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# Effects of sodium acetate dip treatment and vacuum-packaging on chemical, microbiological, textural and sensory changes of Pearlspot (*Etroplus suratensis*) during chill storage

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**Abstract**

The effects of sodium acetate dip treatment, followed by vacuum-packaging, on the shelf life of beheaded, scaled and gutted Pearlspot (*Etroplus suratensis*) during chill storage were examined. Sodium acetate (2%, w/v) solution was used for the dip treatment. Pouches (size: 15 × 22 cm) made of 12μ-polyester laminated with 300 gauge low-density polyethylene were used for packing fish. After packing, all the packs were iced with flake ice in the ratio (1:1) fish: ice in an insulated box and were kept in a cold room maintained at 0–2 °C. The control and the treated packs were analysed periodically for chemical (pH, TBA, TMA, TVB-N), microbiological (total viable count), textural and sensory characteristics. Changes in *Staphylococcus aureus*, *Enterobacteriacea* and *Feacal streptococci* were determined for fresh fish and for fish samples at the time of sensory rejection. Air packed samples were found to have a shelf life of about 8 days; vacuum-packed samples were found to be acceptable up to 10 days, whereas sodium acetate-treated vacuum packed samples were found to be acceptable up to 15 days. Thus, vacuum-packaging, in combination with sodium acetate, was found to delay the spoilage, thereby significantly extending the shelf life of Pearlspot at refrigeration temperatures.


*Keywords:* Vacuum-packaging; Sodium acetate; Pearlspot; Shelf life

## 1. Introduction

Fish are perhaps one of the most vulnerable of the world's resources. For many economically developing nations, fish are the first or second largest export commodity. Since the freshness of fish deteriorates rapidly, freshness may be considered a synonym for quality. The increasing demand for high quality fresh seafood has intensified the search for methods and technologies for better fresh fish utilization. One of the major developments in food packaging (for fulfilling new challenges) is packaging under vacuum or modified atmosphere conditions. Vacuum-packaging suits the demands and requirements of today and tomorrow.

Vacuum-packaging represents a static form of hypobaric storage. It is widely used in the food industry because of its effectiveness in reducing oxidative reactions in the product at relatively low cost (Gopal, Joseph, & Balachandran, 1999). This method of packaging can be a supplement to ice or refrigeration to delay spoilage, extend the shelf life, maintain a high quality, assure the safety and reduce economic loss of fish and fishery products.

Texture can be regarded as a manifestation of the rheological properties of a food. Fish texture differs widely from that of meat because it contains less connective tissue and

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the cross-links formed between collagen molecules are weaker, resulting in a more tender structure (Ashie, Smith, & Simpson, 1996). Many fish species do not have a strong flavour and therefore, texture becomes very important for consumer acceptability. Tests that attempt to imitate (with instruments) the conditions to which the food is subjected in the mouth or on the plate are called imitative tests. It is in this area that texture profile analysis (TPA) falls. A more comprehensive description of the texture of fish is obtained using the texture profile method (Bourne, 1978; Breene, 1975; Friedman, Whitney, & Szczesniak, 1963; Johnson, Peleg, Sawyer, Segars, & Cardello, 1981).

Psychrotropic bacteria are the major group of microorganism responsible for spoilage of fresh seafoods (Adams, Farber, & Lerke, 1964). Antimicrobial agents, such as sodium acetate, are found to be effective in preventing microbial growth and improving shelf life under different storage conditions (Kim, Hearnsberger, Vickery, White, & Marshal, 1995). Sodium acetate is an approved (USFDA) flavouring and pH control agent. Zhuang, Huang, and Beuchat (1996) observed that 2% sodium acetate is effective in controlling the growth of natural flora on catfish fillets.

Temperature abuse of commercial vacuum packaged or modified atmosphere-packaged fresh fillets can result in rapid growth of *C. botulinum* type E spores during storage (1–4 °C). These organisms are non-proteolytic and can grow and produce toxin at a very low temperature (3.3 °C). Although the incidence of botulinum from consumption of refrigerated food is exceedingly low, there have been several reported outbreaks associated with the consumption of fish products (Huss, 1981), mainly involving type E toxin.

However, collective works on various quality aspects (chemical, microbiological, textural and sensory) of vacuum-packaged fish of tropical region, under refrigerated storage, are scarce. Pearlspot (*Etroplus suratensis*) is an important brackish water fish, belonging to the family Cichlidae. It inhabits both freshwater and brackish water and is endemic to the peninsular India and Sri Lanka. It is considered to be a delicacy in the state of Kerala with a good market demand. With the boom of backwater tourism, the demand for Pearlspot, a high-valued food fish in Kerala, is on the increase. This paper reports the effect of vacuum-packaging, with and without dip treatment using sodium acetate, on the shelf life of Pearlspot (*E. suratensis*) during chill storage, as assessed by chemical, microbiological, textural and sensory parameters.

