



Physico-chemical, Microbiological and Sensory Properties of Pasta Fortified with Fish Oil Encapsulates

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ABSTRACT

Background: Fish oils are rich sources of polyunsaturated fatty acids (PUFAs), particularly omega-3 fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are known for their numerous health benefits, including cardiovascular protection, brain development and anti-inflammatory activity. Due to these nutritional and therapeutic properties, fish oils are widely utilized in functional foods and nutraceutical formulations. However, their incorporation into food systems is often restricted because of their high susceptibility to oxidative deterioration, which can adversely affect product quality, shelf life and sensory characteristics. To overcome this limitation, oxidative instability can be minimized through the incorporation of antioxidants or by employing encapsulation techniques such as spray drying, which protect the oil from environmental factors including oxygen, light and heat.

Methods: In this study, microencapsulated fish oil were prepared by spray drying. The maltodextrin, sodium caseinate and gum Arabic are used as wall materials for microencapsulation. Moreover, to minimize oxidation of lipids, pomegranate extract was added into fish oil emulsion and spray dried. Fish oil microencapsulates was used for preparation fortified pasta by cold extrusion process. The major ingredients used were wheat flour (as base material), fish oil microencapsulates (3%) and salt (1%). The physico-chemical and sensory properties of fish oil microencapsulates fortified pasta were analysed up to two months.

Result: The pomegranate extract had a DPPH activity of 76.76%. The encapsulation efficiency of fish oil encapsulates varied from 94.88% to 95.02%. The physical, chemical and functional properties of fish oil encapsulates fortified pasta was evaluated. The total volatile base nitrogen (TVB-N), peroxide value (PV), thiobarbituric acid (TBA) values and total plate count (TPC) were within acceptable limit during storage. Based on the sensory analysis microencapsulated fish oil-fortified pasta contained pomegranate peel extract was found to be superior to microencapsulated fish oil-fortified pasta contained bulk fish oil added one.

Key words: Fish oil, Fortification, Microencapsulation, Pasta, Quality, Spray drying.

INTRODUCTION

Fish oils are rich in polyunsaturated fatty acids (PUFAs) and are great interest because of their effectiveness in prevention and treatment of several diseases (Patted *et al.*, 2024). Due to its health benefits, it can be included in foods as a functional ingredient. The main problem of food enrichment with omega-3 rich fish oil is the unpleasant fishy flavour of fish oil, which has a negative influence on food acceptability (Kolanowski, 2005). However, undesirable off-flavour may be avoided by using high-quality fish oil at moderate addition levels, especially when protected in microencapsulated form and stabilised by the addition of antioxidants (Jeyakumari *et al.*, 2018; Binsi *et al.*, 2017). Encapsulation process is widely used for protecting active ingredients from heat and other environmental factors during processing thereby minimizing the access of undesirable flavours, enhancing stability and controlled release of active ingredients (Nisa *et al.*, 2025; Anggraini *et al.*, 2025). Spray-drying has been widely applied for the encapsulation of phenolic compounds derived from pomegranate peel, utilizing a range of carrier systems (Nisa *et al.*, 2025). Very few studies have been reported on fortified snack food with fish oil (Agnikumar *et al.*, 2015; Jeyakumari *et al.*, 2016; Kumar *et al.*, 2021). Pasta is a widely consumed ready to cook product all over the world. It is an appealing

