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Influence of blanching temperatures on the biochemical, microbiological, and sensory characteristics of freeze-dried *Metapenaeus affinis* (Jinga shrimp) during ambient storage

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Abstract

This study evaluated the influence of different thermal blanching pretreatments on the storage stability and quality characteristics of freeze-dried Jinga shrimp (*Metapenaeus affinis*). Fresh shrimp were subjected to four treatments: an unblanched control (T_0) and blanching in a 1.5% NaCl solution for 2 min at 70 °C (T_1), 80 °C (T_2), and 90 °C (T_3). Following freeze-drying, samples were packed in high-barrier multilayer pouches (PES/Al/BOPA/LDPE) and stored at ambient temperature for 180 days. Quality deterioration was monitored at regular intervals through biochemical (pH, TVB-N, TMA-N, Peroxide Value), microbiological (Total Plate Count), and sensory evaluations. Results indicated that while all samples experienced significant degradation over the 180-day storage period, thermal pretreatments effectively retarded the spoilage rate. Treatment T_2 (80 °C) demonstrated superior preservation, maintaining the lowest biochemical degradation indicators at the end of storage: pH (7.08 ± 0.05), TVB-N (46.12 ± 1.98 mg/100 g), TMA-N (19.83 ± 0.35 mg/100 g), and Peroxide Value (8.54 ± 0.42 meq/kg). Furthermore, T_2 exhibited the highest microbial stability with a TPC of 2.44 ± 0.22 log CFU/g, remaining well within regulatory safety limits, whereas the unblanched control exceeded acceptable thresholds. Sensory evaluation confirmed that T_2 retained the highest overall acceptability score (6.50 ± 0.53) after 180 days. In conclusion, blanching at 80 °C for 2 min serves as an optimal pretreatment to minimize biochemical deterioration, ensure microbial safety, and extend the sensory shelf life of freeze-dried *M. affinis* under ambient storage.

Keywords: *Metapenaeus affinis*, freeze-drying, blanching pretreatment, storage stability, biochemical degradation

1. Introduction

Seafood is an important source of high-quality protein, essential amino acids, vitamins, and minerals, and plays a significant role in global food and nutritional security. Aquatic animal foods contributed approximately 15% of animal protein and 6% of the total protein supply worldwide in 2021 (Food and Agriculture Organization [FAO], 2024) [16]. Owing to the presence of omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), seafood consumption has increased considerably. It is widely recognized for its health benefits (Rahmaniya and Sekharan, 2018) [37]. Regular consumption of seafood has been associated with proper growth, brain development, and a reduced risk of several lifestyle-related diseases, including cardiovascular disorders (Guallar *et al.*, 2002; Krauss *et al.*, 2000; Liao and Chao, 2009; Singh *et al.*, 1997; Von Schacky *et al.*, 1999) [18, 23, 25, 41, 45].

India is one of the leading seafood-exporting countries, exporting 16, 98, 170 MT of marine products valued at ₹62, 408.45 crore (US\$ 7.45 billion) during FY 2024-25. Frozen shrimp remains the most valuable export commodity, accounting for 69.46% of total export earnings. In contrast, dried marine products contribute comparatively less to export value despite their shelf-stable nature, highlighting the need for improved processing technologies and value-added seafood products (Marine Products Export Development Authority [MPEDA], 2025) [29].

Among commercially important crustaceans, *Metapenaeus affinis* (H. Milne Edwards, 1837), commonly known as Jinga shrimp, is widely distributed throughout the Indo-Pacific region

and supports an economically important fishery along the Indian coast (ICAR-Central Marine Fisheries Research Institute [CMFRI], 2016, 2025) [9, 20]. Shrimp is highly valued because of its excellent nutritional profile, containing high-quality protein, vitamin B12, selenium, omega-3 highly unsaturated fatty acids, and astaxanthin, a potent natural antioxidant (Dayal *et al.*, 2013; Venugopal, 2008) [13, 44]. However, shrimp is highly perishable due to its high moisture and protein content, which promotes microbial proliferation and biochemical deterioration soon after harvest (Akonor *et al.*, 2016) [1]. Therefore, effective preservation methods are essential to maintain product quality, safety, and marketability.

Drying is one of the oldest and most widely adopted preservation methods for seafood. By reducing water content, drying inhibits microbial growth and enzymatic activity, thereby extending shelf life (Rahman and Perera, 2007) [36]. Nevertheless, conventional drying methods often result in undesirable changes in nutritional value, texture, colour, and flavour because of prolonged exposure to heat (Al-Hilphy *et al.*, 2022) [3]. To overcome these limitations, advanced drying technologies such as freeze-drying have gained considerable attention (Wang *et al.*, 2011) [46].

