



## Research article

## Application of structured triacylglycerols in food products for value addition

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## ABSTRACT

The present study aims to evaluate the suitability of structured triacylglycerol (ST) consisting of medium chain triacylglycerol (MCT) as low calorie and instant energy source in combination with essential fatty acids for formulations in different food products to add value to existing products. The study investigates the effect of presence of ST on the physicochemical and sensory properties of various food products such as mayonnaise enriched with ST synthesized from medium chain fatty acid (MCFA) and rice bran oil, cookies enriched with ST synthesized from MCFA and oleic acid rich moringa oil, energy bar with ST synthesized from MCFA and omega 3 enriched fish oil, as well as yogurt drink with ST synthesized from MCFA and omega 6 enriched flaxseed oil. The obtained results established the suitability of incorporation of ST in food products and comparison with standard market products revealed the validity of the products to sustain the demand with value addition. The oxidative stability studies of all the products in the presence of natural antioxidants from moringa leaves and pomegranate peel using the peroxide value test and rancimat analysis demonstrated similar stability to the standard marketed product. Application of plant wastes and residues in the form of leaves or peels as the likely sources for isolating bioactive compounds demonstrates potential of the sustainable approach also giving benefit of increasing the stability of the product. The study also points towards possible replacement option for synthetic carcinogenic antioxidants with natural antioxidants obtained from moringa leaves and pomegranate peel. The present work clearly demonstrates the effective use of structured triacylglycerols synthesized using green methodologies for creating unique health enriched food products with all worthy and green components.

## 1. Introduction

Consumers nowadays are becoming very much aware about the nutrition aspects of different food products. Consumers want the food, which is healthy yet simple to prepare and consume. Most of health conscious people are now switching towards healthier options of the food products. Beneficial health effects of structured triacylglycerols (ST) are receiving considerable attention. ST helps to improve immune function, reduce cholesterol, improve nitrogen balance and reduce the cancer risk (Akoh and Kim, 2008). ST consist of medium chain fatty acids at the sn-1, 3 positions which are easily hydrolyzed and do not accumulate as body fat whereas long chain fatty acids containing essential fatty acids present at sn-2 position are absorbed rapidly (Jandacek et al., 1987). Thus, addition of ST consisting of dual properties of MCFA and long chain triglyceride (LCT) add value to the food products in terms of the nutritional enrichment.

Nutritional products are mainly useful for people on modified diets requiring nutritional enrichment, and for patients recovering from illness or injury (Osborn et al., 2003). There are several nutritional products available as health supplement, which can be consumed with meals or in between meals as important source of nutrition. The main aim of the present study was to introduce ST synthesized using MCFA and LCT in the products, which can impart easily metabolized energy source to the body at the same time offering extra benefits with natural antioxidants obtained from moringa leaves and pomegranate peel. If the ST is to be effectively introduced in real foods and acceptable to the consumers, physical and chemical properties and sensory assessment should be comparable to the marketed traditional food products. There have been some reports of application of ST in the food products for enhanced benefits. ST produced from rice bran oil and caprylic acid was reported to be useful in the production of butter and margarine blends, and also in different beverages (Jennings et al., 2010). Osborn et al. (2003) investigated incorporation of ST obtained from canola oil and caprylic acid in

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chocolate-flavored nutritional beverages and reported that the sensory profile of the beverage showed acceptability of product by a trained panelist. Bell et al. (1991) also reported the formulations of beverage with ST to yield a safe and ready source of metabolism compared to the existing beverages. Kim et al. (2005) studied the effect of addition of a ST obtained from canola oil and caprylic acid in butterfat-vegetable oil blend in terms of the sensory analysis. It was reported that spread obtained with ST was comparable to the marketed product with no significant ( $P < 0.05$ ) differences in the flavour attributes.

Bakery products such as cookies, cakes and pastries contain high level of fats mainly to give proper texture and flavour to the products. The presence of fats, however, imparts high calorie and high trans fatty acids content into the products and this can cause health problems (Arifin et al., 2011). Medium chain triacylglycerol (MCT) can offer as replacement to the fats but they have low smoke point and high foaming tendency and hence are not suitable for frying or baking applications. A combination of LCT and MCT in freshly synthesized ST decreases the foaming and increases smoke point making it suitable for usage (Negishi et al., 2003) along with added benefits of MCT. Kosmark (1996) reported that ST enriched with EPA and DHA has been widely used in infant formula preparation, cosmetics, medicines and food industry. Timm-Heinrich et al. (2003) also reported that milk based products are in great demand in health food area and flavored milk drink containing structured lipid with sunflower oil and caprylic acid has the ability to provide the patients with energy and essential fatty acids in a pleasant way. Lim et al. (2010) investigated the effect of addition of flaxseed oil to ice-cream and studied its physicochemical as well as sensory properties. It was clearly demonstrated that addition of flaxseed oil showed no effect on physicochemical properties of ice-cream. Hence it can be said that the ST produced from LCT and MCT with additives can offer a useful combination retaining beneficial properties of the both the constituents.

