FDA SEAFOOD HACCP INSPECTION

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(Text based on actual oral presentation)

Thank you. I appreciate the opportunity to talk to you today about the application of HACCP to seafood. Last March, Commissioner Kessler announced an intention on the part of FDA to require something called HACCP of the seafood industry. This requirement is to be initiated through the issuance of a federal regulation, first as a proposal for public comment, then as a final document. Neither of these documents has published yet, although we hope the proposal will shortly, so my remarks will intentionally be long on general policy considerations and short on detail.

Dr. Kessler's announcement of last March has been commonly characterized as involving "HACCP inspection" of seafood. That is true in part. Actually, HACCP is something that the industry would do, while FDA would examine how well these establishments were doing it, among other things, during the course of FDA's inspections of seafood processors and establishments.

As an aside, it is fair to say that Dr. Kessler's speech generated a considerable amount of interest. We in the FDA office of seafood immediately found ourselves in great demand by the media, and if it is true that we all have been allotted 15 minutes of fame in this life, we quickly ran through our allotment thanks to HACCP.

One morning, for example, I found myself with less than 30 seconds at my disposal to try to explain over the radio to the morning commuters in Tampa, Florida, what HACCP is all about and why they should be pleased that it was coming. I'm still not quite sure what I said.

But I remember what the commissioner said last March. The essence of it is worth reiterating today because it forms the basis for our emerging policy in this area. He said the following:

- First, food safety will be a major issue that will occupy federal policymakers over the next several years.

- Second, that while the public does not expect absolute assurances that food is perfectly safe, they do expect that a system is in place to ensure that food is as safe as we can possibly make it.
Third, that the current system of food safety regulation is too reactive and places too much of the burden on the taxpayer to find problems. What is needed is a system that is built on preventing problems in the food supply and that gives regulatory agencies the tools to know that the system is working.

Fourth, that the best way to do that is to institutionalize basic preventive controls to ensure safety. And the best way to do that is by companies developing and following state-of-the-art quality assurance plans and by the government verifying that the plans are being successfully carried out.

The commissioner then used seafood as an example of both how and why such a preventive system could and should be applied.

As I am sure we all know by now, HACCP, or hazard analysis critical control point, is a system of preventive controls that can be applied by a food producer to ensure, to the maximum extent possible, the safety of the food being produced.

HACCP was first applied to food by Pillsbury in the late 1950's during that company's effort to develop food for astronauts, after it occurred to them that the amount of end-product testing necessary to ensure safety would use up most of the food. So they tried an opposite approach that was designed to prevent hazards from occurring in the first place rather than to catch hazards at the end through testing. The result is a system that has become recognized throughout the developed world.

Briefly, a processor operating a HACCP system develops and implements a HACCP plan that

- Identifies likely hazards that could cause the product to be unsafe to consumers;
- Identifies what have been termed critical control points in the process where a failure would likely cause the hazard to occur;
- Identifies critical limits, or proper operating parameters, for each critical control point;
- Includes monitoring procedures for tracking the performance of critical control points and recordkeeping procedures for recording the results of that monitoring.

As envisioned by Pillsbury, HACCP could be applied to hazards that could occur in the plant and those that could occur before a processor takes possession of raw materials. The latter types of hazards could include those with an Environmental origin, such as toxins in seafood. For these types of hazards, the receiving dock becomes figuratively, and in many cases literally, the first critical control point in a HACCP system.

To the extent that it is reasonable and appropriate for the federal government to mandate HACCP controls within the food industry, seafood is, in our view, a good place to start. For the reasons that
I will discuss. (Although, as an aside, FDA first applied HACCP principles to the regulation of low acid canned foods in the 1970's to control botulism, so seafood would really be number two.)

The philosophical underpinning for government-mandated HACCP is the view that the industry should be responsible for the safety of the food it produces. This responsibility should be exercised by design and not by happenstance. And for those who appreciate an alliteration, that design must be demonstrable. The role of the government should be that of verifier that the industry is meeting its responsibility.

Now let's apply that philosophy to seafood.

- Since seafood is still predominantly wild-caught, it is at least potentially exposed to a wide range of natural hazards and hazards from human pollution.
- It is the most perishable of all flesh foods.
- It is consumed raw much more than any terrestrial flesh food.
- It consists of literally hundreds of species from all over the globe, many having little in common other than an aquatic origin.
- No other flesh food is imported in such quantity or from so many places -- over 135 countries. Some of these countries have advanced regulatory structures for seafood safety, but many do not.
- It has a far flung distribution system that can affect both safety and shelf life.
- Some recreational activity finds its way into commercial channels.
- The seasonal nature of the business, sometimes at very remote locations, presents the industry with special challenges in terms of training and facility upkeep.

Given these realities, it is imperative that those who handle and process seafood for commerce know the potential likely hazards and demonstrate that the likely hazards are being controlled to the extent possible.

It is not unusual, however, for FDA to receive inquiries about safety requirements and related matters from individuals who wish to process or import seafood, or who already do, that indicate a lack of awareness of hazards specific to their products.

For the most part, such knowledge is not a legal prerequisite to doing business. HACCP would go a long way toward making it so.

HACCP is not a zero risk system, but it is a system for preventing problems that are preventable, or at least significantly reducing the likelihood of their occurrence. Moreover, its use, in our view,
constitutes an appropriate alignment of industry and government responsibilities for food safety. Put another way, HACCP provides an opportunity to link the food industry's system for producing safe food with the government's system of regulatory oversight.

The adequacy of the government's system of regulatory oversight of seafood has been seriously questioned in recent years, as many of you probably know. Seafood, and the regulatory program for seafood, have been the target of considerable media scrutiny as well as congressional attention since the late 1980's. Both the number of bills relating to seafood regulation and the number of hearings held in the congress on the adequacy of the federal program are cumulatively in double figures over the past three congresses. That is truly staggering. Seafood sales stopped growing around the same time. There are many probable reasons why; consumer concern over safety probably contributes to some degree. The industry itself went to the congress looking for additional legislation in order to regain consumer confidence. (Incidently, the overwhelming majority of seafood safety bills introduced over the past several years would have authorized HACCP, either explicitly or implicitly.)

These in and of themselves are not reasons to institute HACCP, but they are not irrelevant either.

FDA's inspection program for seafood is mandatory, but it is far from continuous. In the absence of cause, FDA inspects at most once a year for products that it considers relatively high risk and at a lesser frequency for relatively low risk products. To significantly increase the frequency of inspection would require resources that may well not exist any time soon.

These inspections provide us with a "snapshot" of conditions at the moment that the inspector is in the plant. Assumptions have to be made about conditions during the bulk of the time that the plant is operating. The reliability of these assumptions over the intervals between inspections raises questions about the adequacy of the system.

Moreover, current federal inspection and surveillance strategies place a heavy burden on the government to prove that a problem exists rather than on the firm to establish for itself, for the regulator, and for consumers, that adequate controls exist to ensure safety by design.

A similar situation exists for imports. Nearly 60 percent of the seafood consumed in the U.S. is imported. The number of U.S. customs entries for seafood is approaching 200,000 annually. FDA is committed to ensuring that imported seafood products meet the same standards that are required of domestic products.

Just as the adequacy of our domestic inspection frequencies have been questioned, we have been frequently asked whether we physically examine enough import entries. While our import examinations are highly targeted and there are a number of other mitigating factors, the fact remains that most imported seafood is not physically sampled or examined by a federal health official. Increasing the physical sampling and analysis of seafood to statistically significant levels would cost substantial additional health resources.