Freeze-drying removes water from frozen materials through sublimation under low-temperature and vacuum conditions, thereby minimizing thermal damage and preserving the original characteristics of the product (Donsì *et al.*, 2001) [15]. This technique has been widely recognized for its ability to retain nutritional quality, flavour, colour, and sensory attributes while producing lightweight products with extended shelf life (Berk, 2013) [6]. Freeze-dried seafood products have gained increasing commercial importance because of their convenience, long storage stability, and ease of transportation (Crapo *et al.*, 2010) [12]. Furthermore, the porous structure developed during freeze-drying enhances rehydration characteristics and improves consumer acceptability (Liu *et al.*, 2022) [26].

Pretreatments applied before drying can significantly influence the quality and stability of the final product. Among these, blanching is commonly employed to reduce microbial load, inactivate enzymes, and improve product quality (Arroqui *et al.*, 2003a; Arroqui *et al.*, 2003b) [4, 5]. The effectiveness of blanching depends on processing conditions such as temperature, time, and salt concentration, which may influence the biochemical, microbiological, and sensory characteristics of the finished product (De Corcuera *et al.*, 2004) [14]. Optimisation of blanching conditions before freeze-drying may therefore contribute to improved storage stability and product acceptability.

Despite the commercial importance of *M. affinis* and the advantages of freeze-drying, research regarding the optimization of blanching conditions as a pre-treatment for this species remains limited. Therefore, the present study was undertaken to evaluate the influence of different blanching temperatures on the biochemical, microbiological, and sensory quality of freeze-dried *M. affinis* packaged in multilayer pouches and stored under ambient conditions.

2. Materials and Methods

2.1 Raw Material and Experimental Design

Fresh Jinga shrimp (*Metapenaeus affinis*) weighing approximately 39 kg were procured from the Veraval Fish Landing Centre, Gujarat, India. Immediately after procurement, the shrimp were adequately iced and

transported to the Fish Processing Technology Laboratory, College of Fisheries Science, Kamdhenu University, Veraval, in insulated ice boxes. During transportation, the temperature was maintained between 1 °C-2 °C to preserve freshness and minimize biochemical and microbial deterioration.

Upon arrival at the laboratory, the shrimp were thoroughly washed with chilled potable water to remove adhering slime, dirt, and other extraneous materials. The samples were manually beheaded, peeled, and deveined before being subjected to experimental treatments.

The experiment was conducted in a Completely Randomized Design (CRD) comprising four treatments. The control treatment (T₀) consisted of shrimp samples without blanching, whereas treatments T₁, T₂, and T₃ involved blanching in 1.5% sodium chloride solution at 70, 80, and 90 °C, respectively, for 2 min. Each treatment was replicated three times.

2.2 Processing and Freeze-Drying

Processed shrimp were divided into four equal portions corresponding to the treatment groups. For blanching treatments, a 1.5% (w/v) sodium chloride solution was prepared and maintained at the respective temperatures. Shrimp samples were immersed in the blanching solution for 2 min, then drained.

Following pretreatment, all samples were subjected to vacuum freeze-drying using a vacuum food freeze dryer (PVFD10, Precise Vacuum Systems Pvt. Ltd., India). Samples were initially frozen at -25 °C for 360 min. Primary drying was carried out under vacuum (600 mTorr; 0.8 mbar) at a shelf temperature of 40 °C, followed by secondary drying at 50 °C for 360 min. After completion of the drying cycle, the freeze-dried shrimp were packed in multilayer high-barrier pouches (PES/Al/BOPA/LDPE) and sealed using a foot-operated impulse sealer. Packaged samples were stored at ambient temperature for 180 days.

2.3 Biochemical Analysis

2.3.1 pH

The pH of shrimp samples was determined using a digital pH meter (HANNA HI-98107). Ten grams of the sample were homogenized with 20 mL of distilled water, filtered, and the pH of the filtrate was recorded at room temperature.