ST are susceptible to oxidation on longer storage periods and hence needs antioxidants to prevent oxidation in the products. Depending on the types of the products, suitable antioxidants can be selected. Healthy nature of value added products such as yogurt, milk drinks, energy bars and cookies incorporated with EPA, DHA, and ST can attract the attention of the consumers, if they meet all the quality attributes. Food products containing fish oil and flaxseed oil are also susceptible to oxidation and hence addition of natural antioxidants from moringa leaves was applied in the work to prevent oxidation. Antioxidants increases shelf life of the products. For example, Nielsen et al. (2007) studied the oxidative stability of fish oil enriched yogurt after addition of antioxidants such as vitamin K, citric acid ester and EDTA. Sensory analysis and peroxide value tests revealed stability of yogurt at 5 °C for 19 days and the addition of antioxidant further increased the stability further to 29 days. Effect of addition of antioxidant, EDTA in milk drink-type emulsions was reported to improve stability of milk drink coupled with ST (Timm-Heinrich et al., 2003). Similar study performed by Jacobsen et al. (2003) using antioxidant, EDTA in mayonnaise containing ST, at concentration of 240 mg/kg demonstrated excellent stability. Although chemical antioxidants offer good antioxidant activity, considering harmful and carcinogenic effect of chemical antioxidants, the present study was focused on use of natural antioxidants obtained from moringa leaves or pomegranate peels in formulations. There have been some reports on use of moringa leaves and pomegranate peel extracts as natural antioxidants. Bioactives from moringa leaves act as a viable source of natural antioxidants (Siddiq et al., 2005). Moringa leaves

extract are also good nutritional supplement and can be used in food ingredients, pharmaceuticals and cosmetics products (Rodriguez-Perez et al., 2015). Moringa leaf extract was used as natural antioxidant for stability of sunflower and mayonnaise and reports suggested extracts effectively protected both the systems (Bholah et al., 2015). Pomegranate peel also offers very good antioxidant property (Elfalleh et al., 2012) and offers promise for use in the functional food ingredients or as biologically active components in nutraceuticals (Akhtar et al., 2015). For example, pomegranate peel containing ice creams showed effective antioxidant activity without significant changes in the sensory profile (Cam et al., 2013). In another study, pomegranate peel as natural antioxidants was also reported to show effective antioxidant activity in jam (Ventura et al., 2013). Although plenty studies are available about the use of ST in food products, there is lack of studies reporting the use of natural antioxidants from fruit waste such pomegranate peel and moringa leaves as well as demonstrating the potential to replace the harmful chemical antioxidants in food products based on the comparison study in terms of sensory profiles. Natural antioxidants even show potential health-promoting effects such as anti-cancer, anti-microbial and anti-oxidative effects which will exhibit added benefit to the formulated products. Additionally there are limited studies on stability of ST in food products specifically using rancimat analysis. Thus the novelty of the current work dealing with investigation of the application of ST enriched formulations in different food products supported with natural antioxidants is clearly established. The main purpose was to incorporate ST in various food products along with natural antioxidants from moringa leaves and pomegranate peel. The physicochemical and sensory analysis of the products was performed so as to compare with the standard commercial products containing chemical oxidants.

## 2. Materials and methods

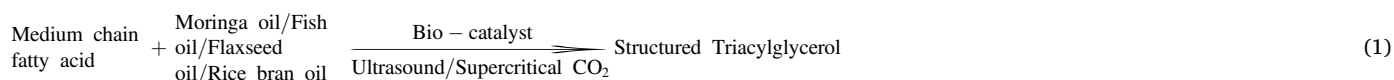
### 2.1. Materials

Sodium thiosulphate, potassium iodide, potassium hydroxide, malt extract, agar plates, standard buffer solutions and starch were procured from S.D Fine-Chem Pvt. Ltd., Mumbai, India. Petri dish of 47 mm diameter was procured from Merck, India. Moringa leaves and pomegranate peel were obtained from local market in Matunga, Mumbai. Baking soda, salt, sugar, whole flour, white oats, skim milk powder, non-fat milk powder, yogurt culture and strawberry squash required for preparation of products were purchased from local market of Matunga, Mumbai.

### 2.2. Methods

#### 2.2.1. Synthesis of structured triacylglycerols

The structured lipids used in present work for application in various products were synthesized by acidolysis of medium chain fatty acids with long chain triacylglycerols as per the methods reported in our earlier research work (More et al., 2018, 2019). Structured triacylglycerols were synthesized using medium chain fatty acid with Moringa oil (More et al., 2018), fish oil, flaxseed oil and rice bran oil (More et al., 2019) in the presence of enzyme (*Novozym 435*) as the catalyst using green intensification technique based on the application of ultrasound and supercritical CO<sub>2</sub>. The generalized reaction scheme has been presented in Eq. (1):



Different oils have a different oil composition offering specific properties suitable for the product. For example, moringa oil is rich in oleic acid (about 76%) followed by other acids such as stearic, behenic, palmitic and arachidic (4%–7%) as reported by Anwar et al. (2005). The best conditions used in the present synthesis were 50 °C as the temperature with 300 rpm as the speed of agitation, molar ratio of 4:1 (medium chain fatty acids: long chain triglycerides), reaction time as 5 h and Novozym 435 as the catalyst as established in the earlier work (More et al., 2018, 2019). The structured lipids thus obtained can possess significant nutritional benefits of medium chain fatty acids at 1,3 position and long chain fatty acid at 2-position, thus making the current application study very important.

### 2.2.2. Extraction of bioactives from moringa leaves (ML) and pomegranate peel (PP)

Moringa leaves and pomegranate peels were washed and blanched with 0.2% potassium metabisulphate. The leaves and peels were oven dried at 50 °C for 8h (Ben Nasr et al., 1996). The dried leaves and peels were powdered in the blender and further extraction of bioactives was done using ultrasound. For a typical extraction run, 25g of ML and PP powder were added to 250ml beaker consisting of 80% ethanol and 20% water for moringa leaves and pomegranate peel separately. Ultrasonic probe was inserted in the beaker and pulse was maintained at 6s/4s (on/off) time with ultrasonic frequency as 20 kHz and power as 240 W for 30 min irradiation time. The beaker was sealed tightly with aluminum foil and mixing was done on magnetic stirrer with 150 rpm. After 30 min, the beaker was removed and mixture was filtered using whatmann filter paper. Ethanol was removed by rota-vacuum. The extracts of moringa leaves and pomegranate peels were then used for its applications in food products.

