Effect of Sodium Acetate on Frozen Storage of Prawns (*Metapenaeus dobsoni*): Functional Properties of Proteins

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The effect of sodium acetate as a prefreezing dip treatment at different concentrations on the functional properties of proteins from prawn (*Metapenaeus dobsoni*) and as a function of frozen storage period at -18 °C has been studied. The results show that foam capacity of prawn proteins increased with increase in acetate concentration. The water absorption capacity values of the proteins decreased from 4.96 to 2.75 g of water/g of dried material in untreated sample over a period of 300 days of storage at -18 °C. With increase in sodium acetate concentration used, from 5% to 20%, the WAC values of samples decreased from 5.8 to 5.0 g of water/g of dried material. The fat absorption capacity values decreased both in untreated and in sodium acetate treated samples as a result of frozen storage. The emulsion capacity was higher in prawns treated with 20% acetate as compared to untreated prawns (114 mL of oil/g of protein).

INTRODUCTION

Prawns and other crustaceans occupy a pre-eminent position in seafood trade. The use of prawn meat in various formulations and salad dressings is very common. Frozen prawns are widely used in most of these food formulations. Due to freezing and frozen storage, muscle proteins undergo a series of alterations which will affect their major functional properties (Sikorski et al., 1976). The role of myofibrillar and sarcoplasmic proteins on viscosity and emulsifying capacity of marine fish muscle homogenates has been been reported (Tejada et al., 1984).

Organoleptic attributes of marine foods reflect the physical and chemical properties of food constituents. Thus, water, carbohydrates, lipids, and proteins affect the final quality of the product after any processing. Proteins contribute significantly to the functional behavior of several major foods including flesh foods (Kinsella, 1976). The major functional properties attributed to proteins include nitrogen solubility, water absorption, fat absorption, viscosity, emulsification, foaming properties, and gelation phenomenon.

The functionality of proteins from fish muscle could alter during ice storage (Reddy and Srikar, 1991). Hence, in the processing of prawn/fish, care must be exercised to prevent such changes. However, the inherent effect of individual processing conditions on the structure and conformation of protein molecules have an indirect bearing on functional properties. An alternative possibility of retaining or enhancing the functional properties of prawn/fish proteins is to use suitable additives during processing and storage.

The major change of prawn protein during frozen storage is attributed to association–dissociation of myosin–actomyosin (Godavaribai et al., 1987). This equilibrium is altered with the addition of certain salts. The effects of these salts may be divided into two classes, within which there is a characteristic order of effectiveness (Jencks, 1969). In one class of salts, such as in the case of sodium acetate, addition of salt tends to precipitate proteins and protect them against denaturation and dissociation (Robinson and Jencks, 1965). In the other class of salts, anions such as thiocyanate and perchlorate tend to dissociate and denature proteins (Robinson and Jencks, 1965; Jencks, 1969).

In the present investigation, the effect of sodium acetate at different concentrations used as a prefreezing dip treatment of prawns on the functional properties of total proteins during frozen storage has been investigated.

MATERIALS AND METHODS

The preparation of prawns, freezing and storage of prawns, and estimation of acetate in prawns, protein extractability procedure, estimation of protein and nonprotein nitrogen were carried out as described previously (Shamsunder and Prakash, 1994a,b). Four different concentrations of sodium acetate solutions, *viz.* 5%, 10%, 15%, and 20% (w/v), were prepared in deionized water. The peeled and deveined prawns were dipped in sodium acetate solution for 5 min. The quantity of solution used for dip treatment was in the ratio of 2:1 (sodium acetate solution/prawn). The excess sodium acetate solution was removed by gentle pressure on the prawns. The dip-treated prawns were packed separately in polyethylene bags and were frozen as described in the preceding paper. Along with treated prawns, untreated prawns were packed separately for freezing.

After thawing, representative samples were drawn from the polyethylene bags for assessment of the functional properties. About 15–20 prawns were drawn from different lots and then cut into small pieces. An aliquot of exact quantity of meat was drawn and then used for assessment of the functional properties. All of the functional properties are the average value of three experiments. For assessing water absorption and fat absorption capacity, the prawn samples were freeze-dried in a Virtis freeze mobile 6 lyophilizer to a moisture content of less than 3%.

