty acids was due to the deodorization of the blends. Steam distillation of edible oils under high vacuum removes most of the free fatty acids from the treated stuffs (Erickson 1999). Free fatty acids content in edible fats and oils is considered an important quality criterion in establishing the quality of crude and processed stuffs of fats and oils, higher values in crude and processed oils decreases the price, increase process loss and poor keeping quality. Peroxides and other oxidation products are reduced in bleaching earth by absorption and volatile oxidation products are removed by steam distillation (Fereidoon 2005). Peroxide, anisidine and colour values of all the blends under question and control were at par with each other ($P>0.05$). Colour of processed oils should be as low as possible, bleaching with activated earth and steam distillation of the blends and substrate oils could be correlated to the lower peroxide and anisidine values. The peroxide value of the blends of butter oil and *Moringa oleifera* oils were similar to the butter oil (Nadeem et al. 2013a). *Transesterification* had a significant influence on melting point of the blends; T₂ and T₃ were similar to the control in this context. Solid fats are more popular in subcontinent due to the taste preference; therefore, melting point is considered an important criterion in the setting of blends of vegetable oils for the manufacturing of vanaspati. Rearrangement of the esters can have a pronounced effect on the melting characteristics of the fats, melting point of the randomly or selectively rearranged fats can decrease, increase or remain same depending upon the compositional characteristics of the substrate oils employed in the blends (Erickson 1999). It is evident that *transesterified* substrate oils cannot be a substitute for vanaspati, due to the low melting point. However, melting characteristics of T₂ and T₃ were similar to the control, offering their suitability as a substitute of vanaspati. The melting point of sesame oil and butter oil blends increased after the rearrangement of esters (Nadeem et al. 2013b). The change in the melting point of interesterified blends of butter oil and

Moringa oleifera oil has also been reported (Nadeem et al. 2012). The addition of *Moringa oleifera* oil increased the iodine value of the blends in a concentration dependent manner. The iodine value of the blends was virtually unaffected in the rearrangement reaction. The iodine value of fats and oils depends upon the degree of unsaturation. *Transesterification* had a major effect on the fatty acid composition of palm olein and *Morigna oleifera* oil blends. Higher degrees of unsaturation in fats has a health perspective, fats with higher iodine value are usually regarded as healthier. *Transesterification* of canola oil and caprylic had a great effect on the fatty acid composition of the blends over the substrate oils (Kim and Akoh 2005). *Transesterification* of high oleic fraction of *Moringa oleifera* oil had a major effect on the fatty acid composition of blends of butter oil and high oleic fraction of *Moringa oleifera* oil (Nadeem et al. 2014). *Transesterified* milk fat with canola oil had a different triglyceride composition (Nunes et al. 2010).

Fatty acid composition The fatty acid composition of palm olein, *Moringa oleifera* oil and their blends are given in Table 3. All the blends had a different fatty acid composition from the control and substrate oils ($P<0.05$). Oleic acid considerably increased in T₁, T₂ and T₃ as a function of addition of *Moringa oleifera* oil. The enhancement of unsaturated fatty acids in zero *trans* fatty acids prepared from palm olein, sunflower and low erucic rape seed oil as a function of blending and interesterification has been achieved (Fermani et al. 2009). Enhancement of unsaturated fatty acids in the blends had a great deal of health perspective due to their perceived role in uplifting beneficial HDL cholesterol. Saturated fatty acids are hypercholesterolemic and increase the risk of cardiovascular disease by increasing the LDL cholesterol in blood. Oleic acid, linoleic acids and linolenic acid reduce the LDL cholesterol (Lokuruka 2007). Diets rich in monounsaturated fatty acids have shown cardiac protective effects with better storage stability (Sacks and Katan 2002). The relative rate of oxidation of C18:0, C18:1, C18:2 and

Table 3 Fatty acid composition of palm olein and *Moringa oleifera* oil blends

Fatty acids	Control	T ₁	T ₂	T ₃	T ₄	T ₅
C12:0	–	0.11±0.01b	0.75±0.09a	0.03±0.01c	0.15±0.03b	–
C14:0	–	0.57±0.04b	0.58±0.05b	0.28±0.02c	1.15±0.09a	–
C16:0	12.5±0.34e	32.35±0.69b	23.61±0.44c	15.16±0.32d	40.5±1.17a	6.72±0.29f
C18:0	13.2±0.19a	4.23±0.18b	3.48±0.06c	3.32±0.09c	4.7±0.22b	2.86±0.11d
C18:1	28.4±0.68f <i>cis</i>	50.79±1.27d	59.70±1.34c	68.60±0.59b	41.9±0.94e	77.51±1.42a
C18:2	22.9±0.25a [<i>trans</i>]	9.40±0.31c	7.70±0.14d	6.00±0.10e	11.1±0.43b	4.31±0.18f
C18:3	–	0.22±0.03a	0.18±0.02b	0.08±0.02c	0.3±0.02d	–