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product to the consumer due to its taste, texture, appearance, different shapes and sizes. The demand for ready to eat or ready to cook food products are gaining interest among the consumers with convenience preparation. Moreover, there is an increasing awareness towards the consumption of nutritious and healthy foods. Omega-3 polyunsaturated fatty acids (PUFA) have numerous human health benefits. Enrichment of foods with omega-3 PUFA is regarded as a way of increasing dietary intake of these fatty acids in order to reduce levels of risk of various diseases (Kolanowski, 2005). Pasta is also considered to be a good energy source due to its

complex carbohydrate content and low GI. Moreover, its convenience and palatability makes it a popular dish (Vito *et al.*, 2009). Pasta is considered to be a potential vehicle for fortification by different nutraceuticals such as vitamins and polyunsaturated fatty acids. (Jacobsen *et al.*, 2008). Traditionally, pasta is prepared from durum wheat semolina, although refined wheat flour is also commonly used in certain varieties. While semolina-based pasta serves as a good source of carbohydrates and provides moderate protein content, it is generally considered limited in functional and nutritional properties when compared to fortified or value-added pasta products enriched with dietary fiber, proteins, or bioactive compounds (Petitot *et al.*, 2010; Karpagavalli and Amutha, 2015; Sinha and Sharma, 2023). Conventional pasta is mainly rich in carbohydrates and provides moderate amounts of protein, but it contains very low levels of essential fatty acids. Incorporation of encapsulated fish oil enhances the nutritional profile of pasta by supplying bioactive lipids, particularly omega-3 fatty acids such as EPA and DHA, which are associated with several health benefits in human (Kolanowski, 2005; Patted *et al.*, 2024). Hence, the present study aimed to develop fish oil-encapsulated fortified pasta and evaluate its physicochemical, microbiological and sensory properties.

MATERIALS AND METHODS

Raw materials

The fish oil (Seacod, Universal Medicare, Mumbai, India) was procured from local market at Mumbai. Sodium caseinate, maltodextrin and Gum Arabic were purchased from Himedia, India. The pomegranate extract purchased from Veda oils Pvt. Ltd, Cochin.

Methods

Preparation of fish oil microencapsulates by spray drying

For the preparation of fish oil emulsion, wall materials consisting of sodium caseinate, maltodextrin and gum Arabic were dissolved in distilled water under continuous stirring until complete hydration was achieved. Subsequently, fish oil (1%, w/v) as the core material and pomegranate extract (0.5%, w/v) as a natural antioxidant were added to the hydrated wall material solution. The emulsion was prepared using a core-to-wall material ratio of 1:4. Accordingly, for every 1 g of fish oil used, a total of 4 g of wall material was incorporated, comprising sodium caseinate (2 g), maltodextrin (1 g) and gum Arabic (1 g). The formulation was then homogenized to obtain a stable emulsion prior to encapsulation. To ensure appropriate mixing of the components the emulsion was stirred at 1000 rpm for 30 minutes using magnetic stirrer. Then it was homogenised with a homogeniser at 25,000 rpm for 5 minutes. Then it was allowed to settle for 1 hour at room temperature. Control was kept as fish oil emulsion prepared without pomegranate extract. The prepared fish oil

emulsion were spray dried (Hemaraj Pvt. Ltd, Mumbai, India) under the following experimental conditions viz., inlet temperature 180°C, outlet temperature 90°C. The obtained fish oil encapsulates were stored in airtight conditions until further analysis. Since fish oil was used as a functional ingredient in the formulation, the final pasta product is categorized as a non-vegetarian functional food product.

Preparation of fish oil microencapsulates fortified pasta

Four different formulations were made for preparing the fish oil microencapsulates fortified pasta viz. i) Control-contained wheat flour (ii) CE-contained wheat flour, fish oil encapsulates (3%) iii) PE- contained wheat flour, fish oil encapsulates (3%) and pomegranate extract (0.5%) and iv) FO-contained wheat flour, fish oil (1.0%). Commercially available whole wheat flour made from whole wheat grains was used in the study. Salt was incorporated at 1% in all formulations. Water was added at the required level to obtain a uniform dough consistency and the dough was subjected to a cold extrusion process for pasta preparation. The extruded pasta samples were then dried in a hot air dryer at 60°C for 1 h until the desired moisture level was attained. After drying, the pasta samples were cooled to room temperature, packed in laminated polyethylene pouches and stored under ambient conditions for further analysis.