Functional Properties. Foam capacity (FC), foam stability (FS), water absorption capacity (WAC), fat absorption capacity (FAC), emulsion capacity (EC), and emulsion stability (ES) of the protein solution were determined as described in the preceding paper (Shamasunder and Prakash, 1994a).

Statistical Analysis. Effect of sodium acetate on nitrogen solubility was assessed by the Wilcoxon signed ranks test (Fowlie, 1969). Analysis of variance was applied to determine the effect of treatment on various functional properties (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

The initial sodium acetate concentration after dip treatment for 15 min with dip solution containing 5%,

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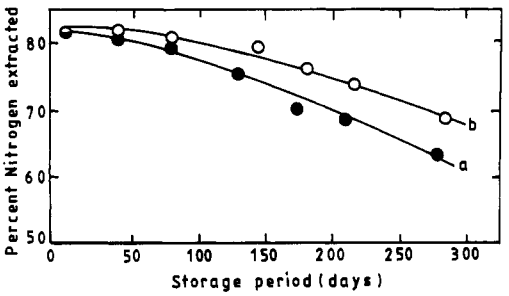

Figure 1. Effect of storage period on the nitrogen solubility profile of treated and untreated prawns: (a) untreated prawns frozen and stored at −18 °C; (b) fresh prawns dipped in 10% sodium acetate for 5 min before freezing, frozen and stored at −18 °C. The nitrogen was extracted in phosphate buffer (0.03M, pH 7.8) containing 1 M NaCl.The treatment was significant ($P < 0.05$) at the concentration tried.

Table 1. Changes in Nonprotein Nitrogen Content of Untreated and Treated Prawns during Storage at −18 °C

	NPN content (%)	
storage period (days)	untreated	10% sodium acetate treated[a]
fresh	0.54 ± 0.11[b]	0.54 ± 0.11
40	0.42 ± 0.16	0.52 ± 0.12
80	0.45 ± 0.10	0.41 ± 0.08
128	0.41 ± 0.11	0.42 ± 0.10
174	0.38 ± 0.14	0.43 ± 0.16
210	0.40 ± 0.10	0.41 ± 0.16
280	0.38 ± 0.11	0.37 ± 0.10

[a] Not significant ($P > 0.05$). [b] Individual standard deviation, $n = 3$.

10%, 15%, and 20% sodium acetate were found to be 0.68%, 1.1%, 1.19%, and 1.2%, respectively (Shamasundar and Prakash, 1994b). When the dip solution contained more than 10% sodium acetate, the acetate in the meat was greater than 1.1%.

Protein Extractability. The nitrogen solubility profiles of total proteins from prawn, frozen and stored at −18 °C, of untreated and 10% sodium acetate treated samples are shown in Figure 1. In both samples the solubilities decreased with increase in period of storage. The decrease in solubility is attributed to possible irreversible polymerization of protein leading to insolubilization as well as structural changes as a result of denaturation. Similar observations are made with fish muscle stored at −18 °C (Tran, 1975). In the present study, the decrease in nitrogen solubility was higher in 10% acetate treated sample as compared to untreated sample.

Nonprotein Nitrogen. The muscles of the prawn meat are known to contain high NPN (Bose, 1969; Konosu and Yamaguchi, 1992). The NPN content did not show much variation throughout the storage period in either treated or untreated samples (Table 1). The NPN content of squid meat and oysters decreased during frozen storage, as nonprotein nitrogen is shown to leach out in drip during thawing (Sastry and Srikar, 1985; Misra and Srikar, 1989).