## 2.3. Formulation of products

### 2.3.1. Formulation of mayonnaise

Mayonnaise is used as sauce in various food products such as burger and fries. In present work, mayonnaise was formulated using ST from flaxseed oil and MCT. The formulation components of mayonnaise are given in Table 1A and formulated mayonnaise is shown in Figure 1A. During the process, firstly egg and vinegar were mixed and then all the other ingredients except ST were mixed together using mechanical stirrer. Lastly, ST was added slowly at 1500 rpm as the agitation speed operated for 1 min followed by 2000 rpm speed for 4 min. All the formulations were refrigerated throughout the storage.

### 2.3.2. Formulation of cookies

Cookies are favourite among consumers and are eaten in breakfast or at any time to curb the appetite. The cookies mainly are made up of Maida (processed wheat) that have various health hazards and therefore present work was focused on utilization of whole flour for cookies. Cookies containing high amount of fat also causes various diseases and hence in the present formulation, the fat was replaced with low calorie fat as ST from moringa oil and MCT. The composition for formulation of cookies is represented in Table 1B and formulated cookies are shown in Figure 1B.

During the formulation process, ST was mixed with sugar. It was mixed well until it became light and fluffy. Flour was sieved and then mixed with baking soda and salt. Flour mixed with baking soda and salt was then added to the creamed fat and dough was made by adding required amount of water. Balls of required size were formed with hand carefully so as to avoid any cracks on the surface. The balls were arranged on baking tray at 1.5 inch distance. The cookies were baked at 175 °C for 30 min till light brown color appeared on the top. The cookies were subsequently allowed to cool.

### 2.3.3. Formulation of energy bar

Energy bar is another healthy option, which can be used to curb the appetite and also can help in weight reduction. It is also a supplement for

**Table 1.** Formulation components of Different Food Products considered in the study. A) mayonnaise B) cookies C) energy bar D) yogurt drink.

Sr. No.	Ingredients	Weight (%)
<b>A) Mayonnaise</b>		
1	Structured lipid (Rice bran oil and MCT)	70
2	Sugar	2
3	Lemon juice	1
4	Vinegar	8
5	Salt	1.2
6	Mustard powder	0.3
7	Egg yolk	9
8	water	4.5
9	Moringa leaves extract	1
<b>B) Cookies</b>		
1	Flour	50
2	ST (Moringa oil and MCT)	14
3	Sugar	15
4	Baking Soda	0.1
5	Salt	Pinch
6	Water	5 ml
7	Flavour	Vanilla essence
8	Pomegranate peel extract	1
<b>C) Energy bar</b>		
1	Structured lipid (MCT and Fish oil)	25
2	White oats	20
3	Honey	9
4	Milk powder	10
5	Nuts	15
6	Protein powder	20
7	Moringa leaves extract	1
<b>D) Yogurt drink</b>		
1	Skim milk	60
2	Non Fat dry milk	5
3	Structured lipid (MCT and Flaxseed oil)	5
4	Water	10
5	Yogurt Culture	1
6	Sugar	14
7	Strawberry squash	4
8	Pomegranate peel extract	1

everyone and contains nutrition enhancing ingredients. The formulation used in the present work composed of unique constituents such as white oats, which is full of nutrition along with ST from fish oil to supply EPA and DHA with MCT. The actual formulation of energy bar is represented in Table 1C and formulated energy bar is shown in Figure 1C.

Typically in the process, all the constituents at specified concentration were mixed and set on tray and refrigerated for 1h to allow bars to set. After setting, the bars were covered with butter paper and stored.

### 2.3.4. Formulation of yogurt drink

Yogurt drink is instant source of energy. The formulation studied in the work was based on production from skim milk in the presence of ST and then adding the different ingredients as given in Table 1D. The objective was to achieve yogurt drink which is fat free and low calorie so as to minimize the fat and make it healthy. Yogurt drink was prepared in two steps as preparation of yogurt and syrup followed by second step of mixing yogurt and syrup. For the yogurt preparation, skim milk powder was mixed with non fat milk powder, structured lipid, water and yogurt culture and allowed to ferment and set overnight at room temperature. The syrup was prepared by mixing sugar powder with water and



A) Mayonnaise



B) Cookies



C) Energy bar

**Figure 1.** Formulated Food Products used in the study A) mayonnaise B) Cookies C) Energy bar.

strawberry squash. Subsequently, both the syrup and yogurt were mixed in the blender. The obtained drink was filled in the bottle and stored at 4 °C.

#### 2.4. Evaluation tests

##### 2.4.1. Peroxide value

Oxidative stability of the samples was studied using the peroxide value test performed as per the standard procedure available from the reports of American Oil Chemical Society. Typically, sample of 5 g was mixed with 30 ml of acetic acid: chloroform solution (3:2 ratio) followed by addition of 0.5 ml of saturated KI and kept in dark for 1 min so that iodine liberation occurs. 30 ml distilled water was then added to flask and the resulting solution titrated against 0.01N sodium thiosulphate using starch indicator. Blank was also prepared excluding the step of adding sample. Peroxide value was calculated using Eq. (2) as given below:

$$\text{Peroxide value} = (\text{sample-blank}) \times 1000 \times \text{Normality} / \text{wt. of sample} \quad (2)$$

##### 2.4.2. Determination of acid value

Amount of free fatty acids present in the samples was calculated by acid value test as per the reports of American Oil Chemical Society (Official Method Te 1a-64). Accurately weighed 1 g sample was mixed with 20 ml neutral alcohol in a conical flask. The mixture was refluxed gently to dissolve the sample completely and titrated against 0.01 N potassium hydroxide in the presence of phenolphthalein as indicator until a pink endpoint was obtained. The titration reading was used in the calculation of acid value.