## 2. Materials and methods

### 2.1. Packing and storage of Pearlspot

Fresh Pearlspot, procured from Fortkochi fish landing centre, were brought to the laboratory within 20 min. The fish samples were washed in tap water and kept in the iced condition during processing. Then, these were scaled, gutted and washed in potable water. Fish were given a dip treatment in 2 ppm chilled chlorine water for 10 min and drained well. These were then divided into three lots. Lot I was air-packed (control air pack – CAP) and lot II vacuum-packed (control vacuum pack – CVP) to serve as controls. Lot III (SAVP) samples were given a dip treatment in sodium acetate solution (2% w/v) for 30 min, drained well and then vacuum-packed.

Pouches (size: $15 \times 22$ cm), made of 12μ-polyester laminated with 300 gauge low-density polyethylene, were used for packing fish samples. Physical properties of the packaging material, such as heat-seal strength (ASTM, 1972), tensile strength and elongation at break, were determined in the machine direction and in the cross-direction as per IS 2508 (1984). Oxygen transmission rate (ASTM, 1975) and water vapour transmission rate as per ASTM (1987) were also determined. One fish ($200 \pm 5$ g) was placed in each pouch. Lot I (CAP) was sealed using an impulse heat-sealing machine. Lot II (CVP) and lot III (SAVP) were vacuum-packed at $-1$ bar pressure. A vacuum sealing machine (Model QS 400 VD), supplied by M/s. Sevanna Electrical Appliances Pvt. Ltd., Kerala, India, was used for vacuum-packing. Immediately after packing, all the packs were iced with flake ice in the ratio (1:1) fish: ice in an insulated box and were kept in a chill room maintained at 0–2 °C. Reicing was done everyday to supplement the loss due to melting, after draining off the melted ice. Samples were drawn from each lot at regular intervals and were analyzed for chemical, microbiological, textural and sensory parameters. Sampling was done in triplicate and the mean values were taken.

### 2.2. Reagents and media

Chemicals used for the experiments were of Sigma brand, Analar grade or guaranteed reagent grade. Preservative, sodium acetate (Merck, Bombay), was used. Dehydrated bacteriological media, such as plate count Agar (PCA) (BBL Difco), Baired Parker Agar (BP, Himedia), Kenners Faecal (KF) Agar (BBL Difco), and Violet Red Bile Glucose Agar (VRBGA, Oxoid) were used.

### 2.3. Chemical analysis

Proximate composition was determined by AOAC (1998) method. pH was determined according to APHA (1998) using a digital pH meter (Cyberscan 510, UK) after homogenizing 10 g of the fish sample with the same amount of distilled water. Total volatile base nitrogen (TVB-N) and trimethylamine (TMA) were estimated by the microdiffusion method (Conway, 1950). Thiobarbituric acid (TBA) value of the fish sample was estimated spectrophotometrically (Tarladgis, Watts, & Younthan, 1960).

### 2.4. Microbiological analysis

Twenty-five grammes of fish were aseptically weighed and homogenized with 225 ml sterile 0.85% normal saline

for 1 min, in a Stomacher 400 lab blender (Seward medical, London, UK). The homogenized sample was serially diluted using 9 ml sterile saline for bacteriological analysis. Counts of *Staphylococcus aureus* (AOAC, 2002), *Faecal Streptococci* (USFDA, 1995) and *Enterobacteriacea* (Koutsoumanis & Nychas, 1999) were determined for fresh fish and for fish at the time of sensory rejection. Total viable counts (TVC) were determined in Plate Count Agar by the spread plate method (AOAC, 2002). Fish samples were tested for the presence of *C. botulinum* toxin as per FDA (2001).

### 2.5. Texture analysis

Texture profile analysis (TPA) was measured with a universal testing machine (Lloyd instruments LRX plus, UK), as described by Anderson, Stomsnes, Thomassen, and Steinsholt (1994), equipped with a load cell of 50 N. Fish pieces (2 $cm^3$) were cooked in 1.5% brine for 10 min, drained well and cooled to room temperature. Texture profile analysis was performed on cooked fish pieces, compressed twice by a cylindrical probe, having a diameter of 50 mm, at a test speed of 12 mm/min. The principle of the cylindrical probe is that, as the probe is forced into the specimen, a shearing force acts, which causes the sample to deform or rupture. This produces a curve showing load resulting from deformation. Hardness, cohesiveness, springiness and chewiness were calculated as defined in the texture analyzer user manual. The results of TPA were tabulated using Nexygen software.

### 2.6. Sensory evaluation

Sensory analysis is the traditional method of judging the quality of fish. Various sensory characteristics, such as appearance, texture, odour and flavour, were evaluated by five trained panellists. Score was based on a nine-point hedonic scale (Table 1) as described by Amerine, Pongborn, and Roescler (1965). Taste panel scoring of the fish was conducted after boiling the dressed fish in 1.5% brine for 10 min. A sensory score of 4 was taken as the borderline of acceptability.