2.3.2 Trimethylamine Nitrogen (TMA-N)

Trimethylamine nitrogen was estimated using the micro-diffusion method of Beatty and Gibbons (1937). Trichloroacetic acid (TCA) extracts were prepared by homogenizing shrimp samples with 20% TCA, followed by filtration and volume adjustment. The liberated trimethylamine was trapped in standard sulphuric acid and quantified by titration against standard sodium hydroxide using Tashiro's indicator. Results were expressed as mg TMA-N per 100 g sample.

$$\text{TMA-N (mg/100 g)} = \frac{(V_s - V_b) \times 0.14 \times \text{Volume of extract}}{\text{Volume of sample taken} \times \text{Weight of sample}} \times 100$$

2.3.3 Total Volatile Base Nitrogen (TVB-N)

TVB-N was determined from the same TCA extracts using the micro-diffusion technique described by Beatty and Gibbons (1937). Volatile basic nitrogenous compounds liberated from the sample reacted with standard sulphuric

acid in the diffusion chamber and were subsequently quantified by titration. Results were expressed as mg TVB-N per 100 g sample.

$$\text{TVB-N (mg/100 g)} = \frac{(V_s - V_b) \times 0.14 \times \text{Volume of extract}}{\text{Volume of sample taken} \times \text{Weight of sample}} \times 100$$

2.3.4 Peroxide Value (PV)

The extent of lipid oxidation was assessed by determining peroxide value using the iodometric method described by AOAC (2006). Lipid extracts obtained from shrimp samples were reacted with potassium iodide, and the liberated iodine was titrated against standardized sodium thiosulphate solution. Peroxide value was expressed as milliequivalents of peroxide per kilogram of lipid (meq/kg).

$$\text{Peroxide value (meq/kg)} = \frac{1000 \times (V - X) \times \text{Volume of extract}}{W \times \text{Aliquot sample volume}} \times 100$$

2.4 Microbiological Analysis

Microbiological quality was assessed throughout storage. Ten grams of sample were aseptically homogenized with 90 mL sterile phosphate-buffered saline to obtain an initial 10^{-1} dilution. Further serial dilutions were prepared as required for microbial enumeration.

2.4.1 Total Plate Count (TPC)

Total viable bacterial count was determined by the pour plate method using Plate Count Agar (PCA). Aliquots of appropriate dilutions were plated, mixed with molten agar, and incubated at 37 ± 1 °C for 48 h. Colonies were counted and expressed as colony-forming units per gram (CFU/g).

$$\text{TPC (CFU/g)} = \text{Average No. of colonies} \times \text{Dilution factor}$$

2.5 Sensory Evaluation

The sensory quality of freeze-dried shrimp samples was evaluated using a nine-point hedonic scale developed by Peryam and Pilgrim (1957). A semi-trained panel consisting of ten members assessed colour, appearance, odour, texture, and overall acceptability. Samples were presented under identical conditions, and panelists assigned scores ranging from 1 (dislike extremely) to 9 (like extremely). A score of five was considered the minimum acceptable limit.

2.6 Statistical Analysis

All experiments and analytical determinations were carried out in triplicate. The data obtained were expressed as mean $\pm$ standard deviation. Statistical analysis was performed using analysis of variance (ANOVA) as described by Snedecor and Cochran (2014) to determine significant differences among treatments and storage periods.

3. Results and Discussion

3.1 Biochemical Characteristics

3.1.1 pH Variations

The pH of freeze-dried *M. affinis* increased significantly ($p < 0.05$) throughout the 180-day storage period in all treatments (Table 1). Initial pH values ranged from 6.68 ± 0.07 to 6.82 ± 0.07 , indicating good product quality and freshness. At the end of storage, pH increased to 7.75 ± 0.28 , 7.42 ± 0.16 , 7.08 ± 0.05 , and 7.18 ± 0.18 in T_0 , T_1 , T_2 , and T_3 , respectively. The highest pH was observed in the

unblanched control (T_0), whereas T_2 (80 °C blanching) showed the lowest increase during storage.

The progressive rise in pH during storage may be attributed to the formation of alkaline compounds such as ammonia, trimethylamine (TMA), dimethylamine (DMA), and other volatile nitrogenous substances generated through microbial, enzymatic, and autolytic degradation of proteins (López-Caballero *et al.*, 2005; Chen *et al.*, 2022) [10, 27]. Similar increases in pH during storage have been reported in dried seafood products. Hossain *et al.* (2019) [19] observed pH values increasing from 6.27-6.80 to 7.65-7.86 in salt-smoke-dried *Mystus tengara* during 180 days of storage. Likewise, Rabie *et al.* (2016) [35] reported an increase in pH from 6.12-6.62 to 6.37-6.98 in dried shrimp (*Pandalus borealis*) stored for six months at ambient temperature.