FDA is pursuing two ways of increasing the scope of coverage for imports and they are highly interrelated. The first involves the development of memoranda of understanding, commonly referred
to as "MOU's," with countries that export seafood to the United States and have inspection programs we can rely on. The purpose of a MOU would be to establish that the regulatory system of an exporting country and the regulatory system in the U.S. are equivalent in their ability to ensure safety. A MOU would provide for regular verification by both countries. Products from a MOU country would not require as much examination by FDA as those from other countries.

The second approach is HACCP. HACCP should provide the basis for MOU's. MOU's based on HACCP could ensure that foreign processors are applying systems of preventive controls equivalent to those being required of domestic processors. But even in the absence of a MOU, we have tentatively concluded that all seafood, both domestic and imported, should be subject to HACCP controls, and we contemplate that our regulatory proposal will reflect that tentative conclusion.

The rest of the developed world appears to be heading in that direction. In some respects, we're playing catch up.

There are several additional points I would like to make about HACCP and our HACCP initiative for seafood.

First, HACCP is a system that can "go with the flow" in terms of technology. We do not expect processors to implement controls that are not technologically feasible, but we do expect processors to be aware of what is reasonable and feasible and to integrate such measures into their HACCP controls. For example, there is no rapid test yet available for ciguatera so the controls that can be reasonably put in place to prevent the presence of ciguatoxin are limited in that respect. However, if and when an inexpensive, rapid test does become available, it should constitute a HACCP control where appropriate.

Second, we do not want HACCP to constitute an undue regulatory burden on the industry. In our view, HACCP is really the systematic application of common sense measures to ensure safety, and thus should be an extension of what most people are or should be doing now. It does involve a certain amount of paperwork and plan development, but FDA is working to mitigate the burden through the development of extensive guidelines on hazards and controls that will be made available to the industry and through the development of fill-in-the-blank type plans to get people started. FDA cannot do that sort of thing alone. We look forward to working with and through trade associations, sea grant colleges and others to help develop and provide as much technical assistance as possible to the industry to facilitate the transition to HACCP.

One important aspect of this technical assistance involves basic training to the industry in HACCP principles and how to apply them. The National Academy of Sciences concluded in 1985 the success of our regulatory approach for low acid canned foods, which, as I indicated earlier is based on the application of HACCP principles, has been due to the training requirement in those regulations for each processor. We are contemplating extending the low acid canned food approach to training for HACCP. Under that approach, training is conducted by the private sector after being approved by FDA. We are pleased that trade associations and academia have both shown an interest in conducting HACCP training for the seafood industry.
Third, I am aware that there is some nervousness within the consumer community that HACCP is
deregulatory in nature because inspections under a HACCP-based system would involve little more
that a quick look at industry-generated records of the history of critical control points. We do not
expect that to be the case. While we do expect that inspections under HACCP will be more effective
and efficient, they should provide the legitimate basis for increased, not decreased consumer
confidence. HACCP will build upon the existing system. It will be an additional tool for both the
regulator and the industry, and will not simply be a wholesale replacement for of the current system.

Fourth, we hope that HACCP will provide the basis for additional federal/state cooperative activity.
We continue to believe that the states have a crucial role to play in seafood safety. The federal
government cannot even begin to do that job alone. Ideally, to the extent that states adopt HACCP
programs of their own, a federal/state team approach to inspection can be greatly enhanced. We urge
the states to join with us in our HACCP initiative.

Fifth, after saying all that I have, I do not want to suggest that we believe that HACCP is the end-all
and be-all of seafood safety. It isn't and we know it. It only works in conjunction with many other
things, such as a strong research base, public education, a reasonable resource commitment, adequate
training of federal and state officials, and so on. But it can and should be an important part of the
core of the food safety system.

Finally, we are truly looking forward to the public input part of the regulatory process. We urge
people to read the proposal carefully and we promise that we will read the public's comments back
to us just as carefully.
THE CANADIAN DEPARTMENT OF FISHERIES AND OCEANS' QUALITY MANAGEMENT PROGRAM

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During the past 5 years the Department of Fisheries and Oceans and the Canadian fish processing industry have worked together to develop the Quality Management Program (QMP) and on February 1, 1992, it became mandatory and is now a condition of federal registration for fish processing plants.

The Inspection Branch Mandate

The Inspection Branch of the Department of Fisheries and Oceans (DFO) is mandated through federal legislation to inspect all fish and fish products intended for export from Canada or for inter-provincial trade, and all fish and fish products imported into Canada. Through this mandate DFO provides assurance that both domestic production and imported products meet Canadian and/or foreign country standards for grade, handling, identity, process, quality and safety.

For fish and fish products produced in Canada, DFO has a dual concern, the health and safety of Canadian consumers and the overall quality of Canadian fish and fish products and their acceptability in international markets.

Canada is a major exporter of fish products and exports 84% of its fish products. The Inspection Branch plays an important role in facilitating the trade of these Canadian fishery products through its product inspection and certification programs.

To achieve its mandate the Inspection Branch has developed over the years a multi-faceted program that focuses on the strategic steps of the fish processing industry to ensure safe and acceptable fish products. This involves a variety of inspection activities which include the inspection of:

* domestically produced fish products to determine the acceptability of these products for sale in Canada or on foreign markets;

* domestic fish processing establishments to determine the degree of compliance with construction, equipment and operating regulatory requirements;
* domestic fishing vessels, unloading sites and transport vehicles to determine compliance with the applicable construction and operating requirements;

* imported product and the offshore processing operations to determine the acceptability of these products for sale in Canada; and

* the monitoring of shellfish growing waters through the Canadian Shellfish Sanitation Program.

Approximately 100,000 fishermen and plant workers earn their living directly from fishing and fish processing and Canada is one of the world's largest exporters of fish.

There are approximately 1,300 fish processing plants operating in Canada and 40,000 fishing vessels.

In 1991 fish landings amounted to 1.2 million metric tonnes of fish worth approximately 1.4 billion dollars. The production of this fish amounted to approximately 3 billion dollars worth of final product.

The Canadian Fish Inspection Program is a federal program delivered in 6 regions across Canada. They are as follows:

Newfoundland, Scotia-Fundy, Gulf, Quebec, Central & Arctic, and Pacific. Regional offices are responsible for the delivery of the inspection program and direction of the resources.

The Inspection Branch employs approximately 500 individuals.

320 Inspectors

80 Laboratory personnel

Across Canada there are 14 fish inspection laboratories and 120 Inspection offices.

New Challenges

In the 1980s it became apparent that present DFO resources dedicated to the Inspection Program were stressed and unable to deliver effectively all of the elements of the program. DFO was being forced to direct its resources at the activities of final product inspection and certification. The other areas of the program were being neglected and the Department was not able to respond to new challenges.

One of the key challenges will be to endure the scrutiny of the informed consumer and public media. Because of the increase in contaminants, pollution and threats to the environment, there has
been an increase in media and public concern regarding the safety of the food supply in general and fish products in particular.

Current trends lead us to believe that there will be no let up in media attention in the 1990s. Today's consumers are better educated, better informed and concerned about the safety of the food they eat. In all probability the workload of all food inspection agencies will continue to increase.

The rapid pace of changing technologies is also presenting an additional challenge to industry and food inspection agencies. As the Canadian fish processing industry develops new products and processes the Fish Inspection Program must adapt its inspection methods to continue to meet its mandate.