Table 1
Sensory scores for taste panel studies

| Observation (cooked sample) | Score |
|---|---|
| Like extremely | 9 |
| Like very much | 8 |
| Like moderately | 7 |
| Like slightly | 6 |
| Neither like or dislike | 5 |
| Dislike slightly | 4 |
| Dislike moderately | 3 |
| Dislike very much | 2 |
| Dislike extremely | 1 |

## 3. Results and discussion

### 3.1. Proximate composition and physical properties

Proximate composition of fresh Pearlspot showed 77.75% moisture, 2.04% crude fat, 19.2% crude protein and 0.98% ash. The physical properties of the packaging material used are presented in Table 2. The results indicate that the material meets the requirements for vacuum-packed products.

### 3.2. Chemical assessment

#### 3.2.1. Changes in TBA

Changes in TBA value, which is a measure of oxidative rancidity of the product are presented in Fig. 1. The TBA values increased from an initial 0.08 mg malonaldehyde/kg of fish to 0.31, 0.34 and 0.39 mg malonaldehyde/kg of fish in CAP, CVP and SAVP samples on the 10th, 12th and 17th days of storage, respectively. Results indicate an increasing trend in all the samples during storage. Similar

Table 2
Physical properties of the packaging material

| Physical properties | Value |
|---|---|
| Tensile strength – MD | 363 kg/$cm^2$ |
| Tensile strength – CD | 349 kg/$cm^2$ |
| Elongation at break – MD | 80% |
| Elongation at break – CD | 80% |
| Heat seal strength – MD | 249 kg/$cm^2$ |
| Heat seal strength – CD | 194 kg/$cm^2$ |
| Water vapour transmission rate | 3.62 g/$m^2$/24 h at 37 °C and 90 ± 2% RH |
| Oxygen transmission rate (OTR) | 65 cc/$m^2$/atmosphere/24 h at room temperature 28–32 °C |

MD, machine direction; CD, cross-direction.

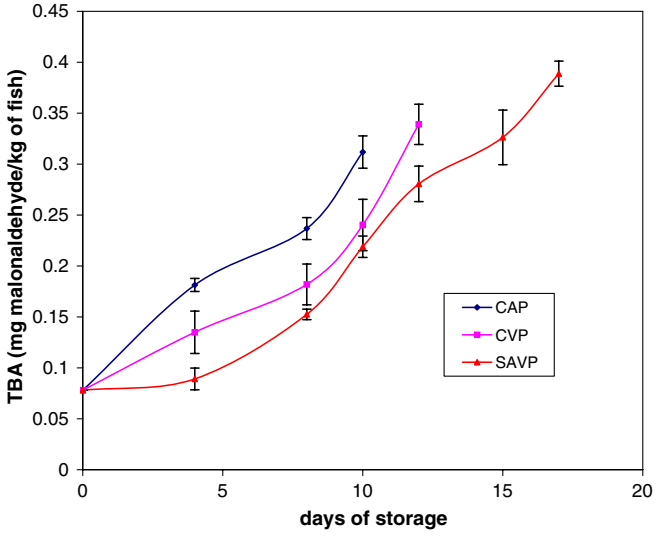


Fig. 1. Changes in TBA values of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

observations were made by several authors (Huang, Lovell, & Dunham, 1994; Josephson, Lindsay, & Stuiber, 1985; Nolan, Bowers, & Kropf, 1989). SAVP samples exhibited still lower TBA values than the control. This is in agreement with Rajesh, Ravishankar, Srinivasa Gopal, and Varma (2002) who observed a reduction in TBA values of sodium acetate-treated seer fish steaks compared to control samples during chill storage. Shalini, Indra Jasmine, Shanmugam, and Ramkumar (2000), also observed lower TBA values in sodium acetate-treated vacuum-packed *Lethrinus lentjan* fillets during refrigerated storage. Oxidation of fat is found to increase during cold storage and the rate was reduced by vacuum-packing and icing (Baldrati, Pirazzali, Broglia, Ambroggi, & Incerti, 1982). Varga, Keith, Michalik, Sims, and Reiger (1980) observed that TBA values were markedly lower in herring fillets (skin on) stored under vacuum compared to the fillets stored in ice. A TBA value in the range 1–2 mg malonaldehyde/kg of fish sample is usually taken as the limit of acceptability (Lakshmanan, 2000). In all the samples, TBA values were within the limit throughout the storage period.

