Research Article
The J. Res. PJTSAU 52(1&2)50-56, 2024

STUDY ON MAHUA (*Madhuca indica)* FAT AND TESTING ITS SUITABILITY FOR BAKING

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Date of Receipt: 18-03-2024 Date of Acceptance: 22-04-2024

ABSTRACT

Mahua fat is an underutilized fat with very less usage in food processing activities and suitability of the fat for bakery applications has not been explored till date. This study evaluated the physicochemical characteristics of mahua fat and assessed its suitability as a bakery shortening through product development, sensory evaluation, and fatty acid profiling. Mahua oil was expelled using a screw-type oil expeller, and tested for various quality parameters. Muffins and buns were prepared using the mahua fat and were subjected to sensory evaluation, and the best acceptable product was subjected to fat and fatty acid analysis. Mahua fat had acceptable Iodine value, saponification value, specific gravity, refractive index, melting point and smoke point, indicating the suitability as a bakery fat. The overall acceptability of mahua muffin was 8.33 ± 0.52, compared to 7.29 ± 0.95 in mahua bun on a 9 point hedonic scale, indicating that mahua fat shows potential for application as a shortening fat for development of bakery products like muffins with very good sensory acceptability. Mahua oil is rich source of palmitic acid, stearic acid among saturated fats and oleic acid and linoleic acid among the unsaturated fats. Essential fatty acid Cis-11-Eicosenoic Acid (C20:1n9), was also detected in traces in both mahua fat and mahua muffin.

Key words: Mahua, Fat, Baking, Fatty acid, Muffins

Oil and fat industries continue to explore novel oil-bearing plants and seeds that provide high oil yields for nutritional applications, food processing, and diversification of agricultural supply chains. In recent years, underutilized and non-traditional fruit seeds have attracted increasing attention for food applications because of their unique chemical composition and potential to expand the availability of nutritionally valuable and functional food ingredients. Ramadan *et al* (2016) and Yadav *et al.* (2011) reported that conventional vegetable oils contribute approximately 85% of the visible edible oils and fats consumed worldwide, while also highlighting the considerable potential of several underutilized plant sources capable of producing commercially viable quantities of oil and fat.

Madhuca indica (Sapotaceae) commonly known as Mahua is one such kind of underutilized tree found in almost all the tribal belts of India, and is considered a boon by the tribal communities / forest dwellers who keenly conserve this tree, for its cultural and economic significance. The mahua tree is medium sized to large deciduous tree, usually with a short bole and a large rounded crown. Mahua flowers are used as food, as well as an exchanger in tribal and rural areas. The tribes consider the mahua tree and locally brewed mahua beverage as a part of their cultural heritage. Approximately 7.5 million tribals are engaged in collection of mahua as a part of livelihood activity, and barter mahua for daily grocery items, the value of which is considerably more than the actual value of mahua traded. The collection and trade of mahua flowers provides employment to 28,600 persons/year, whereas, the potential is of 1,63,000 persons/year (Kumar *et al.*, 2018). One single mature tree provides an income of about Rs. 1500 from sale of flowers and seeds, in addition to various other tangible and intangible benefits (Kulkarni et al., 2013). Mahua seeds that are rich in edible oil with ample economic importance (Bisht *et al.* 2018), are still under-utilized for oil production, which could be due to the lack of technical information with regard to its properties and potential uses (Ramadan *et al.,* 2016). However, industrial utilization depends on several factors, including oil yield, storage stability, supply-chain management, and consumer awareness regarding the use of mahua oil.

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The seeds of mahua have considerable commercial potential as a source of edible vegetable oil, as the fruit seeds contain 50 to 61 % fat leading to excellent oil recovery from the seeds using commercial screw-press expellers (Manjunath *et al.* 2015). The expelled oil is pale yellow in color, semi-solid under the tropical temperature conditions and is classified as non-drying oil based on iodine value, and is reported to be similar to Malaysian cocoa butter or Borneo Illipe butter (Marikkar *et al.* 2010). However, mahua oil also known as mahua butter is softer when compared to Malaysian cocoa butter, which is hard and brittle, due to high Solid fat content. Firmness of fat is an important criterion that imparts the plasticity and rigidity to fatty materials due to the solid components present in the fat (Campos *et al.* 2002).