Another major challenge for the 90s will be responding to trade issues. The movement towards Hazard Analysis Critical Control Point systems (HACCP) in the United States and the developments in the European Community are already indicating additional demands on the Canadian fish processors and the Fish Inspection Program. These countries and others are requiring more assurances from the Canadian Government that standards are being met.

The above factors are all external factors that will affect both the Inspection Branch and the Canadian fish processing industry; but there is also another key factor internal to government that will have an impact on all of the Canadian Food Inspection Agencies. That is the question of resources.

The Canadian Government, as well as other western governments, are under constant pressure to limit spending and inspection programs such as the Department of Fisheries and Oceans and Agriculture Canada's cannot expect to have ever increasing resources to meet the challenges of the future. We must find smarter and more cost effective ways to carry out our mandate.

The challenges of the 90s make it necessary for government and the food processing industries to find, develop and implement innovative and cost effective approaches to food inspection. These new approaches must be flexible and sensitive to the needs of the industry and permit industry to adapt and remain competitive in the changing markets.

The Department of Fisheries and Oceans' Quality Management Program (QMP) is a key component of our strategy for responding to the demands of the future marketplace and addressing both consumer and industry concerns. The Program has been jointly developed by the Canadian fish processing industry and the Department of Fisheries and Oceans and became mandatory February 1, 1992. The QMP is based on the HACCP philosophy. QMP is, as HACCP is, a system designed to prevent instances of public health significance. However, QMP has been designed to also prevent instances of unacceptable quality and economic fraud from occurring.

This is a fundamental difference with the QMP and a pure HACCP Program.

QMP is closely linked to the Canadian Fish Inspection Regulations and the application of a QMP by a processing plant will assist the processor in operating within the regulatory requirements
which mean the fish produced will be safe, of acceptable quality and they will be marketed fairly. By implementing the Quality Management Program the fish processing industry will be able to demonstrate that they are operating on a day to day basis with controls that ensure compliance with the regulations. The development of an individual Quality Management Program for a fish processing operation incorporates all of the basic steps involved in developing a HACCP system for a specific food product. A hazard assessment of the process operation is performed. Critical control points are identified. Defect definitions and tolerances, monitoring procedures, record keeping criteria, corrective action systems, and company verification measures are established for each critical control point.

As of February 1, 1992 each Fish Processing Plant is required by regulation to have in place and be operating under a QMP specific to it's fish processing operations. The Department has developed the QMP Submission Guide to assist the industry in developing their programs. The Guide helps the processor identify the Critical Control Points in the process and the associated hazards and sets out for the fish processing industry the minimum requirements for a plant's Quality Management Program. Under QMP a fish processing plant is required to address 12 elements that are applicable to their operation. Potential hazards will be prevented through the application of controls at each of the elements in the process operation:

1. Incoming Fish  
2. Other Ingredients  
3. Packaging Material  
4. Labelling  
5. Chemicals (cleaning agents, sanitizers, lubricants, and pesticides)  
6. Construction and Equipment  
7. Operation and Sanitation  
8. Process Control  
9. Storage  
10. Final Product  
11. Recall Procedures  
12. Employee Qualifications

"Critical Control Point" is defined as a point in time or a physical location in the process at which failure of preventive measures will expose the customer to unacceptable risks related to tainted, decomposed, or unwholesome fish or to economic fraud.

At each Critical Control Point the fish plant must:

- identify the standard that is being applied to ensure compliance with regulatory requirements;

- identify the monitoring procedures and inspection frequencies that will be followed to ensure that the standard is being met during production;
- identify the reporting mechanism that will be used at each Critical Control Point to
document the results of the inspections; and

- the fish plant will be required to develop contingency plans or corrective action plans
that will be followed if and when the monitoring procedures identify an instance
where the standard is not being met.

The fish processing plant will be required to have available for inspection their documented
QMP that provides a written description of the program being implemented in the processing plant.
The plant will also be required to retain records of all inspections performed as part of their QMP for
3 years. These records must be made available to DFO Inspectors when requested.

The Department of Fisheries and Oceans inspects the fish processing plant against the Quality
Management Program requirements. Individual Inspectors perform QMP Inspections that entail:

* the verification of the written QMP to ensure the documented standards, monitoring
procedures, record keeping systems and guidelines for corrective action meet the
minimum requirements as set by the Department of Fisheries and Oceans;

* the confirmation that the written QMP is being followed in the plant. This will require
the inspector to observe the processor's QMP activities at each critical control point
in the plant; and

* the verification that the processor's records are accurate. This will require the
inspector to withdraw and inspect parallel samples of the processor's products and
compare the results with those of the company's.

The completion of the QMP Inspection will result in the process operation being rated as
either Excellent, Good, Satisfactory, or Fail. These QMP ratings represent the degree of confidence
that DFO has in the company's ability to operate within compliance of the regulations and will
determine the inspection coverage to be directed at the operation in subsequent weeks. Fail rated
plants will be asked to voluntarily correct the deficiencies and improve their rating to at least a
"Satisfactory". Refusal to deal with the problems voluntarily will jeopardize the federal certificate
of registration and therefore the ability of the processing plant to export its products. Plants which
receive a "Satisfactory" rating will be inspected on a frequent basis until they gain greater control over
their process and obtain a higher rating.

Processing operations that are successful in meeting all but a few of the QMP requirements
will receive an "Excellent" or "Good" rating. These plants will be qualified to apply for the use of
the "CANADA INSPECTED" logo on their product labels. Also the product certification process
will be streamlined and provided without delay, and the company will have more autonomy in their
day to day processing operation.
The Quality Management Program - Industry's Role

The major change for industry under QMP is that they must accept more responsibility and accountability in monitoring their own performance. The processing plants will be required to perform inspections of the plant and products and initiate corrective actions when they identify a problem and records of all these QMP activities must be maintained so that they are able to demonstrate that they consistently operating in compliance with the regulations.

The Role of Government in Regulating Under QMP

The implementation of the Quality Management Program will mean a change in the relationship between the fish processing industry and the Department. Under QMP the Department of Fisheries and Oceans' role will shift from solely an inspection function to include an auditing function. The Inspector will continue to perform random inspections of the process operation and products but the focus will not be on individual lots of product or on a day of plant operation as now is the case, but rather on the overall QMP system. The Inspector's decisions will be based upon a compilation of inter-related inspection results gathered over time by both the Inspector and the processor.

Conclusion

The Inspection Branch of DFO is confident that the Quality Management Program will provide the Canadian fish processing industry and the Department of Fisheries and Oceans with an effective mechanism to ensure the protection and assurance needed in today's demanding markets. The price of this assurance is change.

DFO will have to change. Industry will have to change. But this approach should realize more impact from each inspection. The number of inspections we do in total may be somewhat reduced for some plants, but each inspection will count for more. We will be able to focus our effort on areas of higher risk and apply our resources in a more cost effective manner.

In summary, the Department of Fisheries and Oceans' new approach to quality management is a joint industry/government system which is aimed at preventing problems before they occur. Working together, through the Quality Management Program the Canadian Fish Processing industry and the Federal Government will be able to provide Canadian consumers and our international customers even better assurance than in the past that the high standards Canadian fish products have been known for will be met in the future.
POLYPHOSPHATES: RATIONALE FOR USE AND FUNCTIONALITY IN SEAFOOD AND SEAFOOD PRODUCTS

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Food Grade Phosphates

Among the legitimate functional goals for the use of phosphates in seafoods are retention of natural moisture and flavor, inhibiting fluid losses during shipment and prior to sale, emulsification, inhibiting oxidation of flavors and lipids by chelation of heavy metals and cryoprotection, thereby, extending shelf-life. Properly used, phosphates impart no flavor.