### 3.2.2. Changes in pH

Variations in values of pH during storage are depicted in Fig. 2. The initial pH of the fish sample was found to be 6.5. On storage, the pH values increased gradually in CAP. In CVP and SAVP samples, the value decreased initially and then increased. Slight decrease in pH values may be attributed to the dissolution of $CO_2$ in the fish muscle. Similar observations were made by Meekin, Hulse, and Bremner (1982) who reported a decline in pH of vacuum-packed sand flat head fillets stored at 4 °C after 6 days of storage. Several authors have reported a decrease in pH with increase in the concentration of $CO_2$ in the atmosphere (Lannelongue, Hanna, Finne, Nickelsen, & Vanderzant, 1982; Tiffney & Mills, 1982). Increase in pH may be attributed to the production of volatile base compounds by bacterial activity (Cann, Smith, & Houston, 1983). Reddy, Villanueva, and Kautter (1995) reported that increase in surface pH of 100% air-packaged tilapia fillets stored a 4 °C, 8 °C and 16 °C may be partly attributed to the production of volatile basic compounds, such as ammonia, by fish spoilage bacteria.

### 3.2.3. Changes in TVB-N

TVB-N in fish is mainly composed of ammonia and primary, secondary and tertiary amines (Beatty, 1938). A level of 35–40 mg TVB-N/100 g of fish muscle is usually regarded as spoiled (Lakshmanan, 2000). Changes in TVB-N values are shown in Fig. 3. Values were found to increase in all samples during storage. TVB-N contents increased from an initial value of 5.6–19.5 mg% in CAP, 18.3 mg% in CVP and 21.6 mg% in SAVP on the day of rejection. Values were found to be lower in the case of treated packs than in control packs. Similar results have been reported by Shalini et al. (2000) during refrigerated storage of sodium acetate-treated vacuum-packed *L. lentjan* fillets. Low levels of TVB-N in treated samples were due to either a reduced bacterial population or decreased capacity of bacteria for oxidative deamination of non-protein nitrogen compounds or both (Banks, Nickelson, & Finne, 1980). In all samples, the values were found to be within the limit, throughout the storage period.

### 3.2.4. Changes in TMA-N

TMA-N is also used as an index of quality for deciding the state of freshness of fish. Changes in TMA-N are shown in Fig. 4. The TMA-N contents of fish samples showed an increasing trend in the control and in treated packs. The TMA-N contents increased from an initial 1.4–6.55 mg% in CAP, 6.0 mg% in CVP and 6.1 mg% in SAVP on the day of rejection. The results of the present study are in agreement with those of Ishida, Fuji, and Kodata (1976) who reported that, in low temperature stor-

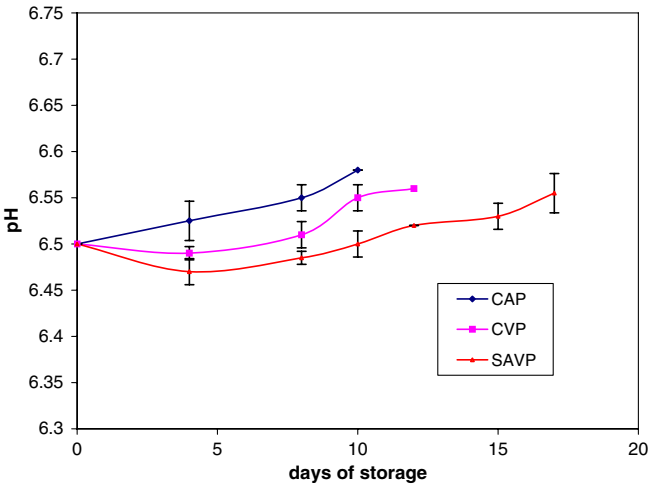


Fig. 2. Changes in pH of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

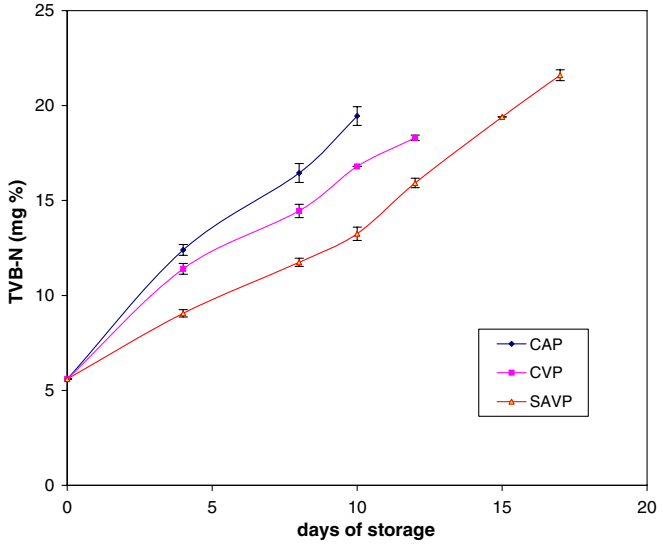


Fig. 3. Changes in TVB-N values of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