A number of functions are induced by lipids in the baking industry, which include mouthfeel, structural integrity, tenderization, air incorporation, lubrication, heat transfer and extension of shelf life (Ghotra *et al.,* 2002; Rogers, 2004). Lipids and plastic shortenings commonly used in the baking industry are often made by partial hydrogenation, to induce the various functional properties, which in turn impart acceptable sensory appeal to the products (Zhou *et al.,* 2011). Baking industry is growing and developing aggressively in India, and is looking for novel sources of potential fats. Convenience foods with good taste, reasonable price and favourable nutritional image are always in great demand (Shaik *et al.,* 2018). Since mahua butter has a semi solid and crystalline appearance, similar to hydrogenated fat, it might have a potential role in the baking industry.

Information concerning the exact composition of mahua butter extracted from kernels of mahua is sparse and its use as a bakery fat has not been explored. In consideration of potential utilization of mahua fat as a bakery fat, detailed knowledge on its suitability for bakery applications is of major importance. Hence, the study was planned with an objective to assess the suitability of mahua fat for preparation of baked products.

MATERIALS AND METHODS

Four litres of mahua oil which was freshly extracted using a screw-type oil expeller, was procured from Adilabad district of Telangana state, India. The oil was expelled in a screw type oil expeller, with screw shaft pitch of 25 mm, and internal barrel of 75 × 315 mm dimensions, with an optimum yield of 35 - 40%, with 30 kg/h machine capacity. The pure oil obtained by pressing followed by filtration was collected for further analysis and product development.

Physico-chemical analysis of mahua oil

The iodine value, saponification value, acid value, specific gravity, refractive index, melting point and smoke point were determined according to the standard AOCS method (1998).

Production of buns and muffins

Muffins and buns were prepared using a standard recipe with slight modifications described by Heo *et al.* (2019) and Arora and Saini (2016) respectively, using mahua butter and sunflower oil (as control). For preparation of muffins, refined wheat flour was mixed with baking powder and salt, sifted and then added to creamed oil, sugar, egg. This mixture was creamed again till it became light and fluffy, followed by filling in greased muffin tray and baking at 180°C for 25 min in a preheated oven. Buns were prepared, by mixing active dry yeast with lukewarm water and the dough was kneaded to required texture. The dough was proofed for 1 hour, till it became double its volume. Later the proofed dough was divided into round equal balls and baked at 180°C for 25 min in a preheated oven. Both muffins and buns prepared using sunflower oil were considered as control.

Sensory evaluation

Products were evaluated for parameters viz., appearance, color, texture, flavor, taste and overall acceptability by 21 semi-trained panelists using nine-point hedonic scale (0 = Dislike extremely to 9 = Like extremely; Meilgard *et al.,* 1999) to select best product among muffins and buns.

Total fat and fatty acid analysis of mahua oil and muffin

Total fat content was analysed in moisture free samples by Gerhardt soxtherm fat analyser (AOAC 2003.06, 20th Edition; Shaik *et al.*, 2017).

Fatty acids were analysed by AOAC (2001. 996.06) and Shaik *et al*., (2017) methods. The isolated fat was trans-esterified using 0.5 M methonolic KOH to form fatty acid methyl esters (FAME). Fatty acids were estimated by Gas Chromatograph (7890B of Agilent Technologies) equipped with flame ionization detector and Agilent - DB-FFAP column (nitro terephthalic-acid-modified polyethylene glycol (PEG) of high polarity for the analysis of volatile fatty acids). The temperature of the column was maintained at initial temperature of 100°C for 5 min, raised to 240°C at the rate of 4°C /min. Nitrogen was used as carrier gas at a column flow rate of 1.0 ml/min. Detector temperature was maintained at 280°C. Standard 47885-*U* Supelco® 37 Component FAME Mix was used at 10 mg/mL in methylene chloride. Individual trans-fatty acids standards like Supelco trans-9-Eliadic methyl ester (10 mg/ml in heptanes), trans-9, 12-Octadecadienoic (linoleliadic) methyl ester and trans-11-Vaccenic methyl ester, were used. Sample fatty acid composition was compared with standard fatty acid composition and percentages were calculated by normalization of peak areas.

Statistical analysis

The generated data on physico chemical properties, total fat and fatty acid composition are presented as mean ± standard deviation of three parallel measurements. The data was calculated using SPSS version 23 (SPSS, IBM, Chicago USA).