Recently, the use of phosphates in some segments of the seafood industry has been subject to government scrutiny. When improperly used, excessive absorption of moisture may lead to charges of economic fraud by the U.S. Food and Drug Administration. It is important to note, however, that seafood myofibrillar proteins readily denature at refrigeration temperatures (5°C) and may lose up to 80% of their water-binding capacity within five days (10) while similar changes to beef muscle take in excess of 45 days at >20°C (8). Failure to protect these delicate proteins leads to significant overpack to meet net stated weight and negative economic consequences to seafood processors.

Phosphates are refined from calcium phosphate which is mined. Through varying degrees of neutralization of phosphoric acid with either alkali metal ions (i.e., sodium or potassium) or alkaline earth metals (i.e., calcium), two general classes of phosphates (simple and condensed) are formed (7). Simple phosphates consist of a phosphorous atom surrounded by four oxygens and valences that can be filled by metal ions or hydrogen. Condensed or combined phosphates are short to long chains or rings, the latter forms have the broadest applications in the seafood industry.

Application of Phosphates

Phosphates are generally applied by dipping in, spraying with or tumbling in a phosphate solution. Injector needle systems may also be used with and without added tumbling. Dry addition is used in comminuted meat systems, e.g., surimi and sausage formulations.
The most predictable way to apply phosphates is through vacuum tumbling, if done properly and the structure of the flesh can withstand mechanical action. Contrary to some practices, tumbling in an excess of solution results in protein extraction rather than absorption of solution. This uniform and rapid means of treating the muscle offsets the inefficiency of protracted holding in phosphate-based solutions (soaking).

It has been demonstrated that treating finfish prior to smoking requires different phosphate concentrations depending on the dimensions of the fillets and/or pieces. For example, with the same size pieces of flesh (within selected species), a 5% phosphate dip requires 24 hours treatment time while a 25% phosphate dip requires only two seconds (16) to reach equal processing effects, i.e., inhibition of surface curd formation and reduced cook-cool losses. This is especially valuable when delicate muscle structure eliminates tumbling as an option. Caution should be exercised when applying phosphates to fish of different muscle thickness, muscle types (e.g., interspecies variation) and initial moisture content (spawning).

Methods to Determine Phosphate Application

Some methods to monitor phosphate use are based upon total moisture content of the muscle. One example would be the French HP (9) method which is used to monitor the ratio of protein to water within muscle. In scallops, the ratio is considered to be between 4.0 and 4.9: 1.0 (water: protein). The moisture content of commercially harvested seafood muscle is 80% or greater in species including, but not limited to, soft-shell blue crab, some mollusks and post-spawned finfish. Webb et al., (21) determined that the moisture content of bay scallop meats was significantly different at the 5% level between harvest years, sounds, locations within the sounds and among months and within locations. These researchers (21) also determined that the moisture content (monthly sampling) of land-shucked bay and Calico scallops ranged between 74.15 to 83.66 and 76.12 to 81.86%, respectively.

The HP ratio then would not be realistic for many species or at certain times of year. This value is based upon Kjeldahl protein to moisture (overnight drying at 100 to 105°C).

In theory, determination of total phosphorous in seafoods might be a useful marker of phosphate treatment; however, it is not necessarily accurate. For example, Crawford (4) determined that the natural level of phosphorous in fresh shrimp (Pandulus jordani) ranged from 537 to 727 mg/100 gm. Shrimp of the same history showed increases of 81±39 and (base not given) ±110 mg of phosphorous, respectively after treatment with either 1.5 or 6% phosphate solutions for five minutes. In shrimp (Pandulus jordani), the natural variation in phosphorous exceeded that added by responsible treatment.

Total natural phosphorous has also been reported to vary in lobster, blue mussels, squid, anchovies, carp, capelin, catfish, Atlantic cod, eel, hake, herring, yellow leatherjacket, European pilchard and albacore tuna (13). Penetration of phosphate, and therefore phosphorous content, will also vary according to concentration of solution used, variations in muscle thickness, subsequent processing, etc.
Other methods to screen for added phosphates include high pressure liquid chromatography (HPLC), ion chromatography and thin layer chromatography. Wood and Clark (22) have reviewed the difficulties associated with these phosphate determinations.

Biochemical decomposition of condensed phosphates necessitates assaying immediately after treatment of the seafood species. Hydrolysis of condensed phosphates occurs due to muscle alkaline phosphatase activity during the post-treatment (lag) time prior to cooking. Sutton (15) determined that sodium tripolyphosphate is rapidly hydrolyzed to pyrophosphate (phosphate dimer) and orthophosphate (phosphate monomer) in cod muscle at either zero or 25°C.

It has also been determined that after two weeks of frozen storage (-26°C), only 12% of the total phosphorous in raw shrimp muscle corresponded to the originally added sodium tripolyphosphate. By ten weeks, phosphorous levels corresponded to 45% orthophosphate (17). Clearly, in treated seafood muscle, the condensed phosphates were unstable over time.

**Mechanism of Action**

Offer and Trinick (11) determined that pyrophosphate [(10 mM), (from beef myofibrils)] in combination with reduced levels of sodium chloride, extracted the A-band completely beginning at both ends. This effect was confirmed by Voyle et al. (1984) with pork. In the absence of pyrophosphate, however, only the center of the A-band was extracted. Lewis et al. (1986) determined from 5 gm pork, beef, chicken and cod samples that an A/I overlap composed of denatured actomyosin and connectin was formed while unassociated myosin and actin were probably dispersed (sol) through the meat structure in the form of a water-holding gel (post heat treatment).

Trout and Schmidt (18) concluded that at high ionic strengths (>0.25), pyrophosphate affected hydrophobic interactions which stabilize the protein structure, and thus, the thermal stability of the protein. Elevating pH (1M NaOH), in combination with pyrophosphate, increased the temperature (from 70 to 87°C) for, and the extent of, protein aggregation. Yagi et al. (25) confirmed that inorganic polyphosphate offered a high degree of protection (to carp myofibrils) from thermal denaturation.

Water retention is correlated with increased pH and normally associated with the use of alkaline polyphosphates such as sodium tripolyphosphate. Orthophosphates have virtually no effect on water-binding (12). Pyrophosphates are associated with improved protein solubility (myosin) and water binding. Consequently, water binding is dependent upon the type of phosphate used and specific physicochemical reactions may require the use of blends.

**Phosphates as Processing Aids**

This area will be given only a cursory mention since it is a topic of a later presentation. Crawford (4) was instrumental in developing a protocol for the treatment of Pacific shrimp (Pandanus jordani) to be mechanically cooked and peeled. By the responsible use of phosphates in treating Pacific shrimp to be mechanically cooked and peeled, meat yield increased an average of 12%. There was no significant uptake of moisture, and there was an added ex-plant income (in Oregon alone) of greater than 65 million dollars in the first eight years of use (1).
Preservation of Freshness

A process for using low concentrations (1 to 2%) of sodium tripolyphosphate in either flaked or crushed ice was patented by Stone (14). Use of this ice increased the yield of shrimp and effectively reduced moisture and nutrient loss. Shrimp stored in phosphated ice could be over-exposed to polyphosphates if treated again during further in-plant processing which could cause either off-flavor, >0.5% residual phosphate or both.