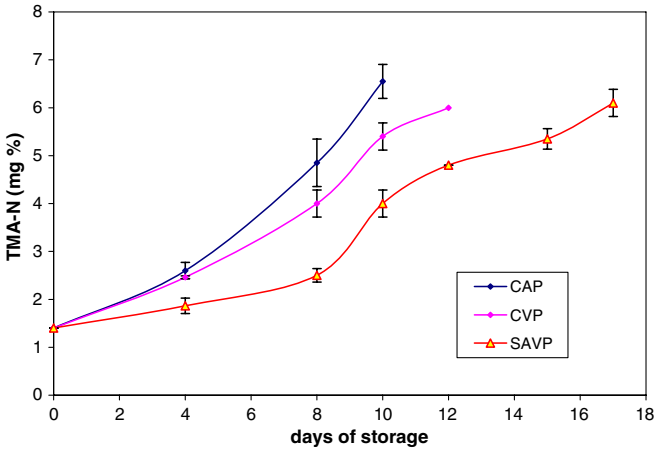


Fig. 4. Changes in TMA-N values of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

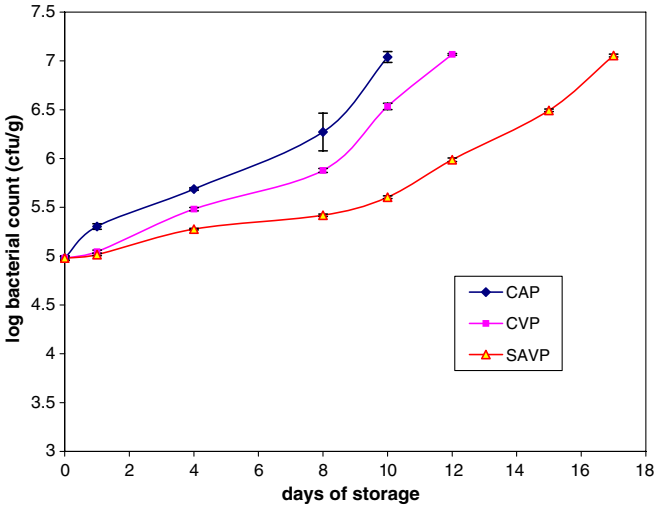


Fig. 5. Changes in total viable counts (20 °C) of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

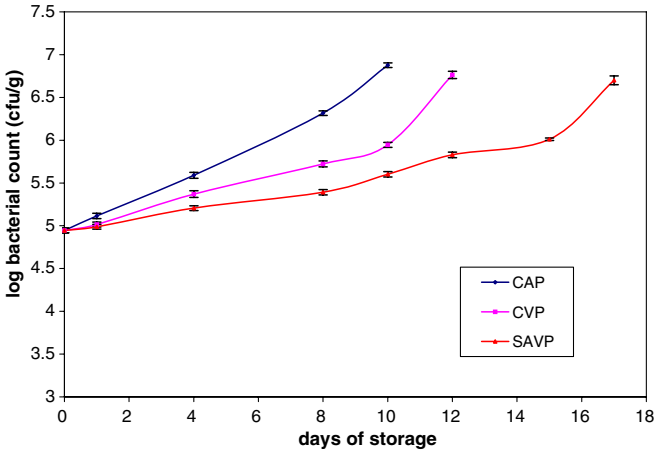


Fig. 6. Changes in total viable counts (37 °C) of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

age, such as refrigeration above 0 °C, TMA-N formation slows down noticeably. Lakshmanan, Antony, and Gopakumar (1996) reported low TMA-N content in Pearlspot, supporting our results. The TMA-N values of treated samples were found to be less than those in both the controls (CAP and CVP). This might be due to the inhibitory effect of sodium acetate over the growth of bacteria. Similar observations were reported earlier by Shalini et al. (2000) and Rajesh et al. (2002). TMA-N from 10 to 15 mg/100 g muscle is considered as the limit of acceptability for human consumption in chilled fish (Connell, 1975). Parkin, Wells, and Brown (1981) reported that TMA-N provided an adequate quality index for air-packed as well as modified atmosphere-packed rockfish fillets stored at 35 °F and could be used as a quality index for refrigerated fish fillets.

### 3.3. Microbiological analysis

#### 3.3.1. Changes in TVC

The initial TVC of fresh pearlspot at 20 °C and 37 °C were 4.98 and 4.94 $\log_{10}$ cfu/g, respectively. Changes in TVC of pearlspot at 20 °C and 37 °C are shown in Figs. 5 and 6, respectively. In CAP samples and CVP samples, TVC rose continuously and reached about $10^7$ cfu/g on the 10th and 12th days of storage, respectively, when the fish were deemed spoiled based on sensory scores. A 1 log increase in the TVC's of SAVP samples was observed on the 12th day and the counts increased gradually and reached $10^7$ cfu/g on the 17th day of storage.

It has long been known that microbiological counts in fish determined at 20–25 °C are much higher than counts determined at 37 °C (Castell, Anderson, & Pivnick, 1948; Liston, 1957). In the present study also, TVC of pearlspot at 20 °C was found to be higher than that at 37 °C. Bacteria grew most quickly in CAP samples, followed by CVP samples, of pearlspot. The results of the study confirm the earlier findings of Leung, Huang, and Harrison (1992); Huang et al. (1994); Lyon and Reddmann (2000), Özogul, Taylor, Quantick, and Özogul (2000), Özogul, Polat, and Özogul (2004) that bacteria grew more quickly in fish stored in air than when vacuum-packed (VP) at 0 °C.