Quality analysis of pomegranate extract and fish oil encapsulates

The antioxidant activity of pomegranate extract was determined by DPPH radical scavenging assay according to Nishino *et al.* (2000). The total phenolic content was measured by the method described by Druckerei (2002). The ferric reducing antioxidant power assay was determined according to Pisoschi *et al.* (2016).

The proximate composition (moisture, protein, fat and ash) of fish oil microencapsulates was determined according to the methods prescribed by AOAC (2023) method. Total nitrogen content was estimated using the micro-Kjeldahl distillation method and the nitrogen-to-protein conversion factor of 6.38 was used for protein calculation, as this factor is widely recommended for milk and milk protein products. Since sodium caseinate was used as a wall material in the fish oil microencapsulates, the measured nitrogen content was multiplied by 6.38 to determine the crude protein content. The bulk density and tapped density of fish oil microencapsulates were determined according to Chinta *et al.* (2009). The Carr index and Hausner ratio of fish oil microencapsulates were calculated as described by Turchiuli *et al.* (2005). The Hygroscopicity of fish oil microencapsulates was evaluated according to Cai and Corke (2000). The total oil was determined according to Soxhlet method (AOAC, 2023). The surface oil was estimated as per the method followed by Sankarikutty *et al.* (1988). Encapsulation efficiency was calculated from difference between total oil and surface oil.

Quality analysis of fish oil microencapsulates fortified pasta

The proximate composition of raw ingredients (whole wheat flour, sodium caseinate, maltodextrin and gum arabic), fish oil microencapsulates and fish oil encapsulates fortified pasta was determined according to AOAC (2023) method. Carbohydrate content was calculated by difference method using the formula:

$$\text{Carbohydrate (\%)} = 100 - (\text{Moisture} + \text{Protein} + \text{Fat} + \text{Ash})$$

Calorific value (Energy) was calculated by using the following formula:

$$\text{Energy (kcal/100 g)} = (4 \times \text{Protein}) + (9 \times \text{Fat}) + (4 \times \text{Carbohydrate})$$

Water absorption capacity and fat absorption capacity of pasta was determined by according to Anderson *et al.* (1969). The swelling Index was determined as described by Cleary and Brennan (2006). The cooking loss in pasta was determined as described in AACC (2000). The cooking time for pasta was determined according to AACC method (2000). Total plate count (TPC) was determined according to USFDA (2021). *Staphylococcus aureus* was determined according to USFDA (2016). The yeast and mold in the dried pasta were determined according to USFDA (2021). The sensory evaluation of pasta were carried out using 9 point hedonic scale (Meilgaard *et al.*, 1999). For sensory evaluation, the dried pasta samples were cooked in potable water using a pasta-to-water ratio of 1:10 (w/v). Approximately 25 g of pasta was added to boiling water and cooked until the optimum cooking time was reached, as determined by the disappearance of the white core upon pressing the pasta strand between two glass plates. After cooking, the excess water was drained using a stainless-steel sieve and the cooked pasta was allowed to stand for 1-2 min to remove surface moisture. The samples were then served warm in coded plates to the sensory panellists for evaluation (Petitot *et al.*, 2010). The panellist were asked to score for the sensory attribute such as appearance, color, texture, taste and overall acceptability.

The data obtained by various quality analyses were subjected to one-way ANOVA (Analysis of variance). Duncan's multiple range test was performed at 95% confidence level ($P < 0.05$) by using the SPSS package with a version of 16.0 (SPSS Inc, Chicago, USA). All the analysis were carried out in triplicate and values were represented as mean $\pm$ SD.

RESULTS AND DISCUSSION

Antioxidant activity of pomegranate extract

The pomegranate extract exhibited a DPPH activity of 76.76%, total phenolic content of 280.50 mg gallic acid equivalent g^{-1} of pomegranate extract and FRAP activity of 134.81 μM (FeII) g^{-1} . Mo *et al.* (2022) reported that the antioxidant activity of pomegranate extracts depended on the presence of anthocyanins, gallic acid, ellagic acid, p-coumaric acid, caffeic acid and punicalagin.