RESULTS & DISCUSSION

The physico chemical analysis of mahua fat (Table.1) resulted in 57.09 ± 1.14g I2/100g Iodine Value; 187.16 ±0.68mg KOH/g Saponification value; 3.51 ± 0.06 mg KOH/g Acid value; 0.93 ± 0.01 Specific gravity at 25 °C; 1.46 ±0.01 Refractive index at 40 °C; 33.94 ± 0.11 (°C) Melting point and 168.99 ± 0.95 (°C) Smoke point. Similar results were observed by Munasinghe and Wansapala (2015) in *Madhuca longifolia* seed oil. High Iodine value is an indication of high amount of unsaturation/double bonds and, a relatively low saponification value is an evidence for existence of more long chain fatty acids. High melting point, high specific gravity and high refractive index values are associated with presence of high amounts of long chain fatty acids and unsaturation/double bonds in mahua fat. Acid value (3.51 ± 0.06 mg KOH/g) was also below the maximum limit (4.0 mg KOH/g) specified by the codex standards (2001) and FSSAI (2015) for cold pressed oils. Smoke point of mahua butter (168.99 ± 0.95ºC) was found to be lower indicating that the degradation of mahua butter might happen at a relatively low temperature.

Table. 1. Physico-chemical analysis of Mahua oil

Mahua Oil	Mean ± SD
Iodine Value (g I2/100g)	57.09 ± 1.14
Saponification value (mg KOH/g)	187.16 ±0.68
Acid value (mg KOH/g)	3.51 ±0.06
Specific gravity	0.93 ± 0.01
Refractive index	1.46 ±0.01
Melting point (ºC)	33.94 ±0.11
Smoke point	168.99 ± 0.95

When compared to previous literature, iodine value of mahua oil used in the study was slightly lesser than that of sunflower oil (84.6 g/100 g fat), while the saponification (188.17 mg KOH/g fat), acid value (3.27 mg KOH/g fat) was similar (Dymiñska *et al.* 2007). Also, the specific gravity of mahua oil

Fig.1. Muffins prepared with mahua butter

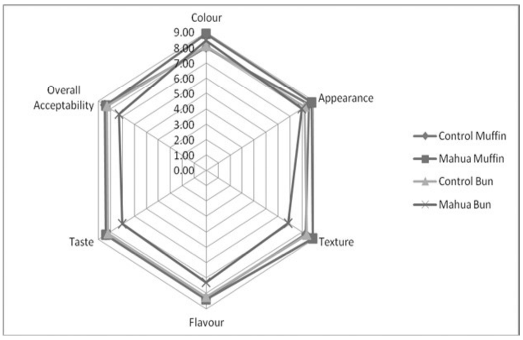

Fig.2. Sensory scores of Control Muffin, bun and Mahua muffin and bun

utilized in present research was almost nearby to that of sunflower oil as reported by Pal *et al.* (2015). As the composition of mahua fat was similar to a bakery fat, the oil was used to prepare two bakery products viz., Muffin and Bun. The baked products prepared (Mahua bun, mahua muffin, control bun and control muffin) were evaluated for sensory parameters by a semi trained panel, and was observed that mahua muffin (Fig.1) was more liked compared to mahua bun. Mahua bun was least liked in all sensory parameters compared to all the products (Fig.2). However, reformulation of the bun can be tried for improving the sensory appeal of the product. The overall acceptability of mahua muffin was 8.33 ± 0.52, compared to 7.29 ± 0.95 in mahua bun on a 9-point hedonic scale. The colour (8.83 ± 0.41) and appearance (8.83 ± 0.41) of mahua muffin was rated higher among all the products, which could be due to the light yellowish orange colour imparted by the mahua fat. The texture (8.50 ± 0.84), aroma (8.33 ± 0.82) and taste (8.33 ± 0.52) of mahua muffin were at par with the control muffin. Hence, mahua muffin was subjected to further analysis. The results of sensory evaluation indicate that mahua fat can be used as a shortening fat for development of bakery products like muffins.

Shortenings are plastic fats commonly used in the baking industry to impart desirable texture and mouthfeel, comprising of a mixture of solid fat crystals and liquid oil, with a three-dimensional crystal matrix that holds the liquid portion of fat and imparts plasticity and rigidity to the system. Satisfactory performance of shortening depends mainly on consistency and crystal structure, which in turn depends on the solid to liquid ratio present at different temperatures (Reddy and Jeyarani, 2001). Lipids interact with gluten and starch particles to strengthen their network, improve the gas retention of dough and enhance heat transfer, due to which bakery products become softened, resulting in consistent grain, lubricated mouthfeel and extended shelf life (Huang *et al*., 2019; Ghotra *et al.,* 2002). Shortening lipids are generally made from milk butter, animal fats (e.g., tallow, lard), or hydrogenated plant oils (e.g., palm oil) (Lai and Lin., 2014). Results of the study indicate that mahua fat can be used as a natural shortening fat for formulating various baked products, due to its crystalline structure and plasticity as observed in muffins prepared with mahua fat.