Water Absorption Capacity. From Figure 2A it can be seen that the untreated sample showed a gradual decrease in WAC, reaching a value of 2.75 ± 0.15% at the end of 300 days of storage at −18 °C. With an increase in concentration of sodium acetate there was a decrease in WAC of prawn meat. However, 5% sodium acetate treated sample had higher WAC as compared to untreated sample at day 0. Salts, by specific ion binding and by increasing ionic strength or by altering solvent properties, can markedly affect the water binding properties of meats and

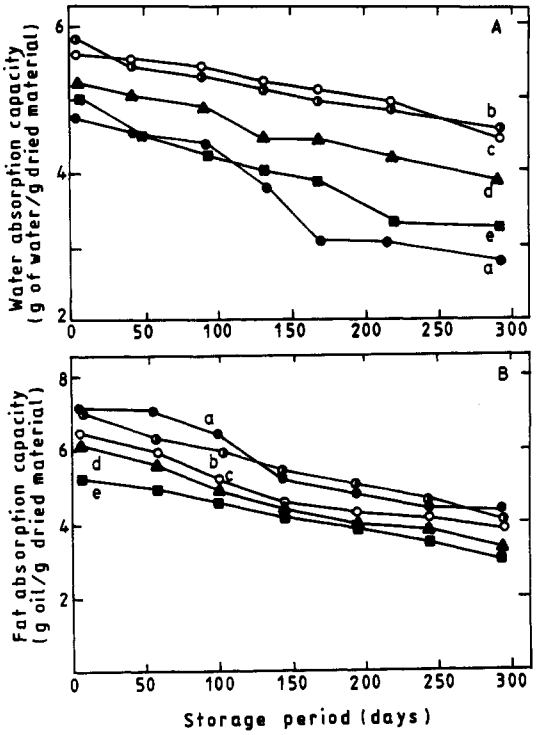

Figure 2. (A) Effect of storage period at −18 °C on the water absorption capacity of untreated and treated prawns: (a) untreated prawns; (b) 5%, (c) 10%, (d) 15%, (e) 20% sodium acetate treated prawns [not significant ($P > 0.05$) between treatments]. (B) Effect of storage period at −18 °C on the fat absorption capacity of untreated and treated prawns: (a) untreated prawns; (b) 5%, (c) 10%, (d) 15%, (e) 20% sodium acetate treated prawns [not significant ($P > 0.05$) between treatments].

meat extenders (Hamm, 1970; Hermansson et al., 1971; Shults et al., 1972). The low values of WAC in sodium acetate treated samples is mainly due to specific ion binding to the sites on the proteins where water molecules are bound by preferential interactions.

Fat Absorption Capacity. The untreated sample at day 0 has a FAC value of 6.7 ± 0.1 g of oil/g of dried material (Figure 2B). As in the case of WAC values, FAC values also decreased with increase in sodium acetate concentration. As a function of storage period at −18 °C the FAC values decreased (Figure 2Bb–e). The ability of protein to bind fat is very important as it enhances flavor retention. The mechanism is mainly attributed to physical entrapment of oil as described by Kinsella (1976). FAC values showed a decreasing trend with increase in period of storage, which has an indirect bearing on the process of association–dissociation and denaturation of prawn proteins (Shamasunder and Prakash, 1994b).

Foam Capacity. The results of Figure 3A demonstrate that with an increase in concentration of sodium acetate there is an increase in foam volume. It is also shown as a derivative plot of foam volume at 115 days of storage vs sodium acetate concentration (Figure 3B). With an increase in storage time there is a decrease in foam volume in both treated and untreated prawns. It has been documented that salts, depending upon their activity, can affect foaming by enhancing solubility initially, whereas at higher concentration salting out may occur, resulting in lesser foam capacity (Hermansson, 1975; Hermansson and Akesson, 1975; Hermansson et al., 1971).

Foam Stability. All of the sodium acetate treated samples had higher foam stabilities as compared to untreated sample (Figure 4). However, the result was

