Vol. 24, No. 7 Research Report December 2009

Ingredient Optimization in Fresh, Marinated Catfish Fillets

Sovann Kin, M. Wes Schilling, Brian S. Smith, Taejo Kim, J. Byron Williams, and Juan L. Silva

Introduction

Traditionally, food preparers have used meat, poultry, and seafood marinades to convey a mixture of ingredients through soaking, massaging, tumbling, or injecting in an effort to enhance flavor, texture, or other sensory attributes. Adding functional ingredients to a marinade can further influence product yield, cook loss, oxidative and microbial stability, and operational efficiency. Catfish marinating is generally geared toward minimizing freezer loss in individually quick frozen (IQF) processes, as well as protecting the product from oxidative rancidity during frozen storage. However, it may be important for catfish processors to take a closer look at each of the ingredients in marinade systems and how improvements can be made in yield and quality by managing each of those ingredients.

This research report highlights recent research findings from studies performed at Mississippi State University that investigated the functionality of different phosphate types for injected and tumbled catfish fillets. Catfish processors must be sure to comply with the maximum allowable concentration of phosphate in catfish fillets (9 CFR 424.21). Since the maximum allowable concentration is 0.5%, it is important for processors to select a phosphate mix that optimizes yields and operation costs. Processors can use similar ingredients in both fresh and frozen products for optimum quality and yield. Additionally, this report will help processors identify opportunities to manage other marinade components, marinade formulation, and mixing.

For most muscle-food-product formulations, water is the second most predominant ingredient. However, water is often the most overlooked ingredient in the formulation. Many factors, including hardness, pH, and temperature, can affect the functionality and final quality of the finished food product. The measurement of hardness, measured as calcium carbonate (Table 1), is likely the most important factor to monitor in source water for food processing. Increased levels of calcium, magnesium, iron, and other minerals contribute to water hardness and have a dramatic impact on the ability of many ingredients to go into solution; these minerals may even reduce functionality. Specifically, sodium or potassium phosphates that are used in brine and marinade systems are powerful antioxidants and water conditioners. When incorporated into solutions of hard water, the phosphates tie up the minerals in the water. The net result is a reduced ability to function in the food system, which means that the phos-

Table 1. Water hardness levels.

Hardness classification	$CaCO_3$ dissolved (ppm)
Soft	0 – 60
Moderately Hard	61 – 120
Hard	121 – 180
Very Hard	> 180

Kin is a research assistant, Schilling is an associate professor, Smith is an adjunct professor, Kim is a research associate II, Williams is an assistant extension/research professor, and Silva is a professor in the Department of Food Science, Nutrition, and Health Promotion. Smith also represents the John R. White Company. This research report was published by the MSU Office of Agricultural Communications, a unit of the Division of Agriculture Forestry and Veterinary Medicine.

MAFES

Mississippi Agricultural & Forestry Experiment Station • Melissa J. Mixon, Interim Director

Mississippi State University • Mark E. Keenum, President • Gregory A. Bohach, Vice President

Table 2. Properties affected by phosphates in meat systems.

Property	Mechanism
Antioxidant	Tying up metal ions prevents their participation in oxidation reactions.
Texture	Contributes to improved tenderness.
Protein extraction	Improves salt soluble protein extraction by adding ionic strength and helps to relax and open up muscle protein structures to accept more water.
pH	Alkaline phosphate products increase pH and improve water-holding capacity. Many of these phosphates have pH ranges from 7.5 to 12.0 in 1% solutions and increase pH values of the muscle food system.
Buffering capacity	Phosphates (especially monophosphates) add buffering capacity and therefore help the system resist changes when acids (or bases) are added to the system.
Oxidation prevention	Tying up water protects fats from oxidation under storage conditions in which muscle foods are not exposed to air.

phates will be unable to enhance yields and tenderness of the meat product. Water pH is another variable that should be controlled. Many food manufacturing plants that use municipal water supplies may see wide fluctuations in water analyses, especially pH, as municipalities manage water characteristics for broad-based criteria, not necessarily for the most effective pH and hardness for food processing. Temperature management of ingredient water is critical for optimal success in food processing. Cold water improves protein extraction efficiency, maintains cold fish temperature for microbial stability, and manages functional ingredient performance by delaying the hydrolysis of phosphates. Water contains organic matter, dissolved solids, and minerals that form scale on surfaces and in distribution pipes, fixtures, equipment, and injector needles. Films form on surfaces in contact with water and reduce the efficiency of cleaning and sanitizing agents. Scale, film, residues, and other deposits reduce efficiency, performance, and longevity of systems and equipment and may ultimately lead to harborage issues in which microorganisms are protected from sanitizers. Therefore, cold, softened water with stable pH values can play a critical role in processing efficiency, ingredient performance, and microbial control in meat products and within facilities.