Within a row means denoted by a similar letter are not different; Refer Table 1 for the detail of treatments

C18:3 is 1:100:1200:2500, respectively i.e. presence of more unsaturated fatty acids will make the fat vulnerable to autoxidation (deMan 1999). Addition of *Moringa oleifera* oil (monounsaturated oil) considerably enhanced the storage stability of sunflower and soybean oils which have a high degree of unsaturation (Anwar et al. 2007). The peroxide value of milk fat with altered fatty acid profile was more than the original milk fat (Baer et al. 2001). The addition of unhydrogenated oils in the formulation of vanaspati could be deleterious from the storage stability view point, due to their oxidation susceptibility. The use of *Moringa oleifera* oil in the formulation of vanaspti can confer a product with increased health benefits and superior storage stability. Fatty acid composition of blends of soybean, sunflower and *Moringa oleifera* oil were different from the individual oils (Anwar et al. 2007). The addition of *Moringa oleifera* oil in butter oil had a great effect on fatty acid composition of the blends (Nadeem et al. 2013a). Blending of vegetable oils can have a significant influence on the fatty acid composition from the substrate oils (Mariod et al. 2005).

Storage stability Table 4 represents the results of storage stability of blends of palm olein and *Moringa oleifera* oil. Free fatty acids of all the blends and substrate oils increased

during 3-months of storage period. The intensification of free fatty acids during the storage period was not related to any blend; all the blends and individual oils were practically affected to the same magnitude. Free fatty acids of vegetable oils customarily increase during storage (Fereidoon 2005). Free fatty acids are produced in fats and oils due to the presence of moisture, hydrolytic enzymes, metal ion contamination; they can induce objectionable odors in fats and oils (Erickson 1999). Free fatty acids of blends of butter oil and *Moringa oleifera* oil increased during long term storage at ambient temperature (Nadeem et al. 2013a). Free fatty acids are strongly correlated with shelf life of edible oils; higher concentration usually limits the shelf life. The pro-oxidant effect of free fatty acids has been studied in detail; the carboxylic group triggers the decomposition of hydroperoxides. The connection between objectionable flavors and free fatty acids has been found (Kiritsakis and Tsipeli 1992; Frega et al. 1995). Peroxide value of all the blends and substrate oils increased in a typical fashion during 3-months of storage period but to varying extents. *Moringa oleifera* oil had a great contribution in the inhibition of lipid peroxidation. The inhibition of lipid peroxidation as a function of *Moringa oleifera* oil in the blends were in the order of T₅ > T₃ > T₂ > T₁. The control used in this investigation was hydrogenate stuff

Table 4 Storage stability of vanaspati substitute

Parameters	Storage days	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Free fatty acids (%)	0	0.11±0.01a	0.08±0.01a	0.08±0.01a	0.09±0.01a	0.08±0.01a	0.11±0.02a
	90	0.12±0.02a	0.11±0.01a	0.10±0.01a	0.11±0.02a	0.10±0.01a	0.13±0.01a
	180	0.14±0.02a	0.14±0.03a	0.13±0.01a	0.14±0.01a	0.12±0.01a	0.14±0.01a
Peroxide value (meqO ₂ /kg)	0	0.22±0.02a	0.20±0.03a	0.18±0.02a	0.19±0.02a	0.26±0.04a	0.21±0.03a
	90	0.72±0.11b	0.98±0.08a	0.81±0.08b	0.77±0.12b	1.05±0.11a	0.52±0.05c
	180	1.93±0.08c	2.36±0.17a	2.12±0.21b	1.75±0.14c	2.44±0.34a	1.14±0.13c
Anisidine value	0	4.39±0.21a	4.56±0.16a	5.72±0.42a	4.36±0.19a	4.67±0.23a	4.45±0.27a
	90	9.45±0.29d	12.39±0.95b	10.27±0.64c	8.62±0.39e	14.38±0.8a	6.52±0.38f
	180	16.57±0.51	19.63±0.76b	15.47±0.59d	12.69±0.45f	25.19±1.34a	14.78±0.57e

Means of triplicate experiments; means denoted by similar letter in a row are not different

