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# Characterisation of Mango Kernel Fat and Preparation of Tran's-Free Margarine for Use in Muffins

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## Abstract

Six different samples of mangoes were found to contain 13.0-15.3% seeds and 41.1-66.7% kernels. The seed kernels contained 9.6-10.6% fat with slip melting point ranging from 24°C-30°C. Gas chromatographic analysis showed that the major fatty acids were stearic acid (31.3-41.3%), oleic acid (38.7- 42.3%) and palmitic acid (8.3-11.3%). Mango kernel fat was blended with palm oil at 0 to 30% levels and margarines were prepared incorporating suitable additives. Margarine containing 30% palm oil blend (experimental margarine-EM) showed textural characteristics closer to commercial bakery margarine (CM). Muffins were prepared by replacing CM with EM at 25, 50, 75 and 100% levels. Fat content of the muffins ranged between 24.8 and 26.2%. Fatty acid composition showed a decrease in palmitic acid and trans fat acid and increase in stearic acid content. Physical characteristics and sensory evaluation showed that muffins prepared by replacing 50% of CM were highly acceptable. Thus, it could be concluded that muffins having improved fatty acid profile can be prepared utilizing mango kernel fat.

**Keywords:** Fatty acid composition; Mango kernel fat; Muffins; Palm oil; Tran's free margarines

## Introduction

Mango (*Mangifera indica* L., Anacardiaceae), referred to as the king of fruits in South Asian countries is one of the most important tropical fruits grown commercially in more than 87 countries. India ranks number one among world's mango producing countries accounting for about 52.4% of total world production [1]. Mango fruits have been utilized for a long time at every stage of growth. The raw fruits are used for products like pickles, chutney, mango sauce and green mango beverages whereas ripe fruits are processed into jams, jellies, frozen slices, canned products, dehydrated slices and ready to serve beverages [2]. After the consumption or industrial processing of the fruits, a considerable amount of the seeds is discarded as waste [3]. The seed content of different varieties of mangoes ranges from 3-25% of the fruit weight, the kernel content of the seed varies from 54-85% and the kernels contain 3.7-12.6% fat [4]. The nutritional and toxicological studies showed that the fat was safe for consumption without adverse effects [5].

Production of edible oil in India was around 8.20 million tons whereas the demand was 17.5 million tons during 2012-13 [6]. India imports more than 50% of its domestic requirements of edible oils and 10% of the total consumption are utilized for vanaspati production by partial hydrogenation process [7]. During this process, there is isomerisation of cis isomers of unsaturated fatty acids resulting in trans fat formation. Commercial hydrogenated fats were found to contain up to 30% trans fat [8]. Several studies have suggested a direct relationship between trans fat acids and increased risk for coronary heart diseases as well as raise of plasmatic lipid levels [9]. Thus in addition to the constraint of availability of edible oils, there is formation of harmful trans fat acids when the edible oil is subjected to partial hydrogenation. WHO recommends that the consumption of trans fat should not exceed 1% energy [10], and a lot of research is going on globally in identifying suitable fats and oils for development of fats devoid of trans fat acids [11].

Margarine is water-in-oil (W/O) emulsified food product which contains at least 80% fat [12]. Margarines are available in various forms such as table margarine, bakery margarine, industrial margarine, soft margarine, tub margarine, etc and are one of the major dietary sources of trans fat [13]. While analysing twelve different samples of tub margarine and stick margarine, Tekin et al. [14] found the absence of trans fat in four samples and reported that those samples were formulated from blended or interesterified fats and oils [14].

Palm oil ranks number one in world's edible oils and fats production and there is a gradual increase in the production from 29.59 million tons during 2003-04 to 49.34 million tons during 2010-11 [15]. It crystallizes in β′ polymorphic form desirable for use in margarines and shortenings [16]. Margarine made from canola oil exhibits β crystal form whereas canola, palm, soybean and corn oil margarines show β′ crystals [17]. Thus, palm oil has been used along with other oils for the preparation of zero Tran's margarines and shortenings. Norlida et al. [18] prepared pastry margarine by blending palm oil, palm stearin and palm kernel oil and reported that the characteristics were similar to that of the commercial sample [18].

The acute and consistent shortage of traditional edible oils in India has necessitated the utilization of unconventional oils in suitable food systems. As early as 1977, it is reported that India has the potential to produce 30,000 tons of mango kernel fat (MKF) annually [19]. Though exact statistics is not available, currently a large amount of mango kernel fat is being produced commercially. To the best of our knowledge, there are no reports on the development of margarines from commercially produced MKF.