Among the treatments, T_2 maintained the lowest final pH (7.08 ± 0.05), indicating better biochemical stability and reduced protein degradation during storage. The results suggest that blanching at 80 °C prior to freeze-drying effectively retards the formation of alkaline spoilage compounds and improves the storage stability of freeze-dried *M. affinis* shrimp.

Table 1: Changes in pH of FD shrimp (*Metapenaeus affinis*) during storage at ambient temperature

Storage Days	T_0	T_1	T_2	T_3
0	6.82 ± 0.07	6.76 ± 0.05	6.72 ± 0.04	6.68 ± 0.07
30	6.90 ± 0.08	6.82 ± 0.07	6.76 ± 0.05	6.73 ± 0.08
60	7.02 ± 0.09	6.90 ± 0.08	6.81 ± 0.07	6.78 ± 0.05
90	7.18 ± 0.17	7.00 ± 0.04	6.86 ± 0.03	6.85 ± 0.10
120	7.32 ± 0.08	7.12 ± 0.13	6.92 ± 0.03	6.95 ± 0.04
150	7.50 ± 0.26	7.26 ± 0.06	6.99 ± 0.04	7.06 ± 0.13
180	7.75 ± 0.28	7.42 ± 0.16	7.08 ± 0.05	7.18 ± 0.18

3.1.2 Total Volatile Base Nitrogen (TVB-N)

TVB-N values of freeze-dried *M. affinis* increased significantly ($p < 0.05$) during the 180-day storage period across all treatments (Table 2). Initial TVB-N values ranged from 14.32 ± 0.47 mg/100 g in T_3 to 22.52 ± 1.14 mg/100 g in the unblanched control (T_0). After 180 days of storage, TVB-N increased to 112.54 ± 4.15 , 84.67 ± 3.21 , 46.12 ± 1.98 , and 61.28 ± 2.54 mg/100 g in T_0 , T_1 , T_2 , and T_3 , respectively. Among the treatments, T_2 (80 °C blanching) exhibited the lowest TVB-N accumulation, indicating superior preservation during storage.

The increase in TVB-N is associated with microbial and enzymatic degradation of proteins and other nitrogenous compounds, leading to the formation of volatile bases such as ammonia, dimethylamine, and trimethylamine (Castro *et al.*, 2012; Ocaño-Higuera *et al.*, 2011) [8, 31]. Similar increases in TVB-N during storage have been reported in dried seafood products. Rabie *et al.* (2016) [35] observed TVB-N values increasing from 17.22-18.35 mg/100 g to 28.36-36.07 mg/100 g in dried shrimp (*Pandalus borealis*) during six months of storage. Likewise, Jarag *et al.* (2025) [21] reported an increase from 8.70-14.51 mg/100 g to 19.48 mg/100 g in dried Jawala shrimp during 90 days of storage. According to Connell (1995) [11], spoilage in dried fish products is generally associated with TVB-N levels of 100-200 mg/100 g. In the present study, only the unblanched control (T_0) exceeded 100 mg/100 g after 180 days, whereas all blanched treatments remained below this limit.

Table 2: Changes in TVB-N (mg/100g) of FD shrimp (*Metapenaeus affinis*) during storage at ambient temperature

Storage Days	T ₀	T ₁	T ₂	T ₃
0	22.52±1.14	19.24±0.85	16.83±0.67	14.32±0.47
30	31.28±1.45	25.41±1.12	19.56±1.21	18.24±0.59
60	43.85±2.02	33.76±1.58	23.44±0.89	28.32±1.17
90	57.41±1.88	42.53±2.14	28.67±1.45	35.19±1.62
120	72.63±2.75	54.18±1.95	33.21±1.76	42.64±2.08
150	91.35±3.41	68.32±2.67	39.88±2.13	51.45±1.85
180	112.54±4.15	84.67±3.21	46.12±1.98	61.28±2.54

3.1.3 Trimethylamine Nitrogen (TMA-N)

TMA-N values increased significantly ($p < 0.05$) in all freeze-dried *M. affinis* samples during ambient storage (Table 3). Initial TMA-N values ranged from 2.18±0.14 mg/100 g in T₃ to 4.14±0.32 mg/100 g in T₀. After 180 days, TMA-N values increased to 35.82±2.65, 27.47±1.63, 19.83±0.35, and 21.85±0.98 mg/100 g in T₀, T₁, T₂, and T₃, respectively. The lowest accumulation was observed in T₂, indicating better control of spoilage-related biochemical changes.