Results of fatty acid composition of mahua oil indicate that mahua oil is rich source of palmitic acid, stearic acid among saturated fats and oleic acid and linoleic acid among the unsaturated fats. To avoid hydrogenation, transesterification and unwanted *trans* fatty acids formation during production of solid fat food products, vegetable oils with high saturated fatty acid levels are desired by food industry. High content of oleic acid is favored as it is the main determiner of oil quality. Moreover, predominance of oleic acid in vegetable oils has been favored by nutritionists as it not only reduces the blood cholesterol, but also reduces the incidence of coronary heart disease (CHD) (Dubois *et al*., 2007, Orsavova *et al*., 2015). The nutritionally essential fatty acid composition and high amounts of MUFA and PUFA makes the mahua fat a special lipid source for production of healthy food products.

The results of fatty acid analysis as shown in Fig.3 indicates that, oleic acid (C18:1n9cis) was highest (36.08 ± 0.59%) followed by Stearic Acid (C18:0) (25.23 ± 0.09%), Palmitic Acid (C16:0) (19.57 ± 0.84%) and Linoleic Acid (C18:2n6cis) (17.83 ± 0.01%). Similar fatty acid composition was found in mahua muffin also indicating the exact reflection of fat incorporation on the product developed. A comparative study by Fu *et al.* (2018) with distilled monoacylglycerols and four acylglycerols (octanoic acid, palmitic acid, stearic acid, and linoleic acid) reported that monopalmitate glycerol and monostearin glycerol led to higher solid fat index and finer crystals (â' form), thus increasing aeration ability in batter formation and tenderizing crumb of layer cakes. High content of stearic and palmitic fatty acids with melting points of 69.3°C and 62.9°C (Stampfli and Nersten, 1995), respectively will render mahua fat remain solid at ambient temperature. Due to presence of high stearic and palmitic fatty acids in mahua fat, the sensory properties of the muffin could have been at par with the control product.

Essential fatty acid Cis-11-Eicosenoic Acid (C20:1n9), was also detected in traces in both mahua fat and mahua muffin. *n*-6 and *n*-3 fatty acids are necessary hormone-like compounds, that are important in prostaglandin biosynthesis and also mediators of the defense system, and mahua fat being a source of n-3 and n-6 fatty acids, can be further explored in development of various other baked products (Subash-Babu and Alshatwi, 2018). Mahua fat being a rich source of essential fatty acids like linoleic (C18:2), linolenic (C18:3), and arachidonic (C20:4) acids, and their presence in the muhua muffin indicate that, manufacturing process