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The objective of the work was to study the characteristics of fat extracted from mango seed kernels and to explore the suitability of MKF for the preparation of zero Tran's margarine for its application in muffins.

## Materials and Methods

### Materials

Three samples of raw mangoes of omlete and senthoora varieties, coded as RW1, RW2 and RW3 and two samples of ripe mangoes of senthoora and totapuri varieties coded as RP1 and RP2 were obtained from a local market in Mysore, India. The sample RP3 was totapuri variety kernels obtained from a fruit processing industry in Krishnagiri, Tamil Nadu, India. Refined, bleached and deodourized commercial MKF was purchased from M/s Pioneer enterprises, Mumbai, India. Bakery margarine used was Golden Seal Margarine (GSM) classic, Bunge India Private Limited, Mumbai, India. Salted butter, plain butter, table margarine, a table spread, bakery margarine, refined palm oil and other ingredients were bought from a local supermarket in Mysore, Karnataka, India.

Standard fatty acid methyl esters and triglycerides were obtained from M/s Sigma Chemical Co. (St. Louis, MO), HPLC solvents and other chemicals were obtained from M/s Qualigens fine chemicals, Mumbai, India.

### Methodologies

**Fat extraction and analysis:** Flesh was removed from a known quantity of mangoes and fruit to seed and seed to kernel weight ratio were calculated as the percentage. The seeds were then dried at 100°C for 1 h, cut open and kernels were collected. The kernels were powdered and fat extracted using petroleum ether in Soxhlet extractor for 8 h. The fat content was calculated as weight percentage of kernels. Triplicate analysis was done and the average value is reported.

Fat samples were heated to 65°C in a water bath and the slip melting point (SMP) was measured using open capillary tubes. The capillary was dipped to fill fat for 10 mm height, was placed on a piece of ice to solidify the fat and then held at refrigerated temperature for about 16 h as per standard AOCS official method Cc 3-25 [20]. Two capillaries were attached gently to a thermometer and fixed onto a Thiele tube. The side arm of the flask was heated slowly (1 °C/min) and the temperature at which the fat melts, slips and raises was noted. Triplicate measurements were made and the average value is reported.

Fat samples were converted to fatty acid methyl esters (FAME) using sodium methoxide as per standard AOCS Official Method Ce 2-66 (AOCS, 2003). The fatty acid composition was determined by GC (Shimadzu 2010) using flame ionization detector operated under the following conditions: RTX-2330 capillary column (30 m × 0.32 mm); Nitrogen flow 40 ml/min; Hydrogen flow 40 ml/min; air flow 300 ml/min; column temperature 180°C; injector temperature 250°C and FID temperature 260°C. The fatty acids were identified using authentic standards and reported as a relative percentage.

Triglyceride composition was determined by high-performance liquid chromatography, (HPLC) using a Shimadzu system controller (LC-10A) and refractive index detector (RID-10A). A C-18 column (Supelco; Discovery; 25 cm × 4.6 mm; 5 µm) maintained at 35°C was used. The mobile phase was a mixture of acetone/acetonitrile (63:37, v/v) at the flow rate of 1 ml/min. The sample was dissolved in chloroform, and 10 µL was injected. The peaks were identified by comparing the retention times with those of authentic standards and reported as a relative percentage of individual triacylglycerols.

### Preparation of margarines

Based on few preliminary trials, fat blends containing 0 to 30% palm oil with commercial MKF was prepared. The blends were melted separately, heated to 70°C to melt away any crystal nuclei and a fat phase containing lecithin and fat blend was prepared. The molten mixture was gently mixed and an aqueous phase containing hot water, skimmed milk powder and salt was slowly added. The mixture was homogenised for 2 min at 1000 RPM and speed slowly increased to 10000 RPM using a homogenizer (IKA T25 digital, Ultra Turrax). The emulsions were crystallized at 8-10°C for 1 h and tempered at 26°C for 24 h. The products were then worked with a whipper for 5 min, poured into containers and stored in the refrigerator.

### Characteristics of margarines

Textural properties of margarines were evaluated at 25°C using the texture profile analysis (TPA) procedure [13]. Fifty grams of samples were filled into texture measurement cups taking care to avoid air bubbles. A double compression test was performed using an instrumental texture analyzer (Model LR5K Lloyd Instruments, UK). A 45° conical probe attached to a 50 N compression load cell was used to penetrate the samples at 1.0 mm/s to a depth of 10 mm from the sample surface, and withdrawn at the same speed. The maximum force (N) during the first compression is reported as hardness. The negative force area for the first compression is reported as adhesiveness in N mm. The ratio of the positive force area during the second compression to that of the first compression is reported as cohesiveness. Average of four values is reported.