Specialty Blends

Among products for extending the shelf-life of fish fillets, Crawford (2, 3) developed a patented blend consisting of sodium tripolyphosphate, sodium hexametaphosphate, citric acid and potassium sorbate (FISH-PLUS™, BK Ladenburg Corporation). Fish fillets were dipped into either distilled water or (ca.) 12% treatment solutions. The shelf-life (aerobic plate count ≤ 1 x 10⁵ CFU/g) for treated samples was 12.4 days and that of the control (water-dipped) was 6.8 days. Both control and treated fillets increased in weight by 4% after 60 seconds of immersion. Those dipped in the patented blend remained at their stated package weight throughout the 14 days of storage at 5°C, while the controls, dipped in water, dropped below the initial weight within four days of chill storage. Shelf-life extension would most likely be increased due to, first, the antimicrobial activity contributed by the sorbic acid, and second, the sequestration by phosphates of enzyme (metal) co-factors.

Frozen Seafoods

Researchers at Texas A&M University reported that sodium tripolyphosphate dissolved slowly in seawater (6). In addition, fresh, shell-on and peeled shrimp (Gulf of Mexico) became translucent and slippery to the touch after dipping in solutions of phosphate-sea water. This led to subsequent treatments which included five minute dips in water and 2, 4 or 5% condensed phosphates. Using a blend of sodium tripolyphosphate and hexametaphosphate (BRIFISOL™ 512, BK Ladenburg Corporation) resulted in rapid solubilization of the condensed phosphate, and more desirable sensory (touch) properties. The dipped shrimp were frozen and stored at -26°C for two weeks. Upon thawing and cooking (four mins), those shrimp dipped in the 4% blend for five minutes lost 0.8% weight after frozen storage (control, 2.0% loss) and 19.8% after cooking (control, 25.3% loss). It was concluded that addition of these phosphate blends imparted a cryoprotective effect.

Woyewoda and Bligh (24) dipped Atlantic cod fillets into 12% solutions of sodium tripolyphosphate, sodium metaphosphate blends or no solution (FREEZ-GARD® FP-19, FP-65 [Rhone-Poulenc] and a control, respectively) for 45 seconds and stored each treatment at either -12°C or -30°C for up to 26 weeks. Phosphate-treated cod showed decreased thaw, and cooked drip loss and resulted in higher moisture content in both raw and cooked product. After 26 weeks (at -30°C), all phosphate treated fillets were judged the most tender and highly acceptable by sensory evaluation. The use of tripolyphosphate significantly reduced expressible water after holding at -30°C up to 26 weeks and up to 24 days at -12°C.
Thermally Processed Seafoods

Struvite, or magnesium ammonium phosphate, may be formed in thermally processed seafoods (e.g., canned tuna and crab). Sodium acid pyrophosphate can be used to sequester magnesium ions and thus, inhibit struvite crystals, which resemble broken glass.

Salmon may develop a surface curd (denatured protein) if either held on ice for a protracted length of time and/or frozen prior to canning. The curd may constitute up to four percent of the pack, by weight, and may be considered questionable by many consumers.

Curd was significantly (P<0.05) reduced by dipping sockeye salmon steaks for 2 to 120 seconds in 15 to 20% solutions of condensed phosphate (BRIFISOL™ 512 [sodium tripolyphosphate and sodium hexametaphosphate], BK Ladenburg Corporation) and by dipping for 30 to 120 seconds in 5 to 10% solutions (19). To avoid dipping, Wekell and Teeny (19) verified that there was a 68% reduction in curd formation by dry addition of the phosphate blend prior to sealing the can. Although it was estimated that 1.0% polyphosphate would be needed to completely inhibit curd formation, this would exceed the legal limits for phosphate in canned salmon.

Domestically, phosphate is not uniformly allowed in canned salmon except for a temporary allowance granted to several processors. Its use in canned salmon has, however, been given provisional approval by the Canadian government.

Phosphates provide significant benefit to the seafood industry when there is a large harvest within close proximity, and conversely, there are limited quotas (i.e., freezing fillets to extend wholesale/retail availability). Spawning salmonids may represent one of the most important applications since the muscle has been physico-chemically altered. Such finfish contain reduced levels of myofibrillar proteins which lead to impaired muscle water holding capacity. This is parallel with elevated levels of sarcoplasmic proteins and total moisture, a combination conducive to curd development.

Troubleshooting

Often when phosphates are added in excess, a glassine look develops. This is particularly noticeable on shrimp. There are regulatory constraints to the use of polyphosphates along with organoleptic problems (a soapy taste) if the phosphates are used in excess. The glassine appearance probably occurs more in error than through intentional overuse of phosphates since there are no standard or defined procedures for their application. Most industrial protocols have been developed by trial and error and/or have been based upon far more resilient terrestrial muscle.

Combining sodium tripolyphosphate with sea water will frequently promote the formation of a "floc" on the surface of certain species. Mineral content and pH of the muscle will exacerbate the formation of this crystalline precipitate.
Polyphosphate insolubility is related to water quality and to the individual type of condensed phosphate. Minerals in hard water will compete with some types of polyphosphate for solubility. In addition, not all forms of polyphosphate are readily soluble in water.

Erratic functionality of phosphates also may be caused by either heating phosphates to promote solubility or using old solutions. Many of the polyphosphates are prone to hydrolysis, and the monomeric forms will not perform the same as the polymers.

The maximum permitted legal level in processed meat and poultry is 0.5% by weight of the final product and serves as the current guideline where their use is permitted. Polyphosphates are not allowed in breaded shrimp and in certain other species (5). They are, however, self-limiting. If much more than 0.5% of the high pH phosphates, such as sodium tripolyphosphate, is used, flavor and appearance will be adversely affected.

Summary and Conclusions

Phosphates are valuable to maintenance of the functional properties of seafood myofibrillar proteins which preserve the natural muscle juices. Inhibiting drip loss in the fresh state, while thawing and in cooking is important to prevent economic loss. Phosphates increase the thermal stability of proteins which, in seafoods, are normally lower than that of terrestrial muscles. Improper use of phosphates leads to sensory defects and the potential for charges of economic fraud.

Literature Cited


FUNCTIONALITY OF POLYPHOSPHATES

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Polyphosphates are used extensively in food processing. Many studies have shown the benefits of polyphosphates in beef, pork, poultry, and seafood. It was found that these compounds have a profound effect on the functional properties of the food products of which they become a part (Deman, 1970). The first patent on the use of polyphosphates to inhibit thaw drip and cook losses in frozen fish were issued in the United States to John H. Mahon in 1962. In recent years, polyphosphates have gained widespread acceptance as additives in the fish and seafood industry. The functional goals when applying polyphosphate to seafood are to retain moisture and flavor, to prevent oxidation and to extend shelf-life. Appropriate applications of polyphosphates result in the retention of natural juices which in turn slow down normal fish deterioration. Excessive (or abusive) use of polyphosphates, however, is linked to excessive water uptake (i.e., economic fraud), which has given rise to tensions between the seafood industries and regulatory agencies like the FDA. The FDA fears that polyphosphates might be used to improve the quality of damaged food products and/or would be used to “add” water to foods. However, if excessive polyphosphates are added, the fish develops a soapy taste and a glassine look which are obviously not desirable. This probably occurs more in error than through intentional overuse of polyphosphates. The problem exists because there are no treatment standards. Standards are difficult to develop since many variables influence polyphosphate uptake in the fish muscle, among these variables are: thickness of the muscle, muscle type, type of polyphosphate used, concentration of the polyphosphate solution, dipping time, post-mortem age, etc. The purpose of this study is to determine the relationship between polyphosphate uptake and water retention in fish in different seafood models as a function of type of polyphosphate (including blend of polyphosphates in
concert with microbial inhibitors), concentration of the polyphosphate solution, and time of dipping. The water retention properties after the different treatments were evaluated by water uptake ability (WUA) and expressible moisture (EM) in order to determine the interaction between protein and polyphosphate.