The significant reduction in TVC observed in the treated samples of pearlspot can be attributed to the inhibitory effect of sodium acetate on aerobic spoilage bacteria, as reported earlier for catfish fillets (Kim & Hearnsberger, 1994; Zhuang et al., 1996) and for *L. lentjan* fillets (Shalini et al., 2000). Surface treatment with sodium acetate (2%) was equally effective in inhibiting microbial growth and extending storage life of Pearlspot to 15 days compared to 10 days for CVP samples and 8 days for air-stored samples.

#### 3.3.2. Changes in counts of Enterobacteriacea, S. aureus and Feacal streptococci

The counts of *Enterobacteriacea* in fresh pearlspot were 2.81 $\log_{10}$ cfu/g. By the end of storage, a 0.2 log increase

was noticed in CVP and SAVP samples whereas, in CAP samples of pearlspot, 0.4 log increase was observed. The count of *Enterobacteriaceae* in fresh Pearlspot is in agreement with those of Drosinos, Lambropoulon, Mitre, and Nychas (1997) and Koutsoumanis and Nychas (1999) for temperate marine fish and Savvaidis, Skandamis, Riganakos, Panagiotakis, and Kontominas (2002) for temperate fresh water fish. *S. aureus* count was 1.2 $\log_{10}$ cfu/g in fresh pearlspot. On the day of sensory rejection, the counts decreased (0.2 log reduction) in all the samples. The counts were within the limit prescribed for fresh fish by ICMSF (1986). *F. streptococci* population was 2.58 $\log_{10}$ cfu/g in fresh Pearlspot. 0.2–0.25 log reductions in *Faecal streptococcal* counts were noticed in CAP, CVP and SAVP samples. The results of the study indicate good microbiological quality of fresh Pearlspot and Pearlspot samples stored at 0–2 °C.

### 3.3.3. Clostridium botulinum

*Clostridium botulinum* toxin was not detected in any of the samples throughout the storage period, which indicates that there was no abuse of temperature during storage. This negative result for *C. botulinum* toxin assay is in accordance with work reported by Lilly and Kautter (1990) for vacuum-packed fish fillets and modified atmospheric-packed salmon fillets by Reddy, Solomon, Yep, Roman, and Rhodehamel (1997).

## 3.4. Texture analysis

### 3.4.1. Changes in Hardness 1 and Hardness 2

Hardness refers to the peak force during the compressive part of the test. Hardness 1 refers to the peak force during first compression and Hardness 2 refers to the peak force during second compression. Hardness 1 and Hardness 2 were found to decrease in all the samples during storage. Changes in Hardness 1 and Hardness 2 values are represented in Figs. 7 and 8, respectively. Hardness 1, decreased from the initial 1.99 kgf to 1.86, 1.60 and 1.54 kgf in CAP, CVP and SAVP samples on the 10th, 12th and 17th days of storage, respectively. Hardness 1 values of vacuum-packed and treated samples were found to be comparatively lower than those of air packed samples.

Hardness 2 values of CAP, CVP and SAVP samples decreased from the initial 1.77 kgf to 1.63, 1.40 and 1.32 kgf on the 10th, 12th and 17th days of storage, respectively. CVP and SAVP samples were found to have lower Hardness 2 values than CAP samples. Decreases in Hardness 1 and Hardness 2 values might be attributed to the weakening of connective tissue of fish muscle during storage.

The results of the present study are in agreement with those of Azam, Mackie, and Smith (1989) who studied the effect of killing method on the quality of rainbow trout during storage on ice from 0 to 15 days and observed a significant softening of both raw and cooked fillet during storage using instrumental measurement (Steven's Compression Response Analyser, SCRA). Sato et al. (1997) demonstrated that weakening of pericellular tissue was correlated with sardine softening. This was confirmed in rainbow trout by Ando, Toyohara, Shimizu, and Sakaguchi (1991). Similar observations were also made by Hatae, Tamari, Miyanaga, and Matsumoto (1985) who reported a softening of the texture in several fish species stored at 4 °C for up to 14 days, in a study using the General Foods (GF) texturometer.