FTIR spectral studies were carried out using an FTIR spectrometer (Perkin Elmer Spectrum 2000, Norwalk, CT, USA). The samples were smeared onto KBr windows and the spectra were recorded from 400 to 4000 $cm^{-1}$.

In order to study the microbial stability, EM was prepared in a sterile container. Portions (25 g) of the sample were taken, diluted in 225 ml saline and plated for quantitative analysis of aerobic mesophilic plate count, yeast and mold count, *Staphylococcus* count and detection of *E. coli* and *Salmonella* as per the methods laid down by Vanderzant and Splittstoesser [21].

### Preparation of muffins

Muffins were prepared by replacing the bakery margarine with experimental margarine (EM) at 25, 50, 75 and 100% levels according to the method described by Chetana et al. [22]. The formula included 100 g refined wheat flour, 84 g sugar powder, 84 g margarine, 84 g eggs, 1.7 g baking powder and 1.5 ml vanilla essence. About 50 g batter was poured into a greased muffin tray and baked at 200°C for 25 min.

### Characteristics of muffins

Volume of muffins was measured by rapeseed displacement method and specific volume (cc/g) was calculated. Texture of the muffins was measured objectively using Texture Analyzer (TAHDi, Stable Micro System, UK) as per the standard AACC method 74-09 [23]. The crumb color was measured using an Instrumental colour measuring system (Colour measuring Labscan XE system, Santa Clara, CA). Fat content was estimated by Soxhlet method and the fatty acid composition was analysed as described earlier.

Muffins were sensorily evaluated by a ten member's semi-trained panel. The panellists were asked to score each sensory attribute using the control muffins as basis for evaluation. The samples were evaluated for appearance, crust colour, crumb colour, grain, tenderness, moistness, flavour, mouth feel and overall quality on a 9-point hedonic scale. The scores assigned in the score card for the parameters were as follows: excellent - 9, very good - 8, good - 6, satisfactory -5, fair - 3, poor - 2 and very poor -1.

### Statistical analysis

Data were statistically analyzed by using ANOVA with varying experimental groups appropriate to the completely randomized design with different replicates. The experimental groups were then separated statistically using Duncan's new multiple range tests, as described by Steel and Torrie at $p \leq 0.05$ [24].

## Results and Discussion

### Fat yield and physicochemical characteristics

The seed content of the mangoes ranged between 13.0 and 15.3% and the kernel content was between 41.1 and 66.7% (Table 1) which were within the range reported in the literature [4]. In a recent review, Ravani and Joshi [25] have provided elaborate details on the processing technologies for a number of mango products giving scope for availability of a considerable amount of seeds from mango processing industries. It was interesting to observe that seed kernels of both ripe and raw mangoes contained 9.6 to 10.6% fat (Table 1). Depending on the variety, various levels of fat content ranging between 6 and 15% has been reported [26-28].

Slip melting point (SMP) of fats is one of the important parameters used to predict the suitability of fats for various end uses. As per the legal requirements in India, the table margarine must have SMP of 31 to 37°C, bakery and industrial margarine should have SMP of 31 to 41°C and the fat spread which is also a water-in-oil emulsion should have SMP not more than 7°C [29]. The SMP of MKF ranged between 23.5 and 30°C (Table 1). The Iranian varieties had the melting point of 30°C [30]; the Keaw variety was reported to have SMP of 35.7°C [3] and the Alphonso variety 35.5°C [26]. The sample RW1 showed higher SMP compared to RW2 (Table 1) indicating the presence of higher levels of saturated fatty acids. The higher SMP due to higher saturated fatty acids has been reported earlier [8].

Fatty acid composition presented in Table 2 shows that the major fatty acids are stearic acid (31.3 to 41.3%) and oleic acid (38.7 to 42.3%). The other fatty acids were palmitic (8.3-11.3%), linoleic (6.1-9.1%), arachidic (2.0-3.1%), linolenic (0.5-1.4%), behenic (0.3-1.4%) and lignoceric (0.5-1.0%) acids. Traces of lauric, myristic and palmitoleic acids were also detected. The higher saturated fatty acid content can contribute to the better stability of the foods.

The triglyceride profile showed the presence of partial glycerides in the fat (Figure 1). The triglyceride composition showed that the fat contained 9.14% triolein, 32.78% SUU type triglycerides with dioleostearin (23.18%) as the major one and 55.64% SUS type triglycerides with 31.04% 2-oleodistearin as the major triglyceride. The heterogeneous type triglycerides contribute to the β′crystals desirable for use as margarines [16].