Refer Table 1 for the detail of treatments

(market vanaspati) the higher peroxide values of 180-days stored T₁, T₄ and T₅ over control could be justified by the better oxidative stability of hydrogenated fats for having greater extents of saturated fatty acids than vegetable oils. The strong lipid peroxidation by the *Moringa oleifera* oil was due to the occurrence of higher extents of monounsaturated fatty acids and non-existence of C18:3. Even then greater peroxide value of 180-days stored T₁, T₂ and T₄ over the control can be correlated to the hydrogenation process which can have a considerable effect over the fatty acid composition. The oxidation rate of C18:2 and C18:3 is 12 and 25 times greater than C18:1 (Pritchard 1991). C18:2 content of T₁, T₂, T₃, T₄ and T₅ was 9.40 %, 7.70 %, 6.0 %, 11.1 % and 4.31 %, therefore, the peroxide value and anisidine value of T₁ and T₄ was higher than other blends. Peroxide value measures the primary stages of autoxidation and gives indication of the oxidative breakdown took place in fats and oils during the course of autoxidation (Mcginely 1991). The use of *Moringa oleifera* oil in vanaspati provides great edge over polyunsaturated oils from the storage stability point of view. The inhibition of lipid peroxidation in sunflower and soybean oils by *Moringa oleifera* oil has been reported by Anwar et al. (2007). Supplementation of butter oil with *Moringa oleifera* oil considerably inhibited the autoxidation process (Nadeem et al. 2013a). Fortification of butter oil with modified fatty acid composition with *Moringa oleifera* leaf extract markedly improved the keeping quality at ambient temperature (Nadeem et al. 2013b). Anisidine value of palm olein, *Moringa oleifera* oil and their blends went on increasing throughout the storage period in a fashion typical to generation of oxidation products. The increase in secondary oxidation products was dependent upon the presence of *Moringa oleifera* oil and concentration of C18:2. Blends or substrate oils having higher concentration of C18:2 yielded the higher extents of secondary oxidation products; *Moringa oleifera* oil improved the oxidative stability of the blends. Determination of anisidine value provides

Fig. 1 Conjugated dienes value of Transesterified blends of palm olein and *Moringa oleifera* oil

Fig. 2 Induction period of transesterified blends of palm olein and *Moringa oleifera* oil

beneficial information of the extents of the secondary oxidation products (Iqbal et al. 2006).

Conjugated dienes The extent of oxidation products increased during the storage period of 3-months (Fig. 1). Conjugated dienes of 3-months stored T₂ and control were not different from each other ($P > 0.05$). *Moringa oleifera* oil had a strong control over the autoxidation; antioxidant activity of the blends increased a function of *Moringa oleifera* oil in a dose dependent manner. The addition of interesterified *Moringa oleifera* oil in butter oil considerably inhibited the generation of oxidation products (Nadeem et al. 2012). Transesterified blend containing 50 % palm olein and 50 % *Moringa oleifera* oil was similar to the hydrogenated vanaspati in terms of extents of oxidation products. The concentration of oxidation products increased in canola and sunflower oil during storage (Anwar et al. 2010; Chatha et al. 2011). The extent of unsaturated fatty acids and oxidation products in edible oils were strongly correlated by Gulla and Waghray (2011). But the results of our study are different from the previously reported work; the difference could be due to natural fatty acid composition of *Moringa oleifera* oil, which can confer this capability to other oils.

Table 5 Sensory characteristics of blends of *Moringa oleifera* oil and palm olein

Treatments	Smell	Texture	Overall acceptability
Control	8.2±0.28a	8.2±0.16a	7.9±0.24a
T ₁	8.1±0.25a	7.5±0.14b	7.2±0.19b
T ₂	8.2±0.41a	7.6±0.34b	7.6±0.10b
T ₃	8.1±0.31a	7.3±0.10b	6.3±0.18c
T ₄	8.0±0.42a	6.5±0.15c	6.0±0.23c
T ₅	7.9±0.23a	6.7±0.26c	5.5±0.15d

Means of triplicate experiments; means denoted by similar letter in a column are not different

Refer Table 1 for the detail of treatments

Table 6 Sensory characteristics of French fries prepared in blends of *Moringa oleifera* oil and palm olein