Proximate composition of raw ingredients

The commercially available whole wheat flour used in the study contained 10.2% moisture, 11.85% protein, 1.2% fat, 1.6% ash and 75.15% carbohydrate. Sodium caseinate, which served as the major wall material for microencapsulation, exhibited a high protein content of 91.50%, along with 3.2% moisture, 0.95% fat, 3.2% ash and 1.15% carbohydrate. Maltodextrin mainly contributed carbohydrates and contained 3.2% moisture, 0.4% protein, 0.35% fat, 1.20% ash and 94.85% carbohydrate. Gum Arabic contained 6.5% moisture, 2.5% protein, 0.50% fat, 3.5% ash and 87% carbohydrate. The significantly higher protein content observed in the encapsulated pasta samples was mainly attributed to the incorporation of sodium caseinate, a protein-rich encapsulating agent widely used in food microencapsulation due to its excellent emulsifying and film-forming properties (Kolanowski, 2005; Gharsallaoui *et al.*, 2007).

Physical and chemical properties of fish oil microencapsulates

The fish oil encapsulates had 2.52 $\pm$ 0.18 % to 2.63 $\pm$ 0.96% moisture, 74.50 $\pm$ 0.5% to 76.12 $\pm$ 0.20% protein, 11.01 $\pm$ 0.03% to 11.45 $\pm$ 0.34% fat and 0.80 $\pm$ 0.32% to 1.42 $\pm$ 0.63% ash. The composition changes in fish oil encapsulates depends on wall material, concentration of oil used, method followed for emulsion and encapsulation (Gharsallaoui *et al.*, 2007). The flow properties of fish oil encapsulates is one of the important property which determines products packaging, storage and application (Fitzpatrick and Ahrne, 2005). In the present study, Hausner ratio of fish oil encapsulates was found to be 1.28-1.32 which indicate the flow properties of fish oil encapsulates are passable (Chinta *et al.*, 2009). The encapsulation efficiency of fish oil encapsulates was found to be 95.02% and 94.88% for control, PEE sample respectively (Table 1). Carneiro *et al.* (2013) observed similar results for flaxseed oil encapsulates contained maltodextrin and gum Arabic. The encapsulation efficiency of microcapsulates influenced by the ratio between the core and wall material (Gharsallaoui *et al.*, 2007). Jeyakumari *et al.* (2018) observed 81.88% encapsulation efficiency for fish oil encapsulates contained oregano extract. In the present study, hygroscopicity of fish oil encapsulates ranged from 5.01% to 5.35% (Table 1). Generally, spray dried powder is easily prone to absorb moisture from the surrounding air. Samborska and Bienkowska (2013) reported that moisture absorption of spray dried powder is influenced by ingredient used and process condition applied.

Proximate composition of fish oil microencapsulates fortified pasta

The moisture content of the pasta ranged from 10.31% to 11.53%. The moisture content in pasta varied with composition and extrusion conditions (Anbudhasan *et al.*, 2014). The recommended moisture content for dried pasta

is below 13%; accordingly, the pasta prepared in the present study met the requirement (Teresa *et al.*, 2009). The results were in agreement with previous reports on pasta enriched with surimi powder and omega-3 fatty acids (Anbudhasan *et al.*, 2014; Asik *et al.*, 2024). The protein content of the fish oil microencapsulate-fortified pasta ranged from 23.81% to 24.31% (Table 2). The control pasta prepared solely from whole wheat flour contained comparatively lower protein levels. The higher protein content observed in CE and PE samples indicated that microencapsulation not only served as a protective system for fish oil but also enhanced the nutritional quality of the pasta by enriching it with additional protein from the encapsulating agents, particularly sodium caseinate. Similar improvements in protein content had been reported in fortified pasta products incorporated with protein-rich ingredients and encapsulated functional compounds (Petitot *et al.*, 2010; Dehghan-Shoar *et al.*, 2010). The fat content was 0.48% in the control sample. In contrast, both fish oil encapsulate-and fish oil-incorporated pasta showed higher fat content ranging from 1.02% to 1.41%. The carbohydrate content of the pasta samples varied between 63.29% and 77.01%, while the calorific value ranged from 357.52 to 367.37 kcal/100 g. The comparatively higher energy values observed in the fortified pasta