TMA-N is formed through bacterial and enzymatic reduction of trimethylamine oxide (TMAO) and is widely used as an indicator of seafood freshness deterioration (Ólafsdóttir *et al.*, 1997) [32]. The progressive increase observed during storage reflects ongoing degradation processes and the accumulation of volatile amines responsible for characteristic fishy odours. Similar trends have been reported by Jarag *et al.* (2025) [21], who observed TMA-N values increasing from 2.00±0.01 mg/100 g to 6.70±0.05 mg/100 g in dried Jawala shrimp during storage. Despite the increase, all treatments remained below the maximum permissible limit of 50 mg/100 g recommended for dried seafood products (Spinelli and Dassow, 1982) [42].

Table 3: TMA-N (mg/100 g) changes in FD shrimp (*Metapenaeus affinis*) during storage at ambient temperature

Storage Days	T ₀	T ₁	T ₂	T ₃
0	4.14±0.32	2.90±0.31	2.47±0.16	2.18±0.14
30	8.43±0.53	5.71±0.39	3.94±0.32	3.90±0.15
60	12.25±0.75	8.94±0.50	5.83±0.43	6.35±0.23
90	17.83±1.38	12.48±0.65	8.15±0.51	8.85±0.30
120	22.30±1.50	16.59±1.20	11.25±0.68	12.25±0.43
150	28.38±1.80	21.24±1.04	15.47±1.35	16.85±0.58
180	35.82±2.65	27.47±1.63	19.83±0.35	21.85±0.98

3.1.4 Peroxide Value (PV)

Peroxide value (PV) increased significantly ($p < 0.05$) in all freeze-dried *M. affinis* samples during the 180-day storage period, indicating progressive lipid oxidation (Table 4). Initial PV values ranged from 1.86±0.24 to 2.18±0.19 meq/kg, while after 180 days they increased to 15.65±0.54, 11.47±0.63, 8.54±0.42, and 10.32±0.45 meq/kg in T₀, T₁, T₂, and T₃, respectively. The highest PV was recorded in the unblanched control (T₀), whereas T₂ (80 °C blanching) exhibited the lowest value, indicating greater resistance to oxidative deterioration during storage.

The increase in PV during storage is attributed to the formation of lipid hydroperoxides, which are primary products of lipid oxidation resulting from exposure to oxygen and residual moisture in the product matrix (Kong &

Singh, 2011; Li *et al.*, 2019) [22, 24]. Similar increases in peroxide value during storage have been reported in dried seafood products. Majumdar *et al.* (2018) [28] observed PV values increasing from 12.08 to 25.35 meq/kg lipid in sun-dried *Mystus vittatus* during storage. Likewise, Rasul *et al.* (2019) [38] reported an increase from 13.84 to 27.87 meq/kg in dried *Trichogaster fasciata* under ambient storage conditions. Rabie *et al.* (2016) [35] also reported progressive lipid oxidation in dried shrimp during storage, reflected by increasing peroxide values.

According to Shahidi and Zhong (2010) [40], acceptable peroxide values in fish products generally range between 10 and 16 meq O₂/kg, while values exceeding 20 meq/kg are considered indicative of rancidity and reduced consumer acceptability (Connell, 1995) [11]. In the present study, all blanched treatments (T₁, T₂, and T₃) remained within acceptable limits throughout storage, whereas the control sample (T₀) approached the upper acceptable limit by day 180.

Table 4: Changes Peroxide (meq./Kg) changes in FD shrimp (*Metapenaeus affinis*) during storage at ambient temperature

Storage Days	T ₀	T ₁	T ₂	T ₃
0	1.86±0.24	2.17±0.23	2.18±0.19	1.95±0.13
30	3.07±0.20	2.97±0.18	2.70±0.18	2.55±0.10
60	4.76±0.42	4.14±0.29	3.52±0.31	3.67±0.18
90	7.20±0.38	5.57±0.30	4.58±0.26	5.10±0.25
120	9.81±0.64	7.41±0.44	5.81±0.37	6.81±0.34
150	12.47±0.68	9.28±0.4	7.11±0.34	8.57±0.43
180	15.65±0.54	11.47±0.63	8.54±0.42	10.32±0.45

3.2 Microbiological Quality

3.2.1 Total Plate Count (TPC)

The Total Plate Count (TPC) of freeze-dried *Metapenaeus affinis* increased significantly ($p < 0.05$) during 180 days of ambient storage in all treatments. Initial TPC values ranged from 1.55±0.03 to 1.88±0.14 log CFU/g, with the lowest count observed in T₃ and the highest in the unblanched control (T₀). After 180 days of storage, TPC increased to 4.12±0.19, 3.42±0.07, 2.44±0.22, and 2.89±0.16 log CFU/g in T₀, T₁, T₂, and T₃, respectively. Among all treatments, T₂ (80 °C blanching) exhibited the lowest microbial load throughout storage, indicating superior microbial stability.