Traditionally, a number of different methods were used to measure the water retention properties in muscle food systems. According to Regenstein (1984), two of the major types of the water retention methods, WUA and EM, respond to different properties of flesh. WUA refers to the ability of a material to hold added water while under the influence of an external (centrifugal) force. Therefore, WUA represents the maximum water retention of insoluble material in the presence of excess moisture at a particular force (Jauregui, 1981 & Regenstein, 1984). EM refers to the amount of water squeezed out of a material by the application of a force (Centrifugal). Both EM and WUA should be measured at the same centrifugal force when they are to be compared. The results of these studies showed that for WUA, the different cations gave similar results while the anions gave very different results. WUA is then found to be a anion-distinguishing technique. The EM, however, is a cation-dependent effect. It divides the salts into two classes of behaviors: with and without changes, e.g., EM of Mg changes with the salt concentration while with Ca it doesn't change.

MATERIALS AND METHODS

Sodium tripolyphosphate (STPP) (FMC Corp., Industrial Chemical Groups, Philadelphia, PA), sodium hexametaphosphate (SHMP) (Sosphadex, FMC Corp., Industrial Chemical Groups, Philadelphia, PA) and FishPlus® (BK Ladenberg Corp., Cresskill, NJ) were used to prepare the dip solutions. STPP is the most popular polyphosphate used as a food additive. SHMP is probably the second most popular polyphosphate used commercially with flesh foods. It is broken down to orthophosphate more slowly than STPP. FishPlus® contains a blend of generally-recognized as safe (GRAS) ingredients: sodium, phosphates, citric acid and potassium sorbate (Technical Bulletin, 1982).

Commercial cod and mackerel of 3 to 5 days age were used as seafood models. Fresh cod fillets and whole mackerel were obtained from the P&C supermarket (Ithaca, NY) as soon as they arrived. After gutting the mackerel, they were cut into fillets. These fillets were skinned and the white muscle was cut into 4 to 8 pieces which were usually between 4 cm x 2 cm x (0.7 to 1.5) cm. Cod skinless fish fillets were cut into pieces (4 cm x 3 cm x 2 cm). Ground samples of cod muscle were prepared by grinding the fillet in a HC20 Handychopper™ Mincer/Chopper (Black & Decker Inc., Shelton, CT). The muscle pieces were then dipped in the polyphosphate solutions at specified concentrations for specific length of times. In the case of mackerel, the
muscle pieces were dipped in 0, 1, 3, or 6% (w/v) STPP for 0.5, 1.5, or 3.0 min. The cod blocks were dipped in 0, 1, 2, 5, 10% (w/v) polyphosphate solution for 0.5, 1, 2, 3, 5 min. The polyphosphate added to the minced sample were 0, 0.1, 0.3, 0.5 and 0.7%. The treated samples were packed and stored on ice for different length of time. In the case of cod, treated samples (fillets and polyphosphate added minced cod) were stored for 1, 4, 7, 10, 15 days. Water retention properties were measured at certain storage periods.

Four different methods were used to measure the water retention properties: EM, WUA, thaw (drip) loss and cook loss. Polyphosphate uptake and, in the case of mackerel, thiobarbituric acid (TBA) were also measured.

**Expressible moisture**

To determine EM, 3 pieces of Whatman (Whatman International Ltd., Maidstone, England) #3 filter paper, 5.5 cm in diameter, and 1 piece of Whatman #50, 7.0 cm in diameter were folded into a thimble shape over the outside of an inverted 16 x 150 mm test tube with the #50 filter paper as the internal surface. The filter paper was weighed on a Mettler H20T balance (Mettler Instrument Corp., Hightstown, NJ) before and after addition of 1.5 ± 0.3 g sample of treated ground fish. The sample in the thimble was then centrifuged in a 50 mL polycarbonate centrifuge tube (Nalgene Co., Rochester, NY) at 16,000 rpm (30,900 x g, measured at the bottom of the tube) in a refrigerated centrifuge (Sorvall RC2b, SS34 rotor) at about 2°C for 15 min. The filter paper and sample were then removed from the tube with tweezers, the fish cake was removed from the filter paper, and the paper was reweighed. EM was reported as the percent weight lost of the original sample (Jauregui, 1981).

**Water uptake ability**

According to the method of Jauregui (1981), 30 mL of water was pipetted into 50 mL polycarbonate centrifuge tubes. The tubes were placed in ice while the treated samples were grounded and 1.7 g was weighed on a piece of wax paper using a Mettler H20T balance. The samples were added to the water and the mixture was blended in an Omni-mixer (Sorvall Omni-mixer Model 17105, Dupont Co., New Town, CT) for 30 sec at the midpoint setting (5). The blades of the Omni-Mixer were then rinsed with 4 more mL of water, to make the ratio of fish to solution 1:20. The tubes were stored in ice for 30 min before centrifugation. The samples were centrifuged in a refrigerated centrifuge at 16,000 rpm for 15 min at 2°C. After centrifugation, the supernatants were decanted and their volume determined. The pellets were placed in aluminum pans, weighed and dried overnight at 105°C in an air oven. The protein concentration of the supernatant and the original sample were determined by the Lowry method (1951).

WUA was calculated by dividing the mg of water in the pellet by the mg of protein in the same pellet. The protein content of the pellet was calculated by difference: total initial protein minus total protein in the
supernatant. The WUA can also be expressed as a percent of the WUA of the control which was run at the same time. In addition, the total bound water based on the original sample weight can be calculated. This can be used to compare WUA values since the amount of insoluble protein in different samples were different.

In addition, the effect of the pH on the WUA was examined. The actual pH of the solution was measured immediately after centrifugation. NaOH and HCl were used to adjust the pH of the system.

**Thaw, drip and cook loss**

The thaw loss determination method was modified from Santos (1990). Frozen samples (kept at -10°C) were weighed and placed in a glass funnel on top of a flask, wrapped tightly with a plastic bag and incubated in a cold room (1 to 4°C) for 24 hr. The thawed samples were weighed and the percent of thaw drip was expressed as the percent of weight loss during thawing.

The drip loss of fresh treated samples were measured using the thaw loss method after different storage time.

After the thaw loss and drip loss determination, the samples were placed in a covered microwaveable baking dish and cooked in a microwave oven at its maximum energy (750 Watt) for 1 min (Amana Touchmatic II Radarange® microwave oven, Amana Refrigeration, Inc., Amana, IW), and air-cooled. The cooked fish blocks were weighed while the liquid remained in the dish. Cook loss was expressed as the percentage of weight loss after cooking (Santos, 1990).

**Phosphate determination**

The Quimocic method was used to measure total phosphate uptake by measuring the concentration of phosphorus (or phosphorus pentoxide) in the treated samples (Anonymous, 1977 & Jauregui, 1981)). The sample is digested in nitric acid to solubilize the orthophosphate and to hydrolyze condensed phosphates to the orthophosphate form. The orthophosphate is precipitated as quinolinum phosphomolybdate which contains 3.207% P$_2$O$_5$.