samples could be attributed to the increased fat and protein contents contributed by fish oil and encapsulating materials. Similar observations had been reported in fortified pasta products enriched with functional ingredients and lipid-based bioactive compounds (Petitot *et al.*, 2010; Chillo *et al.*, 2008).

Functional properties of microencapsulated fish oil fortified pasta

The highest water absorption capacity was found in control (85.34±3.40%). The oil absorption capacity was found to be in the range of 107.47±5.78% to 195.40 ±13.67% (Table 3). The difference in water and oil binding capacity could be related compositions of sample. Swelling index (SI) measures the water absorption by starch/protein during cooking (Alsohaimy *et al.*, 2007). Higher Swelling Index was observed in the all the fortified pasta products compared to control. Sobhy *et al.* (2020) observed similar results for pasta fortified with chick pea isolate. Cooking loss measure the total soluble substances in the cooked water (Filip and Vidrih, 2015). The cook loss of the sample influenced by the drying temperature and density of the sample (Petitot *et al.*, 2010). The highest value of cooking loss was for control and the least loss was observed in pasta contained bulk oil (FO).

Table 1: Physical and chemical properties of fish oil microencapsulates.

Sample	Encapsulation efficiency (%)	Hygroscopicity (%)	Hausner ratio	Carrs index
CE	94.88±0.50	5.35±0.20	1.28±0.01	22.35±0.50
PEE	95.02±0.35	5.01±0.97	1.32±0.02	24.50±0.65

Where, CE- Fish oil encapsulates without pomegranate extract; PEE- Fish oil encapsulates with pomegranate extract. Values are means±SD of triplicate measurements.

Table 2: Proximate composition of fish oil microencapsulates fortified pasta.

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Energy (kcal/100 g)
Control	10.66±0.10 ^{ab}	11.50±0.35 ^b	0.48±0.01 ^a	0.35±0.12 ^a	77.01	357.52
CE	10.92±0.23 ^b	24.31±0.20 ^d	1.02±0.11 ^b	0.46±0.11 ^a	63.29	361.38
PE	10.31±0.23 ^a	23.81±0.44 ^c	1.41±0.24 ^c	0.34±0.14 ^a	64.47	367.37
FO (1%)	11.53±0.20 ^c	10.85 ±0.50 ^a	1.10±0.50 ^{bc}	0.58±0.08 ^b	76.94	359.46

Control- Pasta without fish oil; CE- Pasta with Fish oil encapsulates without pomegranate extract; PE- Pasta with Fish oil encapsulates contained pomegranate extract. FO (1%)- Pasta with 1% fish oil; Values are means±SD of triplicate measurements; values within a column with different superscript letters are significantly (p<0.05) different.

Table 3: Functional and cooking properties of microencapsulated fish oil fortified pasta.

Sample/ parameter	Water absorption capacity (%)	Oil absorption capacity (%)	Swelling index	Cook loss (%)	Cook time (in minutes)
Control	85.34±3.40 ^b	195.40±13.67 ^a	78.39±1.50 ^a	7.16±0.25 ^a	8.5±0.50 ^a
CE	77.63±3.35 ^a	150.69±20.46 ^{ab}	175.99±0.85 ^b	8.01±0.55 ^a	7.5±0.20 ^a
PE	70.35±2.70 ^a	130.04±3.76 ^c	175.70±2.50 ^b	7.33±0.60 ^a	7.9±0.80 ^a
FO (1%)	75.59±8.19 ^{ab}	165.57±11.97 ^b	185.01±3.10 ^c	8.90±0.55 ^b	8.0±0.60 ^a

Control - Pasta without fish oil; CE- Pasta with Fish oil encapsulates without pomegranate extract; PE- Pasta with fish oil encapsulates contained pomegranate extract. FO (1%)- Pasta with 1% fish oil; Values are means±SD of triplicate measurements; values within a column with different superscript letters are significantly (p<0.05) different.