### Characteristics of margarines

Texture of margarine is an important parameter in understanding the spreadability as higher the hardness value the harder is the fat [13]. The commercial fats showed hardness values ranging between 0.47 and 1.74N, the highest value being that of bakery margarine (Table 3). The sample prepared using margarine having 0% palm oil (MM 0P) was

| Samples | Codes | Seed in fruits (%) | Kernels in seeds (%) | Fat in kernels (%) | Fat in fruits (%) | Slip melting point (°C) |
|---|---|---|---|---|---|---|
| Raw mango 1 (Omlete) | RW1 | 13.0 | 55.1 | 9.6 | 0.34 | 30.0 |
| Raw mango 2 (Senthoora) | RW2 | 15.3 | 41.1 | 9.9 | 0.33 | 23.5 |
| Ripe mango 1 (Senthoora) | RP1 | 15.2 | 66.7 | 9.7 | 0.35 | 29.0 |
| Ripe mango 2 (Totapuri) | RP2 | 13.3 | 47.3 | 10.6 | 0.22 | 28.5 |
| Ripe mango 3 (Totapuri) | RP3 | - | - | - | - | 29.0 |

**Table 1:** Fat content and slip melting point of different varieties of raw and ripe mango samples.

| Sample Codes*/Fatty acids | RW1 | RW2 | RW3 | RP1 | RP2 | RP3 |
|---|---|---|---|---|---|---|
| Lauric acid, 12:0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Myristic acid, 14:0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Palmitic acid, 16:0 | 10.1 ± 0.7 | 11.2 ± 0.6 | 11.3 ± 0.5 | 8.3 ± 0.4 | 9.2 ± 0.7 | 8.5 ± 0.6 |
| Palmitoleic acid, 16:1 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 |
| Stearic acid, 18:0 | 41 ± 1.2 | 31.3 ± 0.9 | 34.2 ± 0.8 | 39.6 ± 0.9 | 38.7 ± 0.9 | 41.3 ± 1 |
| Oleic acid, 18:1 | 35.5 ± 1 | 42.3 ± 0.7 | 40 ± 0.9 | 39.1 ± 0.7 | 40.3 ± 0.8 | 38.7 ± 0.6 |
| Linoleic acid, 18:2 | 9 ± 0.2 | 7.9 ± 0.4 | 9.7 ± 0.2 | 6.4 ± 0.3 | 6.6 ± 0.4 | 6.7 ± 0.6 |
| Linolenic acid, 18:3 | 0.6 ± 0.1 | 1.4 ± 0.1 | 1.1 ± 0.1 | 0.7 ± 0.1 | 0.9 ± 0.1 | 0.5 ± 0.1 |
| Arachidic acid, 20:0 | 2 ± 0.2 | 3.1 ± 0.3 | 2.3 ± 0.2 | 2.8 ± 0.1 | 2.2 ± 0.1 | 2.3 ± 0.2 |
| Behenic acid, 22:0 | 0.4 ± 0.1 | 1 ± 0.2 | 0.4 ± 0.1 | 1.4 ± 0.3 | 0.3 ± 0.1 | 0.8 ± 0.1 |
| Lignoceric acid, 24:0 | 0.4 ± 0.1 | 1 ± 0.2 | 0.5 ± 0.1 | 0.7 ± 0.3 | 0.5 ± 0.1 | 0.6 ± 0.1 |
| Σ Saturated fatty acids | 54.1 | 47.8 | 48.9 | 53 | 51.1 | 53.7 |
| Σ Unsaturated fatty acids | 45.3 | 51.8 | 50.3 | 46.4 | 48 | 45.5 |
| Σ Mono unsaturated fatty acids | 35.7 | 42.5 | 40.1 | 39.3 | 40.5 | 38.9 |
| Σ Poly unsaturated fatty acids | 9.6 | 9.3 | 10.2 | 7.1 | 7.3 | 6.6 |

*Refer Table 1 for codes.