Small amounts of dipped sample were added into 300 or 150 mL Erlenmeyer flasks containing 50 or 25 mL concentrated HNO$_3$, respectively, and boiling chips. The flasks were heated on a hot plate until all the samples were dissolved and the solutions were clear. The flasks were left on the hot plate for 4 hr just below boiling. After this, 100 or 50 mL water was added to each flask and the solution was allowed to boil for about 45 min. After diluting the solution to about 100 or 50 mL, 50 or 25 mL of the Quimocic Reagent, respectively, was transferred to the hot solution while stirring and was allowed to boil for two or three min before cooling. The bright yellow precipitate obtained was filtered through a dried pre-weighed Gooch crucible (Coors No 3, Coors Porcelain Co., Golden, CO) containing a glass fiber filter (Reeve Angel No 934Ah, 2.1 cm, Whatman Inc., Chifton, NJ) and washed 5 times with 25 mL distilled water, allowing each portion to pass through the filter completely before another was added. The crucible and contents were
dried in an oven for 30 min at 250°C, cooled in a desiccator and weighed. The weight of precipitate was calculated by subtracting the weight of the empty crucible from the weight of the crucible and precipitate. The amount of phosphorus pentoxide (P₂O₅) in mg was calculated by multiplying the dried weight of the precipitate (g) times a 32.07 factor.

**Thiobarbituric acid (TBA) value**

The TBA determination was adapted from Hwang (1988). A 1.9 to 2.0 g portion of ground sample was weighed, added to a 50 mL centrifuge tube and blended with 25 mL of extracting solution for 30 sec in an Omni-mixer at a low setting (3). The mixture was filtered through Whatman #1 filter paper. Five mL of the extract was mixed with 5 mL of the TBA reagent and added into a 20 mL screw cap test tube. The test tube was capped tightly and heated in boiling water for 40 min. The test tubes were cooled under running tap water. The absorbance of the samples were measured and the μmoles of malonaldehyde (MA) were calculated from the standard curve of 1, 2, 3, 3-tetraethoxypropane, which is quantitatively hydrolyzed to MA when heated, and multiplying this value by the dilution factor (5.0). The TBA value was expressed as μmol MA/g of sample.

**RESULTS AND DISCUSSION**

**Measurement of EM:**

The effect of STPP and FishPlus® on cod fillets were studied by dipping in different concentration of polyphosphate solutions for different time periods (Fig. 1 & 2).

![Graph showing effect of STPP concentration and dipping time on EM](image)

Fig. 1 Effect of STPP concentration and dipping time on EM

Increasing the STPP or FishPlus® concentration and the dipping time decreased EM. Compare to STPP, FishPlus® was not as effective. The differences might be due to the different polyphosphate content and pH of the dipping solutions. At the same total concentration level, polyphosphate
content is higher in the STPP solution than in the FishPlus® solution. In addition, the pH of the STPP solutions were around 9 while the pH of the FishPlus® solutions were around 6. From Fig. 1, we found that dip times over 1 min had a minimal effect. For those samples dipped in FishPlus®, there was little change in the EM when the concentration was above 5% and dip time had no effect.

![Graph showing the effect of FishPlus® concentration and dipping time on EM](image)

**Fig. 2** Effect of FishPlus® concentration and dipping time on EM

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**Measurement of WUA:**

The effect of STPP concentration and dip time on WUA is shown in Fig. 3. Longer dipping times led to increased WUA. Fig. 4 shows the effect of STPP concentration and dip time on the total amount of soluble protein in the supernatant. With the increase of the STPP concentration, the amount of protein in the supernatant increased although the trend is not apparent at low concentration. Since the protein content in the pellets were different with different dip concentrations and dip times, we also calculated the percent water absorbed based on the original sample weight as shown in Fig. 5. Compared to Fig. 3, the total amount of water absorbed in the sample decreased, especially for the sample dipped for 5 min, because the protein content in the pellet decreased with dipping.

Ground cod was used to measure the effect of dip solution pH on the WUA. The pH of the homogenized cod was adjusted after blending. However, since the pH of the solution was not stable (the pH of the solution before and after centrifugation were different), the actual pH of the solution was measured immediately after centrifugation. The sample with the lowest WUA, i.e., at pH 5.5 was used as the control. Fig. 6a show the effect of pH on cod from pH 3 to 11. Since the WUA change was largest at the extreme pHs
and we are more interested in the middle pH range, we replotted the data for pH 4 to pH 9 (Fig. 6b), and from pH 5 to 7 (Fig. 6c). From these results, i.e., a large pH dependence, we would expect that STPP and FishPlus® would have different effects on WUA since their solutions have different pHs. pH change had an important effect on fish WUA. Around pH 5.5, WUA is at its lowest point. And at this pH, there is the least amount of soluble protein in the supernatant and the least amount of water absorbed in the pellets.

Fig. 3 Effect of STPP concentration and dipping time on WUA

Fig. 4 Effect of STPP concentration and dipping time on the amount of soluble protein in the supernatant
Fig. 5 Effect of STPP concentration and dipping time on the water absorbed based on the original sample weight.

Fig. 6 Effect of pH on WUA
Thaw and cook loss:
The effect of STPP and FishPlus® on the thaw and cook loss are shown in Fig. 7a and Fig. 7b respectively. The period of storage had a greater effect on thaw drip than the dip concentration. STPP and FishPlus® concentration were more effective in preventing cook loss than in preventing thaw loss. STPP was more effective over intermediate storage times in preventing total moisture loss.

Fig. 7 Effect of STPP and FishPlus on thaw and cook loss

Phosphate determination:
Increasing dip time and polyphosphate concentration increased the absorption of polyphosphate in fresh cod (Fig. 8). Since the sample size was small, the amount of polyphosphate picked up in the cod blocks was higher than expected. According to the observed changes in phosphate levels, we
expect to be able to control the phosphate uptake by changing dip time and dip solution concentration.

![Graph showing the effect of dip time and STPP concentration on % of phosphorus pentoxide pick-up in cod blocks.]

Fig. 8 Effect of dip time and STPP concentration on the % of phosphorus pentoxide pick-up in cod blocks

Storage study:
The effect of storage time on the EM of Sophadex treated fresh cod fillets

Fig. 9a - 9e show the EM as a function of dipping time and concentration. Each figure represents a different storage time. On day 1 after dipping (Fig. 9a), the EM did not change much with different dipping times and concentrations. The samples dipped in water showed an increase in the EM with dipping time. This is probably due to the increased water uptake. However, in all cases with Sophadex, the EM decreased. The decrease in EM of the samples dipped in 2% and 5% solutions was slight with increased dipping time; the EM decreased about 1% from 0.5 min to 5 min. At 10%, dipping time had a greater effect, the EM decreased about 3% from 0.5 min to 5 min. The EM increased with Sophadex concentration when the dipping time was the same and concentration had a greater effect as time went on. On day 4, notable changes occurred (Fig. 9b). The EM of the samples dipped in water showed large increases with dipping time (4.5%), while the samples dipped in different concentrations of Sophadex showed similar decreasing water loss with dip time. Higher concentrations gave lower EM. The difference of the samples dipped in Sophadex versus that in water was significant. On day 7, 10 and 15, the difference continued and the EM changes were similar to day 4 although the curves all shifted upward without a slope change (Fig. 9c-9e). On the other hand, the EM of the samples dipped in Sophadex kept on increasing. The lowest EM sample (dipped 5 min in 10% solution) changed from 42.4% to 47.0% over 15 days. Sophadex was helpful in lowering EM.
Fig. 9 Effect of storage time on the EM of Sophadex treated cod fillets