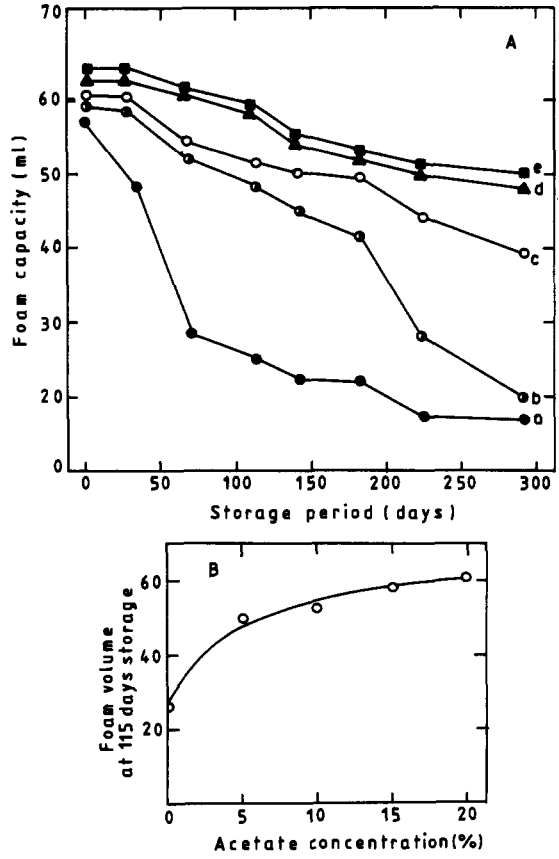

Figure 3. (A) Effect of storage period at −18 °C on the foam capacity of untreated prawn and prawn dipped in different concentrations of sodium acetate solution: (a) untreated prawns at −18 °C; (b) 5%, (c) 10%, (d) 15%, (e) 20% sodium acetate treated prawn [significant ($P < 0.05$) between treatments]. (B) Effect of increasing concentration of sodium acetate concentration on the foam volume of prawn meat stored for 115 days at −18 °C.

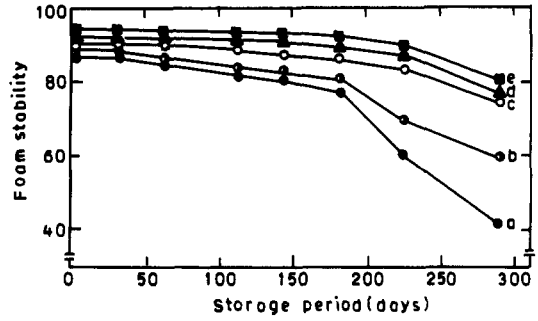

Figure 4. Effect of storage period of prawns at −18 °C on the foam stability of untreated and sodium acetate treated prawns: (a) untreated prawns stored at −18 °C; (b) 5%, (c) 10%, (d) 15%, (e) 20% sodium acetate treated prawns [not significant ($P > 0.05$) between treatments].

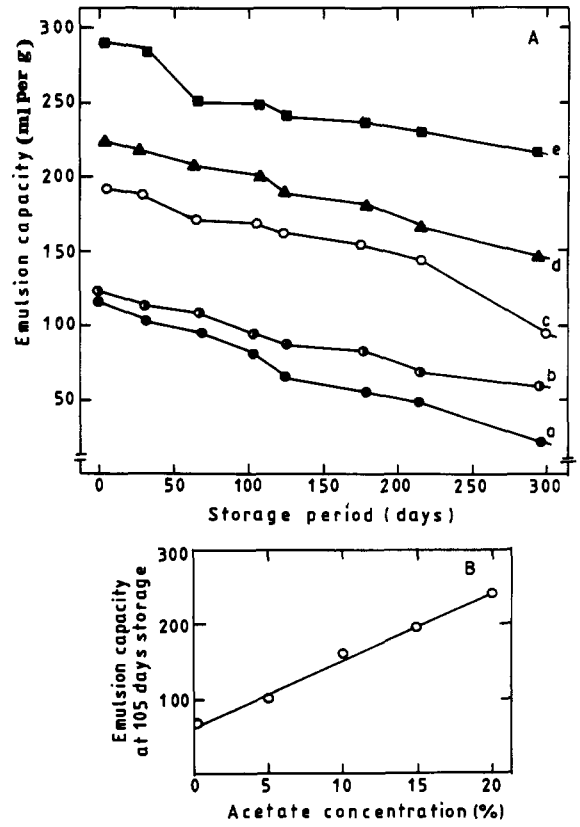

Figure 5. (A) Effect of storage period at −18 °C on emulsification capacity (milliliters of oil per gram of protein) of total protein extracted from untreated and treated prawns: (a) untreated prawns stored at −18 °C; (b) 5%, (c) 10%, (d) 15%, (e) 20% sodium acetate treated prawns [significant ($P < 0.05$) between treatments]. (B) Effect of increasing concentration of sodium acetate on the emulsification capacity of proteins stored for 105 days at −18 °C.