**Table 2:** Fatty acid composition (relative %) of fat extracted from different samples of mango seed kernels.

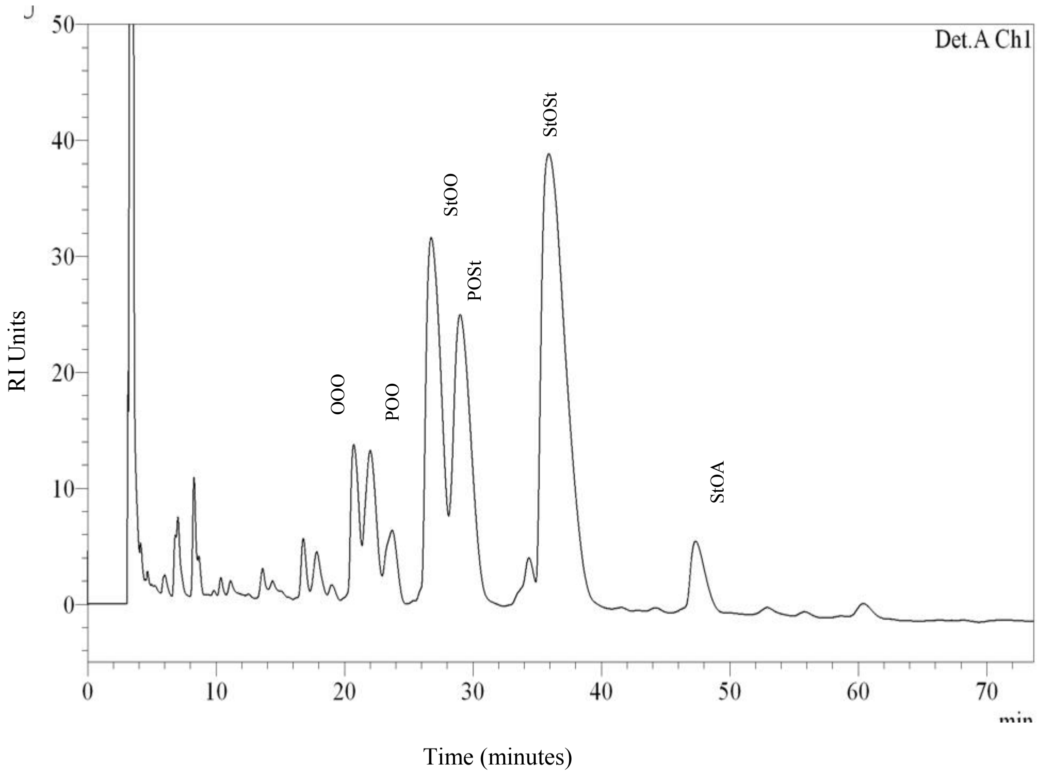


**Figure 1:** Triglyceride profile of mango kernel fat (O: Oleic acid; P: Palmitic acid; St: Stearic acid; A: Arachidic acid).

| Samples | Hardness (N) | Adhesiveness (Nmm) | Cohesiveness |
|---|---|---|---|
| Salted butter | 0.50 ± 0.08f | 0.13 ± 0.01d | 0.52 ± 0.06b |
| Plain butter | 0.47 ± 0.04f | 0.18 ± 0.05d | 0.45 ± 0.03b |
| Table Margarine | 1.33 ± 0.11de | 0.16 ± 0.09d | 0.23 ± 0.03c |
| Table spread | 1.08 ± 0.16e | 0.21 ± 0.03d | 0.33 ± 0.06c |
| Bakery margarine | 1.74 ± 0.09de | 2.80 ± 0.57bc | 0.67 ± 0.06a |
| MM 0P | 14.75 ± 1.79a | 5.49 ± 2.30a | 0.05 ± 0.01e |
| MM 10P | 7.31 ± 0.13b | 3.20 ± 0.62bc | 0.08 ± 0.01de |
| MM 20P | 3.17 ± 0.35c | 4.43 ± 1.30ab | 0.14 ± 0.02d |
| MM 30P | 2.33 ± 0.28cd | 2.42 ± 0.55c | 0.30 ± 0.04c |
| SEM( ± ) | 0.04 | 0.54 | 0.02 |
| df | 18 | 18 | 18 |

MM 0P, MM 10P, MM 20P MM 30P - Margarines prepared using fat phase containing mango kernel fat with 0, 10, 20 and 30% palm oil respectively. Values are means ± SD (n=4); Values followed by different letters in the same column are significantly different from each other ($p<0.05$)

**Table 3:** Texture profile analysis of margarines prepared using mango kernel fat incorporating different levels of palm oil compared with commercial spreadable fats.

very hard with the hardness value of 14.75 N which reduced to 2.33 N when palm oil was incorporated at 10 to 30% levels (Table 3). This data supports the observation of Lumor et al. [13] that the fat having higher levels of saturated triglycerides will be harder than the one having lower levels of highly saturated triglycerides. Samples having higher hardness values are difficult to spread [13] and hence the margarine containing 30% palm oil, hereafter referred as experimental margarine (EM) having lowest hardness values was chosen for further studies.