The effect of storage time on the WUA of Sophadex treated fresh cod fillets

Fig. 10a-10e show the WUA with the same conditions as for EM. In Fig. 10a, WUA of the fillets dipped only in water did not change with dip time, whereas the WUA of the fillets dipped in Sophadex increased from 0.5 min to 2 min and then showed no change from 2 min to 5 min. The higher the dipping concentration, the higher the WUA. On day 4 (Fig. 10b), the water dipped and the 10% Sophadex had similar WUA as day 1. The other 2
samples were different, especially the 5% solution, where WUA decreased after 2 min dipping, and was lower overall than day 1. From day 7, the WUA decreased in all cases (Fig. 10c) and on day 10 (Fig. 10d) the decrease of the 10% dipping sample was notable. By day 15 (Fig. 10e), the WUA of all samples was lower and more similar. This might be caused by the spoilage of the fish.

Fig. 10 Effect of storage time on the WUA of Sophadex treated cod fillets

The effect of storage time on the drip loss of Sophadex treated fresh cod fillets
The drip loss after different treatments is shown as the effect of storage time (Fig. 11). The values of the drip loss were very close at the beginning of the storage (day 1), from 2.0% to 2.2%. With the increase of the storage time, the differences became greater. On day 15, the values had a range of 10.0% to 12.5%. The lower the Sophadex concentration, the higher the drip loss; the shorter the dipping time, the higher the drip loss. However, the drip loss was mostly affected by the storage time.

![Graph showing drip loss over days for different Sophadex concentrations and dipping times.]

Fig. 11 Effect of storage time on drip loss of fresh cod fillet which dipped in Sophadex

The effect of storage time on the cook loss of Sophadex treated fresh cod fillets

Fig. 12 shows the change of the cook loss as the effect of storage time. Although there was no similar pattern, the cook loss, generally decreased with the addition of Sophadex, and there was a trend that increased concentrations and dipping times, decreased cook loss.

The effect of storage time on the EM of STPP treated fresh minced cod

The effect of STPP concentration and storage time on EM of minced cod is shown in Fig. 13. The EM decreased with increased STPP. The decrease was greatest on day 1 with more than a 10% decrease. The changes on day 4 and day 8 were less, around 4-5%. Increase storage time increased the EM. However, on day 15, an unusual change occurred, the EM dropped again. The values of every sample with different STPP concentrations were lower than those of day 4 and day 8, and closer to day 1. The change was unexpected and might be due to the spoilage of the fish.
The effect of storage time on the WUA of STPP treated fresh minced cod

The effect of STPP concentration and storage time on WUA of minced cod is shown in Fig. 14. On day 1 the WUA decreased slightly and smoothly with the increase of the STPP concentration, from 22 to 18 (mg water/mg protein in pellet). On day 4, the WUA increased for all the samples with different STPP concentration with the exception of the samples that had no STPP added. The decrease of the samples with no STPP added was 0.8 (mg water/mg protein in pellet). For the other samples, the values increased, especially for the one with the highest STPP concentration (from 18 to 27 (mg
water/mg protein in pellet)). On day 8, the values decreased again and were all close to the values on day 1. On day 15, the values decreased. The value of the sample with no STPP added dropped to 11 (mg water/mg protein in pellet).

Other changes observed during the WUA test were in the protein in the supernatant and the water absorbed as a function of total sample weight (Fig. 15 & 16). The protein content in the supernatant increased with storage. The effect of STPP on protein solubility was modest, storage time had a greater effect. The increase on day 15 was greater with the highest point at 141.3 (mg protein/1.7 g sample). This might again be caused by the spoilage of the samples. It was interesting that the protein content in the supernatant dropped with the increased STPP concentration on day 1 and increased on day 4 and day 8. For the water absorbed by the samples, the notable changes also occurred on day 15.

Fig. 14 Effect of storage period on WUA of minced fresh cod with the addition of STPP

Since pH had a larger effect on WUA than the concentration of polyphosphates, the pH of the homogenized samples was monitored before centrifugation (Fig. 17). The pH of all the samples increased with storage time and STPP. However, the pH of the samples with the same STPP concentration did not change much from day 1 to day 4, whereas the change from day 4 to day 8 is large. Again, the change on day 15 was unexpected and may be due to the spoilage of the fish. The WUA of the sample increased with the increase of pH in the range of 7 to 9 as suggested.
Fig. 15  Effect of storage time on the amount of soluble protein in the supernatant with the addition of STPP.

Fig. 16  Effect of storage time on WUA (expressed as water (g)/sample (g)) of minced fresh cod with the addition of STPP.
The effect of storage time on the drip loss of STPP treated fresh minced cod

Fig. 18 shows the drip loss for different storage period. The drip loss increased with storage time. For the samples without STPP treatment, the drip change was large, from 3.5% to 11.9%. STPP prevented the drip loss although the concentration did not affect drip loss. In addition, the STPP had some effect on drip loss with longer storage periods. Day 4 and 8 had similar drip loss, while day 15 showed higher values. This again might be due to spoilage.

The effect of storage time on the cook loss of STPP treated fresh minced cod
Cook loss is shown in Fig. 19. The concentration of STPP did not have a big effect on cook loss compared to the storage time. There was also no big difference between the samples with STPP and the samples without STPP.

Fig. 19 Effect of storage time on cook loss of minced fresh cod with the addition STPP
Mackerel studies:

Preliminary results on the effect of different concentrations of STPP and dipping time in mackerel samples are shown in figures 20-24. EM decreased with storage time. Both concentration and dipping time (especially the latter) showed an increase in the EM of the samples (see Fig. 20).

As expected then, WUA increased with time, i.e., the older the fish post-mortem, the greater the ability to take up water. The effect of the concentration of STPP was not clearly defined. The highest values for WUA were observed in samples dipped in water (0%) but the lowest were not observed in higher concentrations of the STPP, as we would have expected, but in fact were obtained among the middle concentration levels. The increase in WUA with time, however, seemed to be less in the samples dipped in higher concentrations of the STPP solution. Dipping time appeared to slightly decrease WUA (see Fig. 21).

**Expressible Moisture**

![Graph showing expressible moisture over time and concentration](image)

Fig. 20 Effect of STPP concentration and dipping time on EM of mackerel white muscle on days 2, 7 and 13.
Fig. 21 Effect of STPP concentration and dipping time on WUA of mackerel white muscle on days 2, 9 and 14.

Both the concentration of STPP and the dipping time had the expected effect of increasing the phosphate content of the sample measured as % P$_2$O$_5$ (see Fig. 22). These results, however, were not checked against a no-treatment sample which means that the final phosphate uptake of the different samples was not possible to quantify.

Finally, to compare the polyphosphate uptake with the oxidation of fatty acids (i.e., rancidity), a TBA test was performed (see Fig. 23). At higher concentrations of polyphosphate, the TBA values were lower. This effect was also observed with regard to dipping time (i.e., the longer the dipping time, the lower the TBA values).
Phosphate Content

Fig. 22  Effect of STPP concentration and dipping time on the phosphate content of mackerel white muscle.

TBA value

Fig. 25  Effect of STPP concentration and dipping time on the TBA value of mackerel white muscle

REFERENCES