##### 2.4.3. Stability study (rancimat analysis)

The stability study of all the products was studied based on the rancimat induction period measurements performed using the rancimat Metrohm 98 equipment.

##### 2.4.4. Microbiology analysis

Microbial growth was studied by streaking all the prepared products on malt extract agar plates (MERCK, Germany) with subsequent incubation at 15 °C. The growth of microbes on plate was analyzed using visual observations.

##### 2.4.5. pH measurement

pH of the sample was determined by using pH meter (Equiptronics EQ-610). The pH meter was calibrated using standard buffer solutions. The suspension of 10% w/v for the products was prepared with water and pH was measured for the solution.

##### 2.4.6. Appearance

The appearance of the formulations was judged by its colour and roughness.

##### 2.4.7. Sensory assessment

10 panel members were selected based on their willingness and expertise for the sensory analysis. The panel agreed to identify different attributes of flavour, taste, aroma, appearance, texture, mouth feel, colour and overall acceptability. Panelists evaluated samples in multiple runs (mostly three). Each panelist was provided with a set of all product samples including the marketed product as reference for sensory evaluation. The panelist was asked to evaluate one product at a time. After one test, cold water and crisp bread were given to nullify the effect of



previous taste and again different sample was given. A nine-point hedonic scale was used for the analysis of the responses ('1' indicates disliked extremely, '5' as neither like nor disliked and '9' indicates like extremely). We would like to confirm that these experiments were conducted according to established ethical guidelines, and voluntary consent obtained from the participants.

### 3. Results and discussion

#### 3.1. Analysis of mayonnaise

##### 3.1.1. Physicochemical test of mayonnaise

The physicochemical testing of mayonnaise sample was performed based on the analysis of pH, acid value, peroxide value, microbial testing along with rancimat analysis and the obtained results are represented in Table 2. The pH value decreased with storage time and mayonnaise became more acidic for both the mayonnaise containing the blend sample and standard/control. However, acidity of the standard mayonnaise was higher with actual pH of 3.4 at the final storage condition as compared to the mayonnaise containing the ST with final pH of 3.7. The acid value, which is amount of free fatty acid present in the product, was found to be very low as 0.21 and 0.27 in sample and standard respectively. Microbial study also suggested no growth of microorganism in the agar plate after 7 days testing for both the standard and actual samples.

Karas et al. (2002) investigated stability of light mayonnaise and compared it with standard mayonnaise sample and reported that stability of light mayonnaise was higher than standard sample with peroxide value of standard mayonnaise and light mayonnaise after 2 months storage as 2.54 meq/kg and 2.86 meq/kg respectively. It was also reported that light mayonnaise showed pH of 3.8 with increased peroxide value to 2.86 meq/kg after two months of storage. The presented discussion provides credence to the obtained results in the current work.

##### 3.1.2. Induction time

The induction time in rancimat analysis indicates the stability of the mayonnaise at 110 °C and obtained results represented in Figure 2 showed that standard mayonnaise was stable up to 1.66h whereas mayonnaise containing the blend sample was stable for longer time (up to 1.99h). The increase in stability could be attributed to efficiency of added natural antioxidant from moringa leaves. Similar study was reported by Timm-Heinrich et al. (2004) in which ST consisting of fish oil and caprylic acid was introduced in mayonnaise and it was reported that the peroxide value increased to 2.6 meq/kg after storage of two months whereas induction time of ST enriched mayonnaise was 88 min, which was higher as compared to the control sample. The oxidative stability was reported to be influenced by the type of lipids and the differences in manufacturing processes. It is thus important to note that the lipid type also affects the stability results directing the importance of the current work. Based on the results obtained in the current work, it can be stated that mayonnaise prepared using ST with fish oil and MCT showed better oxidative stability with induction time of 1.99h and maximum peroxide value after 2 months as only 1.5 meq/kg.

**Table 2.** Results for the physicochemical testing of mayonnaise.

Sr. No.	Parameters	Value (S) (0 D)	Value (S) (1M)	Value (S) (2M)	Value (Std.) (0 D)	Value (Std.) (1M)	Value (Std.) (2M)
1	pH	4.1	3.9	3.7	4.0	3.6	3.4
2	Acid value (mg of KOH/gm oil)	0.12	0.24	0.26	0.21	0.27	0.32
3	Peroxide value (meq/Kg of oil)	1.0	1.2	1.5	1.0	1.6	1.8
4	Microbial testing	No Growth	No Growth	No Growth	No Growth	No Growth	No growth

S-sample M-month, D-day, Std.- Standard.

##### 3.1.3. Sensory evaluations of mayonnaise

Sensory evaluation was performed by the panelist members with tests such as appearance, texture, mouth sensation, aroma, taste and colour. The obtained results are represented in Table 3. It can be seen from the table that all sensory attributes seems to be in acceptable range as concluded by the panelist. The presented results clearly established that there was no negative change due to the added ST in the mayonnaise compared to the standard product.

The analysis of Mayonnaise enriched with the structured lipid from flaxseed oil and MCT possesses properties of both the long and medium chain fatty acids. The stability studies performed in terms of the physicochemical tests, induction time, and sensory evaluations confirmed the stable nature of the ST in mayonnaise. Overall, the analysis demonstrated the efficacy of a green approach using natural antioxidants in products with benefit of introducing fatty acids from flaxseed oil with low calorie and instant energy source as MCT adding great value to the investigated food product as mayonnaise.