The gradual increase in TPC during storage may be attributed to moisture uptake and the survival and growth of residual microorganisms under ambient conditions. Similar increases in microbial counts during storage have been reported in dried Jawala shrimp, where TPC increased from 2.58 to 3.03 log CFU/g over 90 days of storage (Jarag *et al.*, 2025) [21]. The lower microbial counts observed in blanched samples can be attributed to thermal inactivation of microorganisms and spoilage-associated enzymes prior to freeze-drying. Comparable reductions in microbial load following blanching have also been reported in dried seafood products (Omodara and Olaniyan, 2012) [33].

According to the Food Safety and Standards Authority of India (FSSAI, 2023) [17] standards, the permissible limit for aerobic plate count in dried fishery products is 4.0 log CFU/g. All blanched treatments (T₁-T₃) remained within the acceptable limit throughout storage, whereas the unblanched control (T₀) slightly exceeded the regulatory threshold at the end of the storage period.

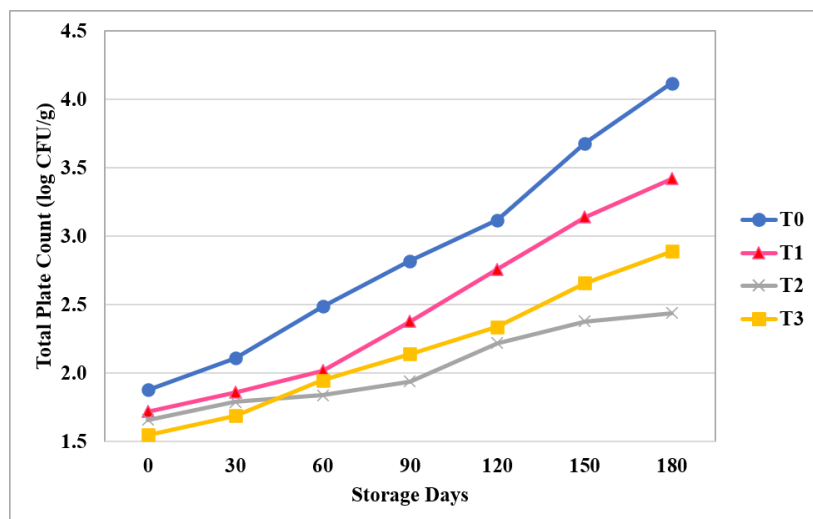


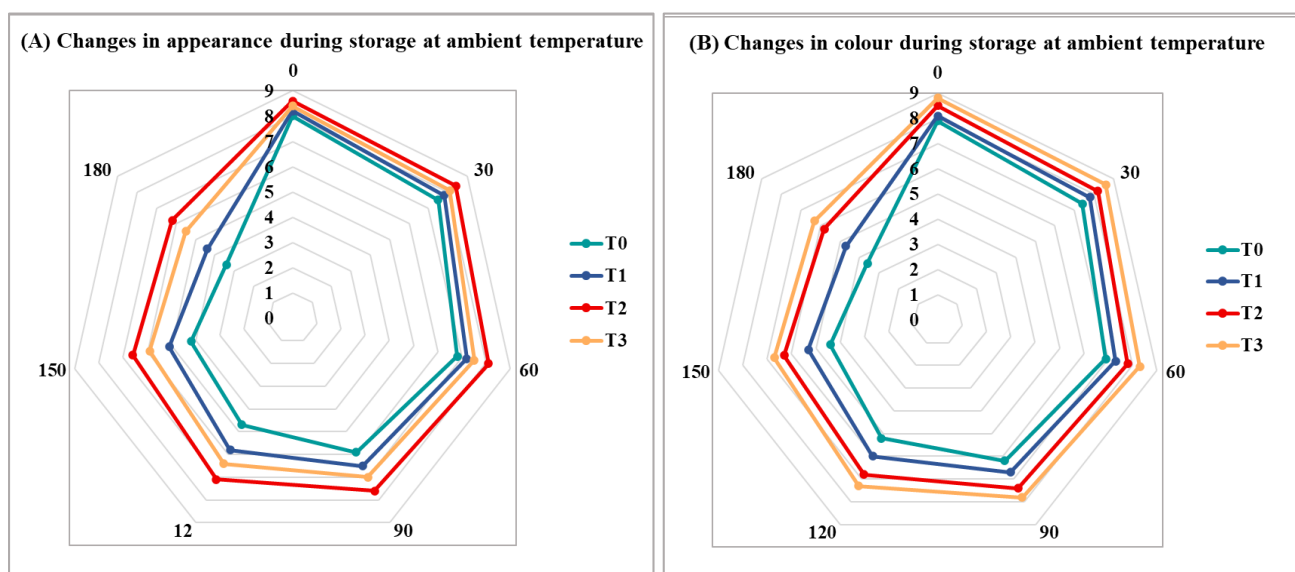
Fig 1: Changes in TPC (log CFU/g) of FD shrimp (*Metapenaeus affinis*) stored at ambient temperature