### 3.4.2. Changes in cohesiveness, springiness and chewiness

Cohesiveness is the ratio of work done during the second compression divided by the work done during the first compression. This result is an indication of the viscoelasticity of the material. A value of 1 indicates total elasticity and a value of 0 indicates that the sample did not recover at all. Changes in values of cohesiveness are depicted in Fig. 9. Cohesiveness slightly decreased from an initial

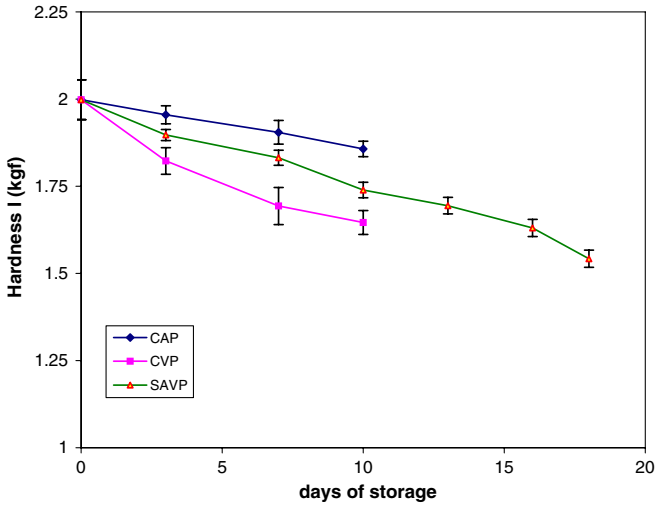


Fig. 7. Changes in Hardness 1 values of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

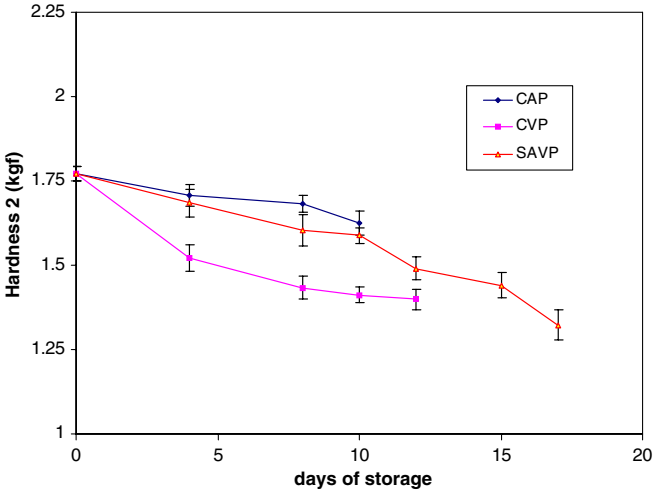


Fig. 8. Changes in Hardness 2 values of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

0.34 to 0.28, 0.26 and 0.22 in CAP, CVP and SAVP samples on the 10th, 12th and 17th days of storage, respectively. This indicates that there was not much change in the internal bonding of fish muscle during storage.

Springiness is the elastic or recovering property of the fish muscle during compression. Changes in springiness of pearlspot samples are depicted in Fig. 10. In general, a decreasing trend was observed in the control, as well as treated packs, during storage. The values decreased from the initial 1.01 mm to 0.92, 0.86 and 0.75 in CAP, CVP and SAVP samples, respectively, on the 10th, 12th and 17th days of storage. The values indicate that the fish muscle is losing its elasticity during storage.

Chewiness refers to the work done. Changes in chewiness values are represented in Fig. 11. Chewiness also was found to decrease in all the samples during storage. The values decreased from the initial 0.65 kgf mm to 0.48, 0.26 and 0.24 kgf mm in CAP, CVP and SAVP samples, respectively, on the 10th, 12th and 17th days of storage. Decrease in chewiness indicates that the fish muscle becomes soft during storage.

### 3.5. Sensory analysis

Changes in sensory scores are presented in Fig. 12. Sensory scores showed a significant decline in both the controls and treated packs with increasing storage period. Fish samples were considered to be acceptable for human consumption until the sensory score reached 4. Fish spoilage gave rise to the subsequent development of strongly fishy, rancid and putrid odours, and fish was clearly rejected for consumption by the taste panel. Sensory scores declined from an initial value of 8.6 to 3.4, 3.8 and 3.6 in the case of CAP, CVP and SAVP samples, respectively, on the day of rejection. Thus, CAP and CVP samples were acceptable up to 8 days and 10 days, respectively, whereas SAVP samples remained in good condition up to 15 days. Meekin

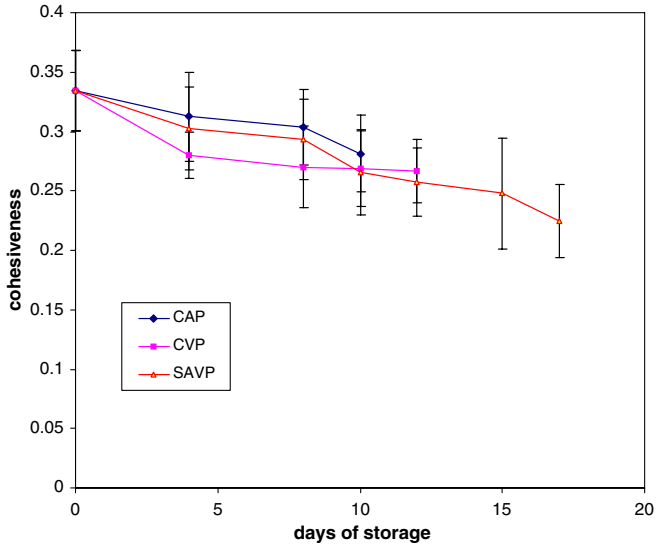


Fig. 9. Changes in cohesiveness of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