Moreover, all the sample had an acceptable limit (9%) of cook loss (AACC, 2000). Mostly the cooking time for all the samples was in the range of 7.5 minutes to 8.5 minutes. The cooking time was the highest for control pasta (8.5 minutes). The reduced cooking time influenced by increase rate water penetration (Padalino *et al.*, 2014).

Changes in biochemical quality of fish oil microencapsulates fortified pasta

Moisture content of the pasta varied from 10.08% to 11.80%. The recommended moisture content in the pasta product is not more than 12.5% (FSSAI, 2011). Accordingly, all the samples had within the acceptable limit of moisture content during storage. The pH values of all the pasta samples showed a gradual increase during storage. Total volatile base Nitrogen value ranged from 2.5 to 6.2 mg% (Table 4). PV and TBARS value measures the level of oxidation in the product. PV and TBARS value showed a gradual increase during storage. Results showed that PE had a lower PV and TBARS value than other which indicated less oxidation. Rahmani-Manglano *et al.* (2023) have reported that antioxidants are plays a major role in

stabilizing fish oil emulsion and provide protection of lipids during spray drying.

Sensory quality of microencapsulated fish oil fortified pasta

The sensory evaluation revealed that sensory score for all the pasta received overall acceptability score between 6.8 to 7.8 (Table 5). However, pasta contained fish oil encapsulates and pomegranate extract (PM) rated high score by the panellist with an overall acceptability score of 7.8 and it was comparable with control. Agnikumar *et al.* (2015) and Jeyakumari *et al.* (2016) observed higher acceptance for fish oil encapsulates fortified cakes, cookies, respectively than fish oil incorporated cookies. Similarly. Results indicated that incorporation of fish oil encapsulates in the pasta found to have better acceptability without affecting texture and taste.

Microbial quality of microencapsulated fish oil fortified pasta

The total plate count in the pasta was varied from 1.45×10^2 cfu/g to 2.90×10^2 . It has been reported that total

Table 4: Biochemical quality of microencapsulated fish oil fortified pasta.

Sample/parameter	0 Days	30 Days	60 Days
Moisture (%)			
Control	10.66±0.10 ^{abA}	10.51±0.29 ^{aA}	11.29±0.65 ^{bA}
CE	10.92±0.23 ^{bB}	10.80±0.15 ^{bB}	10.58±0.04 ^{aA}
PE	10.31±0.23 ^{aA}	10.08±0.08 ^{bA}	10.37±0.12 ^{aA}
FO (1%)	11.45±0.20 ^{cA}	11.53±0.21 ^{cA}	11.80±0.23 ^{bA}
pH			
Control	6.31±0.20 ^{aA}	6.4±0.02 ^{cA}	6.10±0.35 ^{aA}
CE	6.26±0.03 ^{aA}	6.22±0.02 ^{aA}	6.25±0.04 ^{aA}
PE	6.31±0.35 ^{aA}	6.40 ±0.02 ^{cA}	6.40±0.20 ^{aA}
FO (1%)	6.175±0.01 ^{aA}	6.32±0.0 ^{bB}	6.40±0.03 ^{aC}
TVB-N (mg%)			
Control	2.5 ± 0.25 ^{aA}	2.8±0.01 ^{aB}	3.0±0.02 ^{aB}
CE	3.2±0.10 ^{cA}	4.5±0.05 ^{cB}	5.5±0.5 ^{cC}
PE	2.8±0.10 ^{bA}	3.20±0.04 ^{bB}	4.25±0.02 ^{bC}
FO (1%)	4.0±0.10 ^{dA}	5.5±0.5 ^{dB}	6.2±0.35 ^{dC}
PV (milli equi.O₂/kg)			
Control	1.41±0.08 ^{aA}	1.80±0.57 ^{aA}	1.95±0.25 ^{aA}
CE	3.50±0.15 ^{cA}	4.45±0.08 ^{cB}	6.03±0.03 ^{cC}
PE	2.36±0.01 ^{bA}	3.27±0.02 ^{bA}	4.53±0.89 ^{bB}
FO (1%)	4.04±0.09 ^{dA}	6.47±0.14 ^{dB}	8.98±1.35 ^{dC}
TBARS (mg MDA/kg)			
Control	0.18±0.01 ^{aA}	0.10±0.01 ^{aA}	0.24±0.05 ^{aA}
CE	0.25±0.08 ^{bA}	0.35±0.01 ^{bB}	0.50±0.01 ^{aC}
PE	0.14±0.01 ^{aA}	0.22±0.08 ^{cB}	0.25±0.01 ^{bB}
FO (1%)	0.53±0.01 ^{cA}	0.85±0.02 ^{dB}	1.25±0.02 ^{cC}