3.3 Sensory Characteristics

Sensory evaluation is a widely accepted method for assessing the quality and freshness of aquatic products using human senses, and in the present study, a 9-point hedonic scale was used where 9 indicated excellent quality and scores below 5 were considered unacceptable due to spoilage-related deterioration (Alasalvar *et al.*, 2005; Bonilla *et al.*, 2007; Sant'Ana *et al.*, 2011) [2, 7, 39]. All sensory attributes of freeze-dried shrimp (*M. affinis*), including appearance, colour, odour, texture, and overall acceptability, showed a consistent declining trend during 180 days of ambient storage across all treatments, with statistically significant interaction effects between blanching treatments and storage period ($p < 0.05$). Initially, all samples exhibited high sensory quality with appearance scores ranging from 8.00 ± 0.47 to 8.60 ± 0.70 , colour from 7.90 ± 0.57 to 8.80 ± 0.42 , odour from 8.00 ± 0.47 to 8.80 ± 0.42 , texture from 8.00 ± 0.47 to 8.70 ± 0.48 , and overall acceptability from 8.20 ± 0.42 to 8.90 ± 0.32 .

However, progressive deterioration was observed during storage, and by 180 days, marked reductions were recorded in all parameters, with appearance declining to 3.40 ± 0.52 – 6.20 ± 0.42 , colour to 3.60 ± 0.52 – 6.30 ± 0.67 , odour to

3.80 ± 0.63 – 6.40 ± 0.70 , texture to 3.70 ± 0.67 – 6.00 ± 0.82 , and overall acceptability to 4.00 ± 0.67 – 6.50 ± 0.53 . Among treatments, the untreated control (T_0) consistently showed the fastest and most severe quality deterioration across all sensory attributes, frequently falling below acceptable limits, whereas thermally treated samples, particularly T_2 followed by T_3 , demonstrated better retention of sensory quality throughout storage, maintaining comparatively higher scores even after 180 days. The observed decline in sensory quality is primarily associated with lipid oxidation, microbial activity, enzymatic degradation, and pigment breakdown, leading to off-odours, textural softening, and discoloration (Ocaño-Higuera *et al.*, 2011; Tsironi *et al.*, 2009; Niamnuy *et al.*, 2008) [30, 31, 43], and the results are consistent with previous reports on dried and freeze-dried seafood where gradual sensory degradation occurs during prolonged storage (Pratheep & Solanki, 2025; Rabie *et al.*, 2016) [34, 35]. Overall, the findings indicate that while all samples experienced quality loss over time, blanching treatments, especially T_2 , were most effective in preserving sensory acceptability and extending the shelf stability of freeze-dried shrimp under ambient conditions.