Fourier Transform Infrared Spectroscopy (FTIR) is a rapid analytical technique that measures vibrations of bonds within functional groups. Tran's absorption region was found to be in the range of 995-937 $cm^{-1}$ with a peak at 966 $cm^{-1}$. The FTIR spectrum of commercial bakery margarine showed a distinct absorption peak at 966 $cm^{-1}$ (Figure 2A), which is a characteristic of Tran's compounds [31]. The peak was absent in EM (Figure 2B) and based on this study, it could be concluded that the margarine prepared utilizing MKF did not contain trans fat.

The margarines containing 12-16% water are usually stored under ambient conditions and the microbial safety is very important. There is no mention about the microbial parameters for margarines as per Indian regulations [29]. However when compared with pasteurized butter, the EM showed that the total plate count, yeast and mold count and *Staphylococcus* count were well below the permissible limits and *E. coli* and *Salmonella* were absent showing that the sample was safe for consumption. Water-in oil emulsions are more stable than the water itself because only a small fraction of droplets of the emulsion is

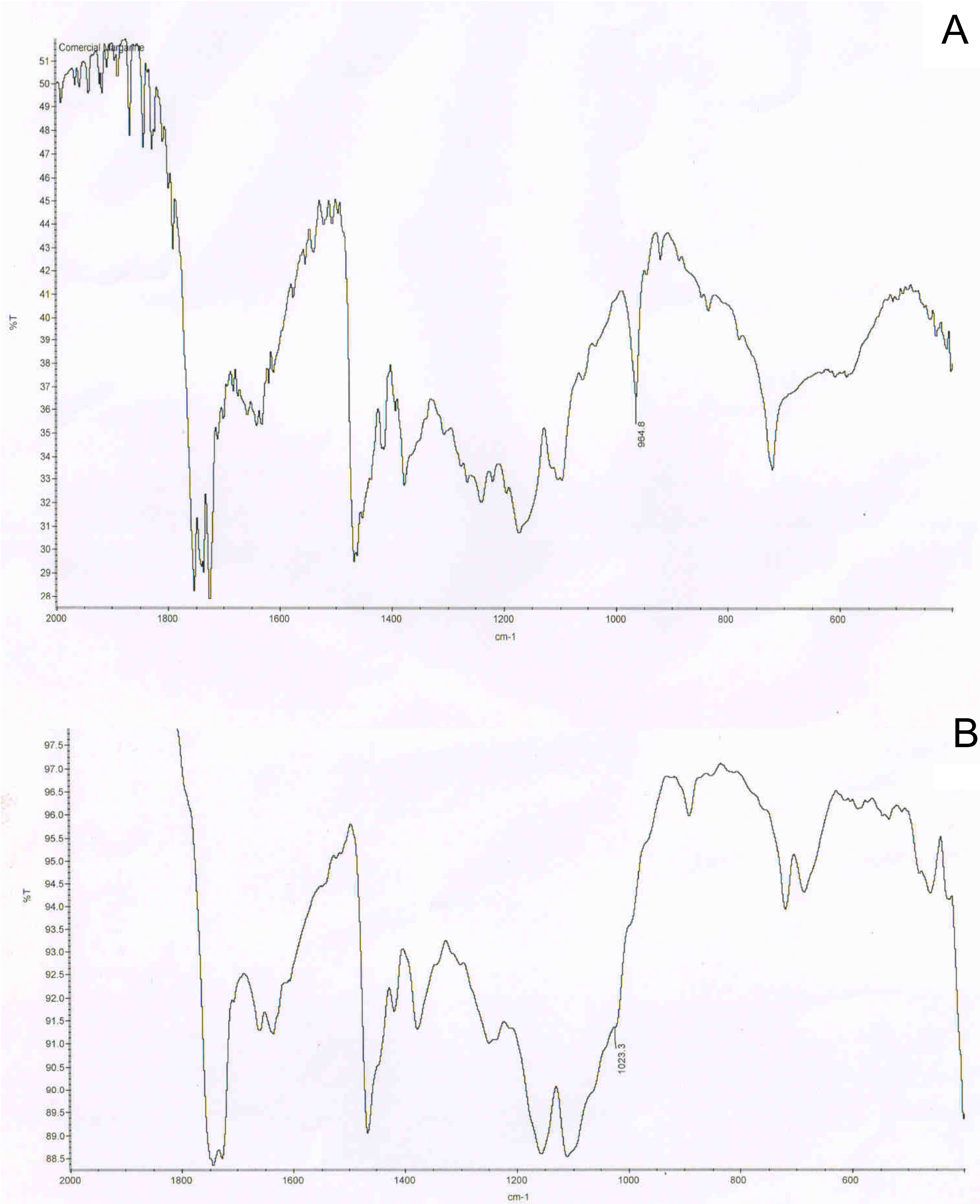


**Figure 2:** FTIR spectra of commercial bakery margarine (A) highlighting the peak corresponding to trans fat acids compared with experimental margarine (B).