#### 3.2. Analysis of cookies

##### 3.2.1. Physicochemical test of cookies

Analysis of cookies was done performing tests such as acid value and peroxide value. The tests were repeated at periodic intervals during the 2 months storage and effect of storage on properties of cookies was determined and compared with similar studies involving the standard cookies. The obtained results reported in Table 4 confirmed that not much difference is seen in the acid value and peroxide value of the sample and standard cookies after storage. It can be thus concluded that the values for both cookies are within safe limits and also the cookies having ST as the additives showed marginally better results as compared to the standard cookies obtained from markets.

##### 3.2.2. Rancimat analysis of cookies

The obtained results for the induction time in the rancimat analysis performed at 120 °C as the temperature of both standard and sample cookies is represented in Figure 3. It can be seen from Figure 3 that the induction time for the sample cookies blended with ST from moringa oil/ rice bran oil and MCT along with pomegranate peel extract as antioxidants was 3.53h whereas induction time for the standard cookies having sunflower oil blended with chemical antioxidant as EDTA was 3.44 h at temperature of 120 °C. The results confirmed that marginally better activity was obtained for the natural antioxidants used in the work. Bhangar et al. (2007) investigated the use of rice bran oil for stabilization of cookies and reported that cookies shows appreciably less increase in peroxide value on storage with induction time of 7.5 h at temperature of 80 °C which was better as compared to the standard cookies.

##### 3.2.3. Sensory evaluations of cookies

The cookies formulated using ST from moringa oil and MCT were also tested for its sensory attributes and results are presented in Table 5. It was seen that the acceptability of the ST enriched cookies was very good in terms of sensory attributes as well as physicochemical properties. The

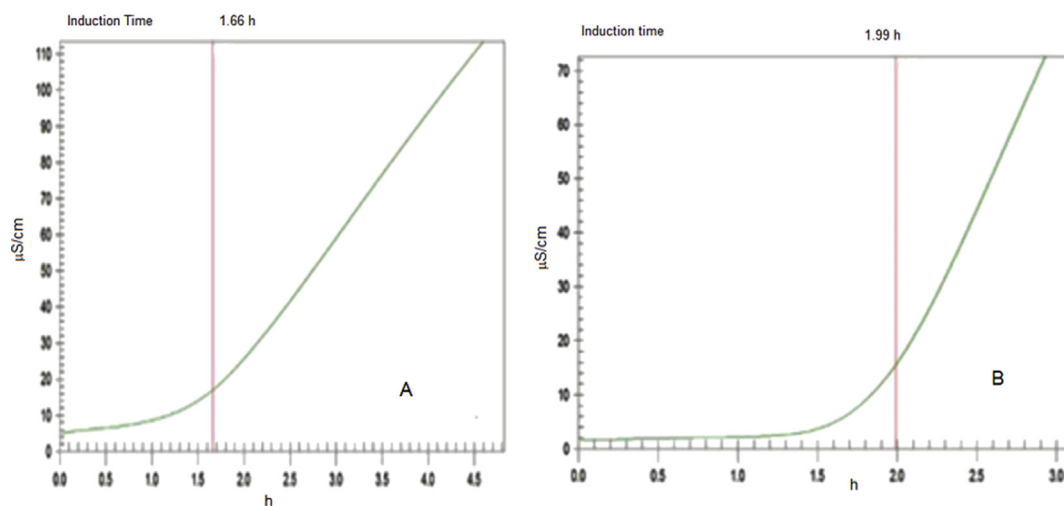


Figure 2. Induction time of mayonnaise A- Standard and B. Sample.

Table 3. Sensory evaluations of mayonnaise.

Panel Member	Sensory Attributes											
	App. (0 D)	App. (2 M)	Tex. (0 D)	Tex. (2 M)	MS (0 D)	MS (2 M)	Aro. (0 D)	Aro. (2 M)	Tas. (0 D)	Tas. (2 M)	Col. (0 D)	Col. (2 M)
1	9	9	9	8	8	9	9	9	9	9	9	8
2	8	9	8	9	8	8	8	8	9	8	8	9
3	9	8	8	8	8	7	9	8	9	9	9	8
4	9	9	9	9	8	8	9	7	8	8	8	9
5	8	8	8	9	8	8	8	8	8	8	9	9
6	9	9	9	8	8	9	8	9	9	9	7	9
7	8	9	8	9	8	8	9	8	8	8	9	8
8	9	8	9	9	8	7	8	8	8	8	8	8
9	9	8	8	8	8	8	8	7	8	9	9	9
10	9	9	7	8	8	9	9	9	9	9	9	8

App.- Appearance, Tex.- Texture, MS- mouth sensation, Aro. -Aroma, Tas.- Taste, Col.- Colour.

addition of moringa leaves extract in cookies did not show any negative effect on sensory properties of cookies. Arifin et al. (2011) investigated effect of addition of ST in bakery shortening products. The results indicated that the cake had good sensory properties as well as similar liking confirming that the blended products are also equally desired by consumers. Kosmark (1996) studied the application of ST in cookies reporting acceptability of cookies by consumers as the cookies showed same properties as standard cookies. Thus, the literature analysis as well as present study confirmed that use of ST composed of rice bran oil and MCT can be successfully used in formulation of cookies without any changes in the attributes at the same time adding value to the final food product.

The cookies incorporated with moringa oil and MCT enriched ST showed very good results in terms of acceptability in various tests such as physicochemical tests, induction time, sensory evaluations. ST with moringa oil rich in oleic acid and low calorie MCT was thus demonstrated to give added benefits of both the oils and also impart value addition in terms of nutraceutical application in cookies with no negative change in any of the characteristics.