Control- Pasta without fish oil; CE- Pasta with Fish oil encapsulates without pomegranate extract; PE- Pasta with fish oil encapsulates contained pomegranate extract. FO (1%)- Pasta with 1% fish oil; Values are means±SD of triplicate measurements; values within a column with different superscript letters are significantly ($p < 0.05$) different between the sample; values within a row with different superscript letters are significantly ($p < 0.05$) different during storage days.

Table 5: Sensory quality of microencapsulated fish oil fortified pasta.

Sample/ parameter	Appearance	Color	Flavour	Texture	Taste	Overall acceptability
Control	8.0±0.45 ^a	7.2±0.20 ^a	7.2±0.20 ^{ab}	7.6±0.24 ^a	7.0±0.32 ^{ab}	7.8±0.31 ^b
CE	7.80±0.37 ^a	7.6±0.51 ^a	7.6±0.24 ^b	7.2±0.49 ^a	7.7±0.30 ^b	7.4±0.32 ^{ab}
PEE	7.86±0.51 ^a	7.6±0.49 ^a	7.8±0.58 ^b	7.6±0.50 ^a	7.8±0.58 ^b	7.8±0.42 ^b
FO (1%)	7.6±0.51 ^a	7.6±0.51 ^a	6.8±0.51 ^a	7.2±0.40 ^a	6.8±0.65 ^a	6.8±0.39 ^a

Control- Pasta without fish oil; CE- Pasta with Fish oil encapsulates does not contained antioxidant; FO (1%)- Pasta with 1% fish oil; PMO- Pasta with Fish oil encapsulates contained pomegranate extract. Values are means±SD of triplicate measurements; values within a column with different superscript letters are significantly ($p < 0.05$) different between the sample.

plate count in the marketable form of pasta should not be more than $<10^4$ cfu/g (FSSAI, 2011). Accordingly, all the sample prepared in the study had a total plate count within acceptable limit during storage. *Staphylococcus aureus*, yeast and mold were absent in all the samples which indicated the pasta were prepared in hygienic condition with controlled drying process.

CONCLUSION

It can be concluded that fish oil encapsulates prepared in the study had highest encapsulation efficiency of 95.02%. the pasta prepared in the study met the requirements of moisture and protein content. The chemical and microbiology quality of fish oil encapsulates fortified pasta revealed that total volatile base nitrogen (TVB-N), peroxide value (PV), thiobarbituric acid (TBA) values and total plate count (TPC) were within acceptable limit during storage. The sensory analysis indicated high score of acceptability for microencapsulated fish oil-fortified pasta contained pomegranate peel extract than pasta contained bulk fish oil.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

This research did not involve any animal/human participation or any material that requires ethical approval. Therefore, informed consent was not required.

Conflict of interest

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