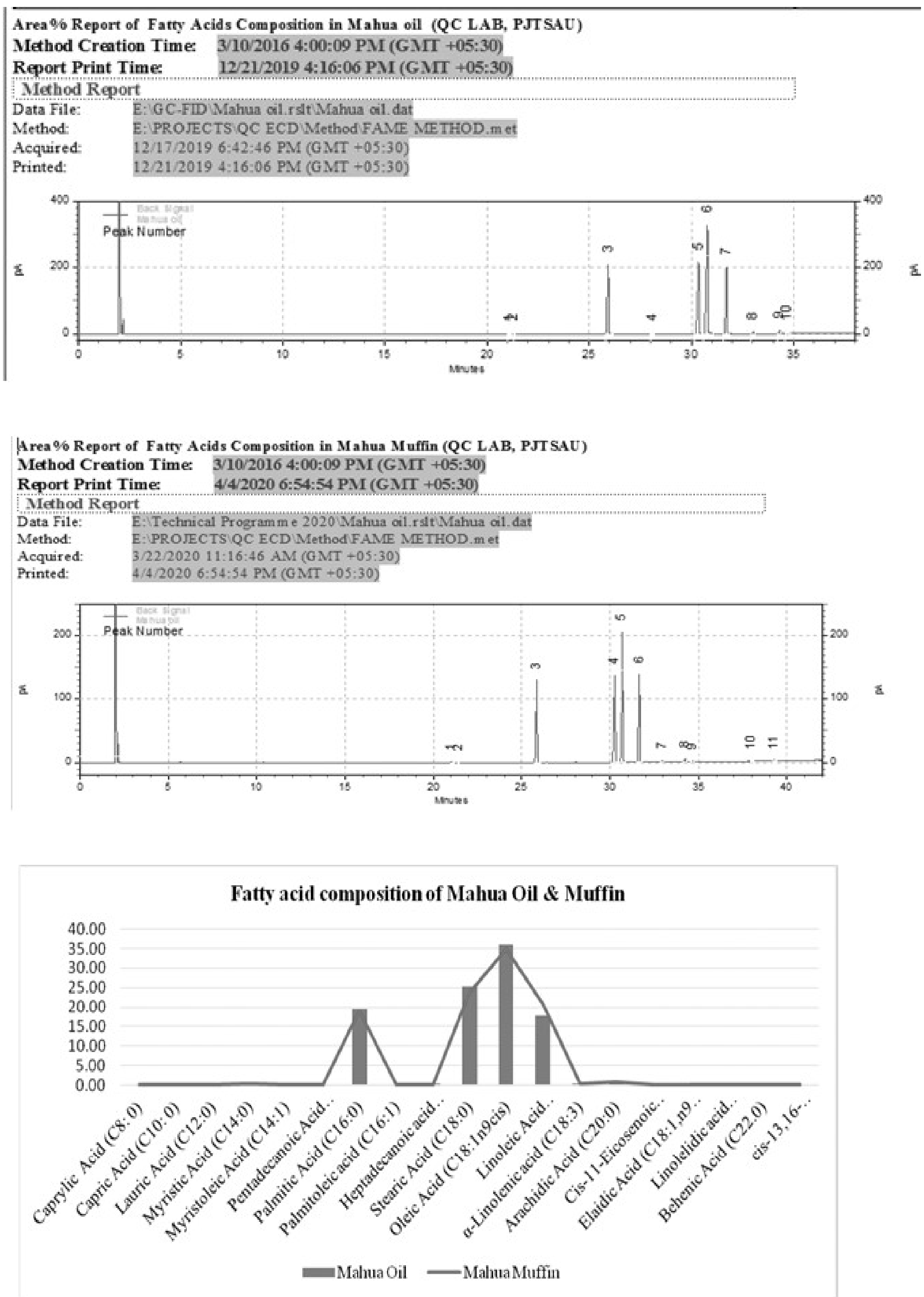

Fig.3: A. Fatty acid Chromatogram of Mahua oil; B: Fatty acid Chromatogram of Mahua muffin; C. Comparision of fatty acid composition of Mahua oil and muffin

also had no effect on the essential fatty acid composition of the product. Absence of trans-fatty acids in the mahua fat implies that the fat was not subjected to any processing or refining method such as hydrogenation, deodorization nor any heat treatment were not carried out (Maggio and Orecchio, 2018).

Adequate quantity of fat in the diet is indispensable for health for their contribution to energy needs, essential fatty acids and to facilitate absorption of fat-soluble vitamins. Oleic and linoleic acid can play important role in protecting cardiovascular diseases, cancer and age-related cognitive decline (Onacik-Gür *et al.*, 2015; Maggio and Orecchio, 2018). Arachidonic and eicosapentaenoic acids are very important in the regulation of blood pressure, renal function, blood coagulation, inflammatory and immunological reactions, and other functions (Huang *et al.,* 2019). Hence, the higher proportions of oleic and linoleic acids, along with the presence of arachidonic and eicosapentaenoic acids, suggest that mahua fat may offer potential nutritional advantages, in addition to its suitability as a bakery fat.

Therefore, mahua fat can be used as a potential bakery fat due to its functional properties and nutritional importance, with special reference to fatty acid composition for development of baked goods. Muffins prepared with mahua fat had very good sensorial acceptance, and fatty acid composition, implying the possibility of development of baked products with good sensory acceptance. Further studies on improvement of sensory properties of buns, and development of other baked products with mahua fat could enable the utilization of underutilized mahua fat for development of a range of baked products with acceptable sensory and nutritional appeal.

CONCLUSION

The fatty acid composition of mahua fat and its potential application in bakery products, while maintaining nutritional quality and sensory acceptability, deserve greater attention. The present study demonstrates that mahua fat possesses physicochemical and functional characteristics suitable for bakery applications, particularly as a natural shortening in muffins. Its favourable fatty acid profile and satisfactory sensory performance indicate its potential as a sustainable alternative fat source. Future studies should focus on optimizing formulations for other bakery products and evaluating storage stability and consumer acceptance under commercial conditions. The utilization of underutilized fats such as mahua fat deserves greater emphasis because of their nutritional and industrial potential as bakery fats, contributing to improved processing performance and consistent product quality. Furthermore, value addition to mahua fat can enhance the economic opportunities and livelihoods of tribal communities that depend on mahua trees.

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