### 3.3. Analysis of energy bars

Energy bars were the second food product application of ST obtained from fish oil and caprylic acid tested in the work. Energy bars are also known as nutrition bar as they serve as source of fuel for athletes and body builder. In our present study, energy bar was formulated using ST from fish oil and MCT and natural antioxidant from moringa leaves extract. In addition, oats, nuts and protein powder were added to increase the value of nutrition and sugar was replaced with honey. Energy bars are typically formulated with the objective to provide maximum nutrition in one single bar. In our present work, changes in formulations by substituting the existing components with more promising healthy ingredients would increase acceptability by consumers, provided that there are no changes in the characteristics. Painter and Prisecaru (2002) reported that foods formulated with added protein and low calorie fat resulted in very slow increase in the blood sugar and hence does not cause any problems for diabetic patients. In the present formulation of energy bar, sugar was replaced with honey and fat with low calorie fat which is typically not stored in the body and instead gives instant energy

Table 4. Results for the Physicochemical tests of cookies.

Sr. No.	Parameters	Value (S) (0 D)	Value (S) (1M)	Value (S) (2M)	Value (Std.) (0 D)	Value (Std.) (1M)	Value (Std.) (2M)
1	Acid value (mg of KOH/g Oil)	0.18	0.20	0.24	0.19	0.23	0.27
2	Peroxide value (meq/Kg of oil)	0.9	1.3	1.5	1.2	1.6	1.8

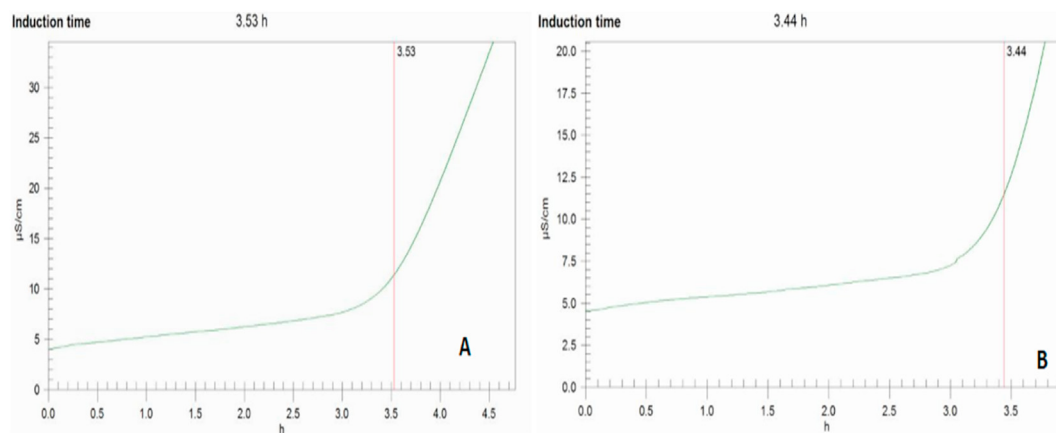


Figure 3. Induction time of sample and standard cookies A – sample and B – standard.

Table 5. Sensory analysis of cookies.

Panel Member	Sensory Attributes											
	App. (0 D)	App. (2 M)	Tex. (0 D)	Tex. (2 M)	MS (0 D)	MS (2 M)	Aro. (0 D)	Aro. (2 M)	Tas. (0 D)	Tas. (2 M)	Col. (0 D)	Col. (2 M)
1	8	9	9	9	9	8	9	9	9	9	9	7
2	9	8	8	9	8	8	8	9	9	7	8	9
3	8	8	9	9	8	9	7	8	9	9	9	8
4	9	9	9	9	8	8	9	7	8	8	7	9
5	9	9	8	7	9	8	9	8	8	8	9	7
6	8	9	9	8	9	9	8	9	9	9	7	9
7	9	8	8	8	9	8	9	9	9	8	9	8
8	9	9	9	9	8	7	9	8	8	9	8	7
9	8	8	8	8	9	8	8	7	8	7	9	9
10	9	9	7	9	9	9	9	9	9	9	8	8

Table 6. Analysis of physiochemical properties of energy bar.

Sr. No.	Parameters	Value (S) (0 D)	Value (S) (1M)	Value (S) (2M)	Value (Std.) (0 D)	Value (Std.) (1M)	Value (Std.) (2M)
1	Acid value (mg of KOH/g Oil)	0.18	0.26	0.28	0.16	0.23	0.29
2	Peroxide value (meq/Kg of oil)	3.4	6.8	8.3	3.5	5.2	7.4
3	Microbial testing	No growth	No growth	No growth	No growth	No growth	No growth

with added benefits. Hurley and Liebman (2000) reported use of whole grain and dried fruits as best strategy for obtaining efficient energy bars. Thus, in the present formulation, nutritious oats were also used along with dry fruits.

### 3.3.1. Physiochemical test of energy bars

The tests such as acid value, microbial growth and pH were performed for energy bars. The obtained results for the physiochemical properties of energy bar are represented in Table 6. The acid value of the energy bar increased only gradually and no microbial growth was seen even after two months of storage. The initial peroxide value was 3.4 meq/kg for sample and 3.5 meq/kg for the standard which increased to 8.3 meq/kg and 7.4 meq/kg respectively after two months storage. The peroxide value increased gradually but drastic change in peroxide value was not observed in the case of samples blended with ST compared to the change in standard confirming better characteristics. Nielsen and Jacobsen (2009) investigated effect of adding fish oil in energy bars and reported highest peroxide value of 25 meq/kg at elevated temperatures for 2 months. Comparison of the results clearly indicated that the blend of ST with natural antioxidants performed very well as compared to

standard energy bars or the combination with only fish oil. Pimentel (2002) also reported the use of MCT and defatted soybean in energy bar and reported the bar contained adequate level of nutrients to serve as meal. The energy bar by natural means suppressed the appetite thereby decreasing calorie intake and helped in reduction of body weight compared to the intake of standard meals. Rancimat study and peroxide value test were used for determination of stability of the product. From peroxide value, it was demonstrated that energy bar is potable even after 2 months whereas from rancimat analysis, the shelf life was found to be more than 2 months at 30 °C.