| Code | EM (%) | Crude fat[A] (%) | Moisture[A] (%) | Volume[A] (cc) | Specific volume[A] (cc/g) | Firmness[B] (g force) | L*[A] | ΔE[A] |
|---|---|---|---|---|---|---|---|---|
| Control | 0 | 25.76 ± 0.69a | 20.01 ± 0.03 | 130 ± 2.1c | 2.50 ± 0.13c | 1021 ± 3.7c | 67.9 ± 0.1a | 29.6 ± 0.1e |
| EM 1 | 25 | 25.05 ± 0.02ab | 20.80 ± 0.01 | 150 ± 2.2b | 2.87 ± 0.14b | 1001 ± 5.9d | 67.0 ± 0.2a | 30.4 ± 0.2d |
| EM 2 | 50 | 24.22 ± 0.77b | 20.60 ± 0.02 | 160 ± 2.4a | 2.92 ± 0.09a | 980 ± 4.1e | 66.7 ± 0.3b | 31.9 ± 0.1c |
| EM 3 | 75 | 25.15 ± 0.77ab | 20.40 ± 0.03 | 130 ± 1.3c | 2.21 ± 0.11d | 1545 ± 6.2b | 65.5 ± 0.3c | 34.8 ± 0.1b |
| EM 4 | 100 | 26.80 ± 0.76a | 20.50 ± 0.01 | 120 ± 2.7d | 1.83 ± 0.18e | 2013 ± 5.3a | 60.6 ± 0.2d | 35.6 ± 0.1a |
| SEM (±) | - | 0.12 | 0.11 | 0.49 | 0.12 | 5.23 | 0.42 | 0.19 |
| df | - | 10 | 10 | 10 | 10 | 25 | 25 | 25 |

Values are means ± SD (n: A=3, B=6), Values followed by different letters in the same column are significantly different from each other (p ≤ 0.05)

**Table 4:** Physical characteristics of muffins prepared by incorporating different levels of experimental margarine (EM).

| Sample Codes | EM (%) | Appearance (9) | Crumb colour (9) | Texture (9) | Taste (9) | Overall quality (9) |
|---|---|---|---|---|---|---|
| Control | 0 | 8.00c | 8.00bc | 8.0bc | 8.00ab | 8.00bc |
| EM 1 | 25 | 8.25b | 8.23ab | 8.23ab | 8.20a | 8.25ab |
| EM 2 | 50 | 8.45a | 8.50a | 8.50a | 8.20a | 8.50a |
| EM 3 | 75 | 7.50d | 7.50d | 7.00d | 7.52b | 7.50d |
| EM 4 | 100 | 6.75e | 6.5e | 6.50e | 7.25c | 7.00e |
| SEM ( ± ) | - | 0.12 | 0.13 | 0.23 | 0.21 | 0.18 |

Values followed by different letters in the same column are significantly different from each other (p ≤ 0.05) at 25 degrees of freedom

**Table 5:** Sensory characteristics of muffins prepared by incorporating different levels of experimental margarine (EM).