Treatments	Color	Smell	Taste	Overall acceptability
Control	8.5±0.25	8.1±0.14	8.4±0.16	7.6±0.13
T ₁	8.2±0.17	8.0±0.19	8.2±0.23	7.5±0.09
T ₂	8.4±0.31	8.2±0.27	8.3±0.14	7.5±0.29
T ₃	8.1±0.19	8.0±0.34	8.0±0.11	7.4±0.42
T ₄	8.0±0.33	8.1±0.18	8.1±0.08	7.3±0.15
T ₅	8.1±0.15	8.0±0.12	8.0±0.15	7.3±0.12

The mean values presented in a column are not different

Means of triplicate experiments; means denoted by similar letter in a column are not different

Refer Table 1 for the detail of treatments

Induction period Measurement of induction period defines the expected shelf life of edible oil and fats (Anwar et al. 2006). Partially hydrogenated oils are less vulnerable to the detrimental effects of autoxidation (Potter and Hotchkis 1998). The average temperature of the subcontinent is higher for many months of the year, fats and oils are stored in unrefrigerated open shops which speed up the autoxidation process. Therefore, blends selected should be resistant to autoxidation. In this study the employment of *Moringa oleifera* oil in the formulation of vanaspati considerably improved the induction period of the blends in a dose dependent manner (Fig. 2). The induction period of T₂ was comparable to the control (hydrogenated commercial vanaspati). The highest induction period of T₅ can be justified the presence of a wide range of phenolics in higher concentration of *Moringa oleifera* oil and greater free radical scavenging activity (Nadeem et al. 2013a). The intensification of induction period of sunflower and sunflower oils has been achieved in blends with *Moringa oleifera* oil (Anwar et al. 2007). Nadeem et al. (2013a) also reported an increase in the induction period of butter oil as a function of addition and concentration of *Moringa oleifera* oil.

Sensory characteristics The results of sensory characteristics of *Moringa oleifera* oil and palm olein blends are presented in

Tables 5 and 6. In this study we also determined the sensory characteristics of transesterified palm olein, *Moringa oleifera* oil blends and French fries prepared in the same. Score for the smell of blends and substrate oils were not different from the control ($P>0.05$). The non-difference could be connected to the deodorization at the higher temperature till negative Kries test. The judges evaluated the texture on the basis of presence or absence of grains in the experimental samples. Major difference was observed in the *transesterified* blends with respect to textural characteristics. People of subcontinent have preference for the granular vanaspati and believe that granular fats confer better taste to the cooked and fried goods. Therefore, edible oil processors hydrogenated the soft oils alone or in combinations and subsequent slow cooling of the deodorized stuffs in a controlled manner. The granular appearance of the vanaspati is due to the formation of large number of undesirable *trans* fatty acids due to the formation of β -crystals, the higher the *trans* isomers in the partially hydrogenated stuffs, greater would be the granular appearance (Fereidoon 2005). The random rearrangement of the esters also change the crystal formation behavior of the fats, the lack of granular appearance in the tested blends was due to the generation of β -prime crystals which confer pasty appearance to the fats (Erickson 1999). Colour, smell, taste and overall acceptability of French fries prepared in blends of palm olein and *Moringa oleifera* and substrate oils were not different from the control ($P>0.05$). In addition to the determination of suitability of *Moringa oleifera* oil in blends with palm olein as vanaspati substitute, this study also investigated the sensory quality of French fries prepared in *Moringa oleifera* oil. The physico-chemical characteristics of *Moringa oleifera* oil has been extensively studied, however, little information is available regarding the application of *Moringa oleifera* oil in the preparation/formulation of value added food products (Fig. 3). Palm olein is extensively used in the frying of potato chips, fatty acid composition and natural oxidative stability of *Moringa oleifera* oil offers great perspectives for the utilization of *Moringa oleifera* oil as a source of edible oil on commercial scale. The overall acceptability score of the blend containing 50 % palm olein and 50 % *Moringa oleifera* oil was 81 % of the total score (9).

Fig. 3 Correlation between transesterified palm olein: *Moringa oleifera* oil blends and overall acceptability score

Conclusion Melting point of the blend containing 50 % palm olein and 50 % *Moringa oleifera* oil (T_2) was not different from the market vanaspati with no trans fatty acids. The addition of *Moringa oleifera* oil improved the oxidative stability of the blends with virtually no trans fatty acids. The overall acceptability of French fries prepared in T_2 was not different from the control. Transesterified blend containing 50 % palm olein and 50 % *Moringa oleifera* oil can be successfully used as a vanaspati substitute with increased health benefits and extended shelf life.

Acknowledgments The authors are grateful to Sheikh Pervez Ahmed Anwel, General Manger Works, United Industries Ltd. Faisalabad for the tremendous help in this work.

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