### 3.3.2. Induction time

Rancimat analysis of energy bars was done to know the stability of energy bars at elevated temperature. The temperature was set at 80 °C and induction time was noted. The obtained results in terms of the induction time reported in Figure 4 indicated that the induction time of energy bar with ST and moringa leaves extract as antioxidants was 2.07 h whereas that with EDTA as the chemical antioxidant in the standard sample, it was 1.66 h. It can be thus concluded from the results that energy bars incorporated with fish oil and MCT were more

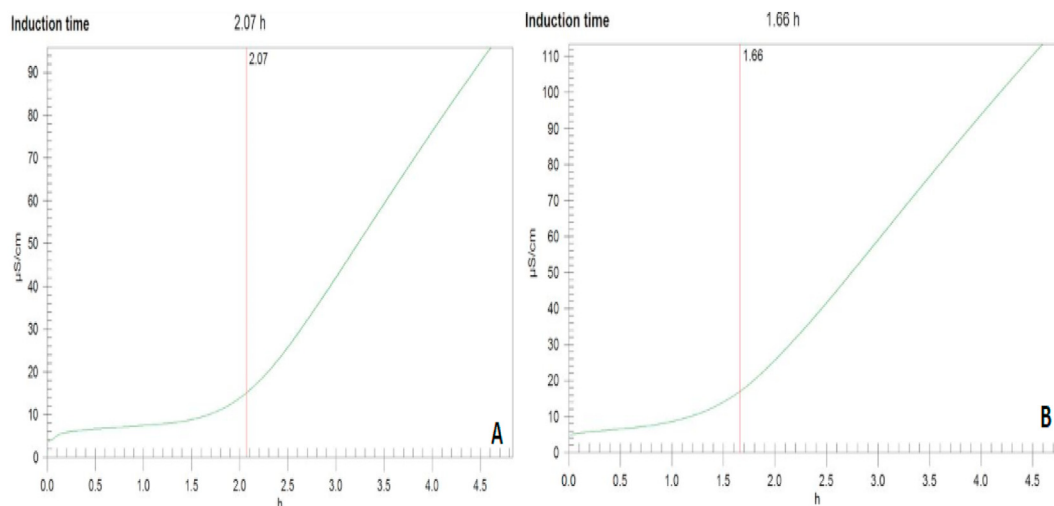


Figure 4. Induction time of sample and standard energy bars A – sample and B – standard.

Table 7. Sensory analysis results for the energy bar.

Panel Member	Sensory Attributes											
	App. (0 D)	App. (2 M)	Tex. (0 D)	Tex. (2 M)	MS (0 D)	MS (2 M)	Aro. (0 D)	Aro. (2 M)	Tas. (0 D)	Tas. (2 M)	Col. (0 D)	Col. (2 M)
1	9	8	9	8	9	8	9	9	8	9	9	7
2	9	7	8	9	8	8	9	8	9	7	8	9
3	8	8	9	9	8	9	8	8	9	9	9	8
4	9	8	9	9	8	8	9	7	8	8	9	9
5	9	7	8	7	9	8	9	8	8	8	9	7
6	8	9	9	8	8	7	8	7	9	7	8	9
7	9	8	8	8	9	8	9	9	9	8	9	8
8	9	8	9	9	9	7	9	8	8	9	8	7
9	8	8	8	8	9	8	8	7	8	7	9	9
10	9	8	7	9	9	9	9	9	9	9	8	8

stable and showed better benefits as compared to the standard energy bar.

### 3.3.3. Sensory analysis of energy bars

The energy bars were given to panelist for studying the sensory properties and obtained results are presented in Table 7. Sensory analysis tests are based on the appearance, texture, mouth sensation, aroma, taste and colour of energy bar. The panelist underwent the tests and reported the results on 9 point hedonic scale. The presented results clearly demonstrated that most panelists had a good impression about the blended product with good liking for the overall taste. Jennings et al. (2010) reported that use of rice bran oil enriched ST in energy bars showed improved nutritional or health-promoting properties and the sensory analysis reported in the work also confirmed satisfactory results in terms of appearance, texture, mouth sensation, aroma, taste and colour.

The energy bar incorporated with ST from fish oil and MCT shows worthy results in terms of suitability in various tests such as

physiochemical tests, induction time and sensory evaluations. Fish oil consists of eicosapentaenoic (EPA) and docosahexaenoic acids (DHA) which are helpful for various body functions. The energy bar will have added benefits of essential fatty acids from fish oil along with instant energy source as MCT at the same providing similar sensory profile and stability.

## 3.4. Analysis of yogurt drink

### 3.4.1. Physiochemical analysis of yogurt drink

Fermented dairy products like yogurt and yogurt drink have grabbed interest of the consumers due to its health benefits. Mainly low fat or no fat varieties are increasing in popularity. The nonfat yogurt drink incorporated with ST was prepared in present work and analyzed for the different physiochemical properties such as pH, peroxide value and acid value. The obtained results represented in Table 8 showed that the peroxide value increased from 2.8 meq/kg for sample and 2.6 meq/kg for standard to 4.5 meq/kg and 4.2 meq/kg

Table 8. Physiochemical analysis of yogurt drink.