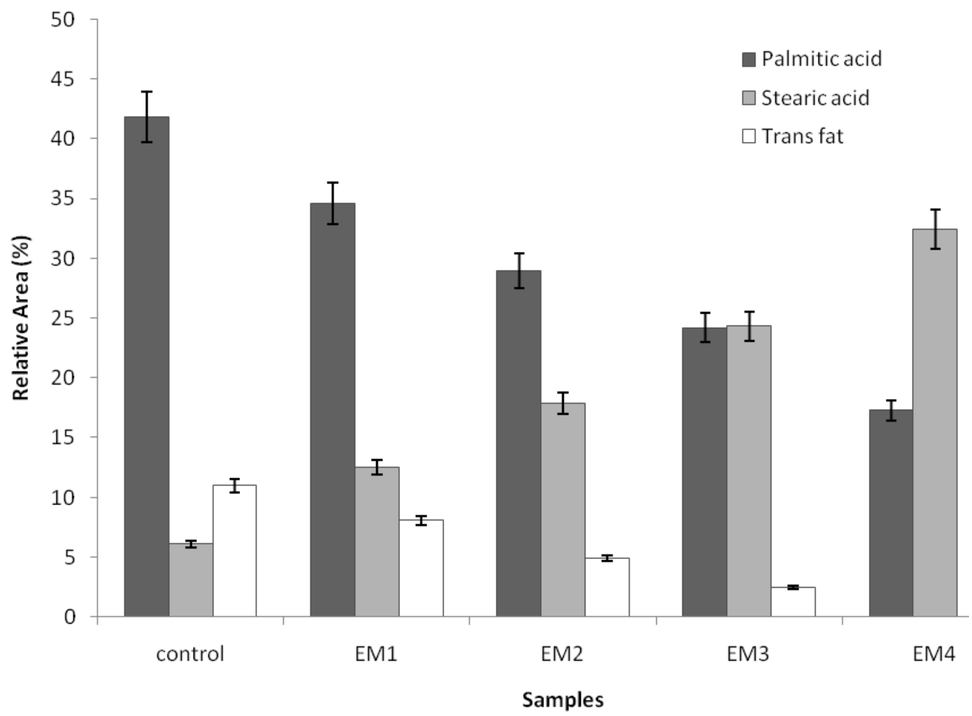


**Figure 3:** Fatty acid composition of muffins incorporated with different levels of experimental margarine. EM1, EM2, EM3, EM4: Samples prepared using 25, 50, 75 and 100% respectively of commercial bakery margarine replaced using experimental margarine.

occupied by the microorganisms originating from the water phase and the size of these droplets limits the outgrowth of microorganisms [32].

## Evaluation of margarine in muffins

Bakery products are generally prepared using hydrogenated fats because of the various functionality it provides while preparing the dough and also during the baking. The role of fat is to cover the proteins and starch granules, isolating them and interrupting the continuity of the structure formed by the protein and starch [33]. Replacing the fat with peach dietary fibre is reported to increase the hardness and chewiness of the muffins due to stronger gluten development [34].

Moisture content of the muffins on replacing the CM using 25,50,75 and 100% EM was about 20% and the fat content ranged between 24.2 and 26.8% (Table 4). Fat content in the formulation is a decisive factor for the final dimensions of the baked products. The L values decreased (67.9 to 60.6) whereas the ΔE values increased (29.6 to 35.6) with an increase in the EM. As the incorporation of EM increased from 0% to 50%, the volume of the cake increased from 130 to 160 cc and with further increase in the EM the volume decreased to 120 cc (Table 4). Similarly, the specific volume of the muffins increased initially from 2.50-2.92 cc/g and later decreased to 1.83 cc/g. This indicates that substituting the CM with EM at 50% levels helped in aerating the cream better and expanded sufficiently during baking. The texture studies showed that the muffins became softer with increase in levels of EM till 50% as seen in the reduction of crumb firmness values from 1021 to 980 g and further increase in the EM to 100%, the firmness value increased to 2013 g, which was double the firmness value of a control sample. This is due to poor expansion and dense crumb structure which increased the firmness value at higher levels of EM. Reduction in CM in the cake formulation reduced the volume of cakes and crumb firmness increased [35]. These results indicate that 50% replacement of CM by EM is acceptable.

Sensory evaluation of the muffins showed that the scores for the crust appearance increased with increase in EM till 50% and decreased with further increase to 100% (Table 5). The shape of the muffins was symmetrical and normal up to 75% level. Similarly, the scores for crumb colour of muffins increased significantly. Up to 50%, the crumb colour was appealing. The texture of muffins was observed softer till 50% replacement and became slightly hard on further increase. Taste was acceptable at 50% EM. The overall quality indicated that 50% EM replaced muffins were highly acceptable. It is reported that 65% fat replacement by inulin, oligofructose etc gave cakes of acceptable texture and sensory attributes and beyond 65% replacement, cakes became harder [36].

With an increase in the percentage of EM, there was a gradual decrease in palmitic acid from 41.8% to 17.28% and trans fat acid content from 10.9% to 0% whereas the stearic acid content increased from 6.08% to 32.41% (Figure 3). Stearic acid does not raise serum total-cholesterol or LDL- cholesterol in the body as it rapidly gets converted into oleic acid [37]. The muffins prepared by replacing CM with EM at 50% had 4.92% trans fat content, compared to 10.97% of control. The increase in beneficial fatty acids and decrease in harmful fatty acids indicate that muffins prepared by incorporating EM are much healthier than control muffins.

## Conclusion

Search towards foods with zero trans fat is becoming highly important because of the concern associated with adverse effects of trans fat acids. Hence, margarine was developed utilizing mango kernel fat and palm oil blend incorporating suitable additives. Sensory characteristics showed that the muffin prepared by replacing the margarine at 50% level was highly acceptable and had 4.92% trans fat compared to 10.97% in control muffins. This study showed the potential for mango kernel fat to be used as zero Tran's margarine.

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