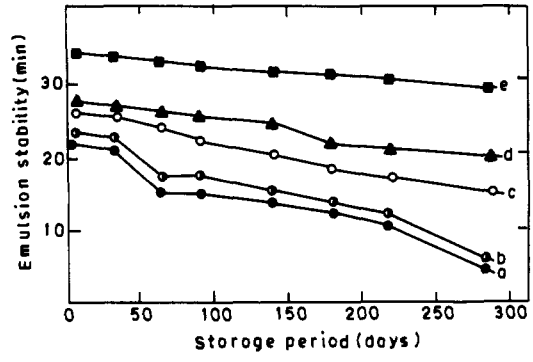

Figure 6. Effect of storage period on the emulsion stability of proteins extracted from untreated and treated prawns stored at −18 °C. (a) untreated prawns; (b) 5%, (c) 10%, (d) 15%, (e) 20% sodium acetate treated prawns [not significant ($P < 0.05$) between treatments].

significant ($P < 0.05$) only after 225 days of storage. There are reports that the structurally altered protein fractions of fish protein concentrate act as foam stabilizers (Shenstone, 1953). Good foam stability in fish protein concentrate has been attributed to its lesser solubility.

Emulsification Capacity. The EC value of untreated sample decreased nearly 5-fold during 300 days of frozen storage (Figure 5A). With increase in acetate concentration the EC values also increased (Figure 5B). The emulsion stability (ES) of fresh untreated prawn was 22 min and decreased gradually to 4 min at the end of 298 days of storage at −18 °C (Figure 6a). The ES of treated prawn was higher than that of untreated prawn, and the decrease was minimal in 20% sodium acetate treated prawns throughout the storage period (Figure 6b–e). The stability or retention of functional properties of proteins such as emulsification properties during freezing and frozen storage is an important criteria that demands an in-depth study and evaluation under different conditions. Several physical and chemical reactions of the proteins can occur during frozen storage such as polymerization, aggregation, complexation, denaturation (Shamasunder and Prakash, 1994b), and interactions with other components such as lipids. These reactions are controlled by temperature, pH, and water activity (Love, 1966; Acker, 1969; Rockland, 1969; Kinsella, 1976; Labuza et al., 1971; Walker, 1972). The dip treatment, duration, concentration, and method of agitation will decide the diffusion of

acetate from the outer surface of prawn forming a gradient to the inner portion of prawn. However, acetate may have a protective action toward surface protein denaturation. This may be indicative of surface protein being protected by anions as compared to the interior portion of protein in the prawn. However, the observed results of changes in functional properties of prawn protein as a result of various physical and storage conditions of prawn would throw more light on such a process.

The results of the present study indicate that acetate ions used as a pretreatment dip method enhance the foaming and emulsification properties of prawn proteins. This has a bearing on the use of such pretreated prawns in several food formulations in which the increased foaming and emulsification properties can be utilized.

LITERATURE CITED

Acker, L. N. Water activity and enzyme activity. *Food Technol.* **1969,** *23,* 1257–1270.

Bose, A. N. Freezing of tropical fish. In *Freezing and Irradiation of Fish*; Kreuzer, R., Ed.; 1969.

Fowlie, J. S. The Wilcoxon Signed Ranks Test. In *Statistical Tables for Students;* Oliver and Boyd: Edinburgh, 1969; pp 16–17.

Godavaribai, S.; Khabade, V. S.; Prakash, V. Effect of freezing and sodium citrate treatment on the association-dissociation of proteins from shrimp. (*Parapenaeopsis stylifera*) *J. Food Sci. Technol.* **1987,** *24,* 243–246.

Hamm, R. Properties of meat proteins. In *Proteins as Human Food*; Lawrie, Ed.; AVI Publishers: Westport, CT, 1970.

Hermansson, A. M. Functional properties of proteins for foods—Flow properties. *J. Texture Stud.* **1975,** *5,* 425–439.