Sr. No.	Parameters	Value (S) (0 D)	Value (S) (1M)	Value (S) (2M)	Value (Std.) (0 D)	Value (Std.) (1M)	Value (Std.) (2M)
1	pH	4.4	4.3	4.1	4.4	4.2	4.0
2	Acid value	0.21	0.34	0.42	0.22	0.31	0.40
3	Peroxide value (meq/Kg of oil)	2.8	3.2	4.5	2.6	3.0	4.2



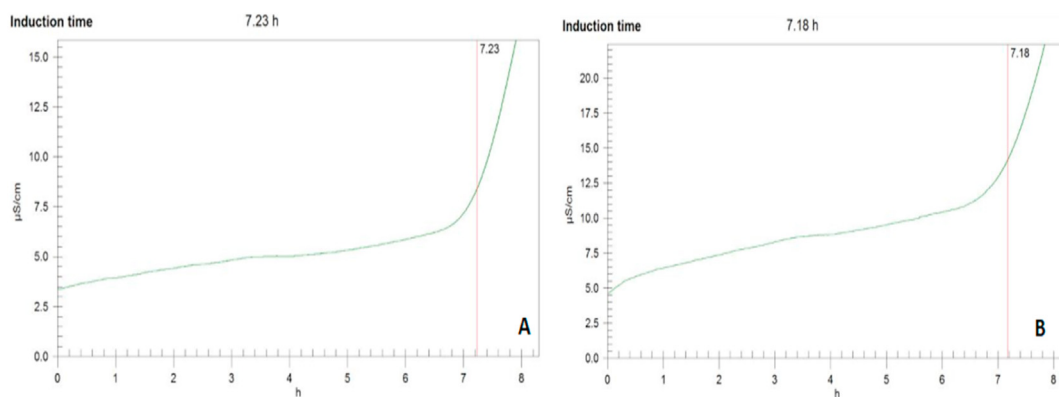


Figure 5. Induction time data for the sample (A) and standard (B) yogurt milk drink.

Table 9. Results for the sensory analysis of yogurt drink.

Panel Members	Sensory Attributes											
	App. (0 D)	App. (2 M)	Fla. (0 D)	Fla. (2 M)	MS (0 D)	MS (2 M)	Aro. (0 D)	Aro. (2 M)	Tas. (0 D)	Tas. (2 M)	Col. (0 D)	Col. (2 M)
1	9	8	9	8	9	7	9	9	8	9	9	7
2	9	8	8	9	8	8	9	9	9	7	8	9
3	9	8	9	9	8	9	8	8	8	9	8	8
4	9	7	9	9	8	8	9	7	8	8	9	9
5	9	8	8	7	9	9	9	8	8	8	9	7
6	9	8	9	8	8	8	8	7	9	7	9	8
7	9	9	8	8	9	7	9	9	9	8	9	8
8	9	8	9	9	9	7	9	8	8	9	8	7
9	8	7	8	8	9	8	8	7	8	7	9	9
10	9	9	7	9	9	9	9	9	9	9	8	7

Fla. - flavour.

respectively. Acid value of standard and sample initially was 0.22 and 0.21 whereas it increased to 0.40 and 0.42 for standard and sample respectively. The results established similar attributes for the ST blends as compared to the standard products. The pH value also remained almost constant over the period of storage. Gonzalez et al. (2011) reported similar results of pH being constant for peach flavored yogurt drink prepared from low fat milk in the presence of ST.

### 3.4.2. Induction time

Rancimat analysis study was carried out to know the oxidative stability of the product at elevated temperatures. The obtained results of sample and standard are reported in Figure 5. The induction time of sample containing ST from flaxseed oil and MCT oil with natural antioxidant from pomegranate peel extract incorporated in yogurt milk drink was 7.23 h whereas that of standard was very similar at 7.18 h. It can be thus said that the stability of both standard and sample were almost same. Timm-Heinrich et al. (2003) reported similar results for the milk drink incorporated with ST from sunflower and caprylic acid with an induction time of 8.3h.

### 3.4.3. Sensory analysis of yogurt drink

The sensory attributes such as appearance of the drink, flavour of strawberry, aroma, taste and colour were studied for the prepared yogurt drink. The results of the panelist in terms of 9 point hedonic scale are represented in Table 9. It was generally observed that the flavour of strawberry was appealing and not sharp to the panelist whereas taste was sweet and tangy. The mouth sensation was good with pleasing appearance and colour. Sensory attributes of the yogurt drink were acceptable to the panelist. Gonzalez et al. (2011) reported similar results for the

sensory analysis of peach flavored yogurt drink containing ST with overall acceptability of the products by the panelist.

Yogurt drink consisting of ST obtained from MCT and Flaxseed oil, which possesses omega-3 and omega-6, shows good results in terms of suitability in various tests as discussed in the current section.

## 4. Conclusions

In present study, ST were used in formulation of food products. The presented results for different physicochemical parameters suggest that the products showed similar results as compared to standard products with added chemicals and hence the proposed formulations could possibly replace the existing products giving added benefits of ST. The nutritional value of the food products seem to increase with addition of ST at the same time maintaining the properties and acceptance. Mayonnaise incorporated with ST from rice bran oil and MCT offered comparable properties to marketed product. Similarly, cookies, yogurt drink and energy bars were also more nutritious and stable in comparison to standard products. The moringa leaves and pomegranate peels extract proves its potency as antioxidant agent in the different products. Overall, the application of ST in various food products have been demonstrated with proven stability based on the use of natural antioxidants and value addition in terms of nutrition.

## Declarations

### Author contribution statement

Snehal B. More: Performed the experiments; Wrote the paper.

Parag R. Gogate: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Jyotsna S. Waghmare: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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#### Competing interest statement

The authors declare no conflict of interest.

#### Additional information

No additional information is available for this paper.

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