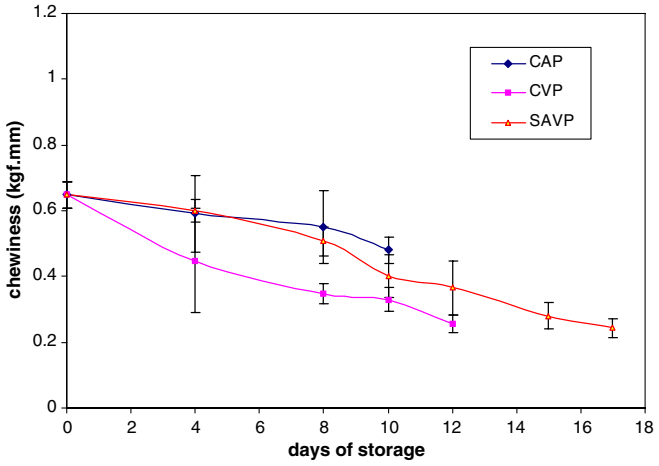


Fig. 11. Changes in chewiness of Pearlspot packed under air and vacuum

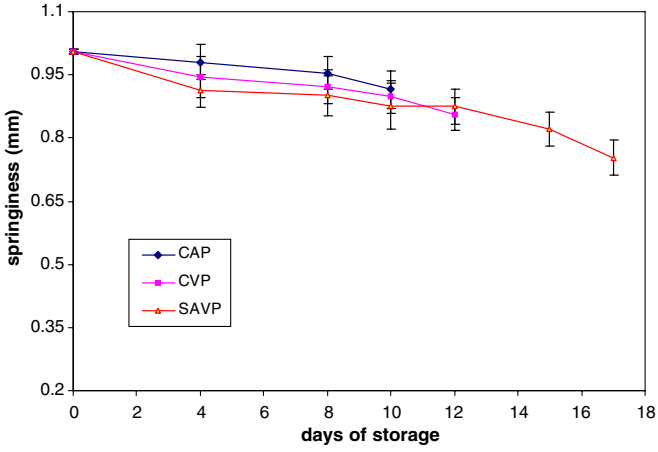


Fig. 10. Changes in springiness values of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

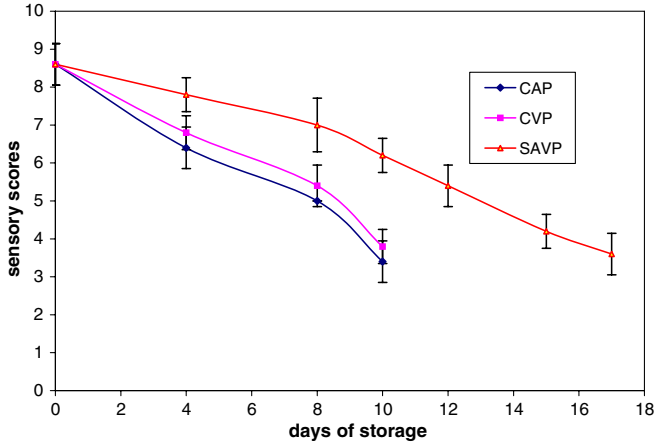


Fig. 12. Changes in overall sensory scores of Pearlspot packed under air and vacuum (sodium acetate-treated and untreated) during storage at 0–2 °C.

et al. (1982) reported that aerobically-packed refrigerated (4 °C) sand flat head spoiled in 8–9 days. Reddy, Schreiber, Bazard, Skinner, and Amstrong (1994) reported that tilapia fillets packed under 100% air spoiled after 9 days at 4 °C.

Zhuang et al. (1996) reported that the addition of sodium acetate at 2% (dip treatment) extended the shelf life of refrigerated catfish fillets. The use of sodium acetate and vacuum-packaging was found to extend the shelf life of fish samples in the present study also. Thus, vacuum-packaging, in conjunction with 2% sodium acetate, can be safely used to extend the shelf life of Pearlspot samples up to 15 days at 0–2 °C.

## 4. Conclusions

The results of the present study revealed that vacuum-packaging alone, without preservative treatment, would not be of much use, under the reported experimental conditions. Several authors have successfully demonstrated the multiple barrier technology or hurdle concept, i.e., combination or superimposing several factors at sub-inhibitory concentrations that can effectively control micro organisms in refrigerated seafood (Leistner & Gorris, 1995; Scott, 1989). The results from this study, clearly suggest that a combination of different factors, namely vacuum-packaging, treatment with preservative (sodium acetate) and storage at refrigerated temperature could be used to prolong the shelf life of Pearlspot to a great extent. It is emphasized that the success of vacuum-packaging is completely dependent on the initial quality of the fish and on adequate temperature control throughout storage.

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