Hermansson, A. M.; Akesson, C. Functional properties of added proteins correlated with properties of meat systems. Effects of various parameters. *J. Food Sci.* **1975,** *40,* 595–603, 611.

Hermansson, A. M.; Sivik, B.; Skjoldebrand, C. Functional properties of proteins: Factors affecting solubility, foaming and swelling of fish protein concentrate. *Lebensm. Wiss. Technol.* **1971,** *4,* 201–204.

Jencks, W. P. *Catalysis in Chemistry and Enzymology*; McGraw-Hill: New York, 1969; pp 351–392.

Kinsella, J. E. Functional properties of proteins in foods. A survey. *CRC Crit. Rev. Food Sci. Nutr.* **1976,** *7,* 219–290.

Konosu, S.; Yamaguchi, K. The Flavour Components in Fish and Shellfish. In *Chemistry and Biochemistry of Marine Food Products*; Martin, R. E., Flick, G. J., Hebard, C. E., Ward, D. R., Eds.; AVI Publishing: Westport, CT, 1982; pp 367–404.

Labuza, T. P.; Heidelbaugh, N.; Silver, M.; Karel, M. Oxidation of intermediate moisture foods. *J. Am. Oil Chem. Soc.* **1971,** *48,* 8–90.

Love, R. M. The use of tasters for investigating cold storage deterioration in frozen fish. *J. Food Technol.* **1966,** *1,* 141–146.

Misra, R.; Srikar, L. N. A comparison of methods for shucking of clams. *Int. J. Food Sci. Technol.* **1989,** *24,* 659–663.

Reddy, G. V.; Srikar, L. N. Pre-processing ice storage effects on functional properties of fish mince proteins. *J.Food Sci.* **1991,** *56,* 965–968.

Robinson, D. R.; Jencks, W. P. The effect of concentrated salt solutions on the activity coefficient of acetyltetraglycine ethylester. *J. Am. Chem. Soc.* **1965,** *87,* 2470–2479.

Rockland, L. B. Water activity and storage stability. *Food Technol.* **1969,** *23,* 1241–1251.

Sastry, H. C.; Srikar, L. N. Protein and related changes in cuttle fish (*Sekai aculeta*) during iced storage. *Harvest and Post Harvest Technology of Fish*; Ravindran, K., Ed.; Society of Fishery Technologists: Cochin, India, 1985.

Shamasunder, B. A.; Prakash, V. Physicochemical and functional properties of proteins from prawns (*Metapenaeus dobsoni*). *J. Agric. Food Chem.* 1994a, first of four papers in this issue.

Shamasunder, B. A.; Prakash, V. Effect of sodium acetate on physicochemical properties of proteins from frozen prawns (*Metapenaeus dobsoni*). *J. Agric. Food Chem.* 1994b, second of four papers in this issue.

Shenstone, F. S. Foaming of fish protein concentrate. *Food Preserv. Q.* **1953,** *13,* 45–48.

Shults, G. W.; Russel, D. R.; Wierbicki, E. Effect of condensed phosphates on pH, swelling and water holding capacity of beef. *J. Food Sci.* **1972,** *37,* 860–864.

Sikorski, Z.; Olley, J.; Kostuch, S. Protein changes in frozen fish. *CRC Crit. Rev. Food Sci. Nutr.* **1976,** *8,* 97–129.

Snedecor, G. W.; Cochran, W. G. *Statistical methods*; Oxford IBH: Calcutta, 1967, 435 pp.

Tejada, M.; Borderias, A. J.; Colmenero, F. J. Myofibrillar and sarcoplasmic proteins: Their role in alterations in certain functional properties of muscle during frozen storage. In *Chemical changes in Food Processing*; Poveda, B. S., Ed.; Consejo Superior de Investigaciones Cientificas: Spain, 1984; pp 103–111.

Tran, V. D. Solubilization of cod myofibrillar proteins at low ionic strength by sodium pyurvate during frozen storage. *J. Fish. Res. Board Can.* **1975,** *32,* 1629–1632.

Walker, N. J. Flavor defects in edible casein and skim milk powder, I. The role of Maillard browning. *J. Dairy Res.* **1972,** *39,* 231–238.

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