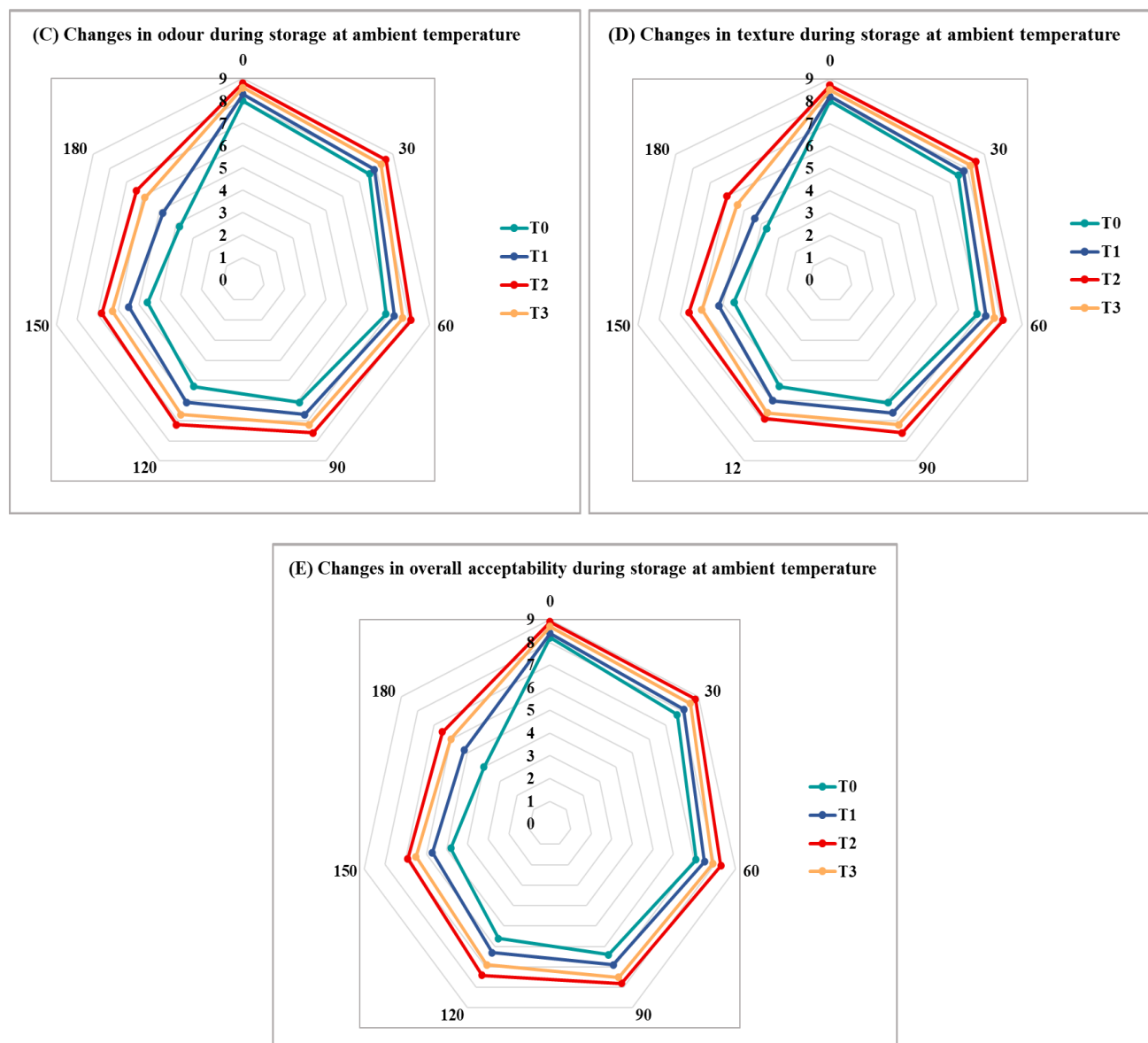


Fig 2 (A), (B), (C), (D), (E): Changes in sensory score of FD shrimp (*Metapenaeus affinis*) during storage at ambient temperature

4. Conclusion

The present study demonstrates that thermal blanching pretreatments significantly influence the storage stability and overall quality of freeze-dried Jinga shrimp (*Metapenaeus affinis*) stored under ambient conditions. Among the evaluated conditions, blanching in a 1.5% NaCl solution at 80 °C for 2 minutes (Treatment T₂) emerged as the optimal pretreatment. Over the 180-day storage period, T₂ most effectively retarded biochemical degradation, maintaining the lowest levels of pH, Total Volatile Base Nitrogen (TVB-N), Trimethylamine Nitrogen (TMA-N), and Peroxide Value (PV).

Furthermore, while the unblanched control samples exceeded the FSSAI permissible limits for microbial load and fell below acceptable sensory thresholds by the end of the storage period, the T₂ blanched samples maintained a safe Total Plate Count (2.44 ± 0.22 log CFU/g) and retained the highest overall sensory acceptability score (6.50 ± 0.53). Ultimately, integrating an 80 °C blanching step prior to freeze-drying, combined with packaging in high-barrier multilayer pouches (PES/Al/BOPA/LDPE), is a highly effective processing strategy. This method minimizes

biochemical deterioration, ensures microbiological safety, and preserves the sensory attributes of freeze-dried *M. affinis*, offering a viable approach for the seafood industry to produce premium, shelf-stable dried shrimp for both domestic and export markets.

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