Salt has been a part of food preservation since ancient times and was likely the first ingredient used to preserve food and extend its shelf life. There are five primary functions of salt in muscle-foods processing:

- Flavor enhancement
- Inhibition of bacterial growth
- Enhancement of salt-soluble protein extraction (bind, yield, texture)
- Increases in the ionic strength of muscle foods systems
- Increases in water-holding capacity

Salt crystals are isometric and cube-shaped but can be purchased from a variety of sources with varying physical forms. The primary manufacturing processes for salt include solar drying, pan evaporation, and mining from salt deposits or salt domes. The manufacturing process influences the crystal size, shape, and surface area. Proper selection of salt will maximize performance in many food-manufacturing processes. Many of the flaked and crystal-modified products have very large surface areas with considerable cavitation on the particles, which contributes to improved solubility in brine mixing systems, thus enhancing its ability to improve yields (Smith, 2007).

We have known for more than 50 years that phosphates increase the yields of muscle food products (Bendall, 1954). Sodium and potassium salts of phosphoric acid are the foundation for any non-meat ingredient formulation. Most ingredients directly manage added water in the formulation. However, phosphates manage the muscle food proteins and thus the water already inherent in the fish raw materials, plus additional formula water. Phosphates perform many functions and are possibly

Table 3. Properties of various phosphate components.

Phosphate component	Chain length (phosphorous units)	Primary functions
Monophosphate (Orthophosphate)	One	pH buffering
Diphosphate (Pyrophosphate)	Two	Binds magnesium in water Extracts muscle proteins
Tripolyphosphate	Three	Binds Calcium
Polyphosphate (Tetra- or Hexametaphosphate)	Six or more	Binds calcium Improves solubility of the phosphate

Table 4. Phosphate product designation and characteristics.				
Product name	**Component phosphates**	**pH in 1% solution**	**P_2O_5 content**	**Code**
Tripolyphosphate	Sodium tripolyphosphate	9.85 ± 0.25 %	57.25 ± 1.25 %	STPP
Agglomerated sodium phosphate	Sodium polyphosphate, sodium orthophosphate	11.50 ± 0.50 %	51.50 ± 2.00 %	ASPOP
Agglomerated sodium poly- and pyrophosphate	Sodium polyphosphate, sodium pyrophosphate	8.50 ± 0.30 %	56.00 ± 1.00 %	ASPPP
Agglomerated sodium polyphosphate	Sodium polyphosphate	9.00 ± 0.30 %	57.50 ± 1.00 %	ASP
Agglomerated potassium and sodium phosphate	Potassium polyphosphate, sodium polyphosphate	8.90 ± 0.20 %	50.00 ± 1.00 %	APSP

the most cost-effective ingredient available today (Brouillette, 2007). As seen in Table 2, proper inclusion of phosphates can have many positive effects on the muscle food system and final product.

Phosphates are typically manufactured by three primary drying methods: drum drying, spray drying, and agglomeration. Of these three methods, agglomerated phosphate products have the greatest solubility (Brouillette, 2007). Benefits of improved solubility include faster marinade and pickle make-up, less sensitivity to solubility in cold water, increased salt tolerance, and improved yields and performance in hard-water systems.

Food-grade phosphates are manufactured through the reaction of the raw phosphoric acid with either sodium or potassium hydroxide, yielding a salt of phosphoric acid. This process allows phosphate components to vary in size and chain length, and thus to vary in specific actions on the fish. A basic phosphate product, commonly known as tripoly phosphate, is a three-phosphate chain compound (Figure 1).

The other various chain length compounds of phosphates would be similar structures with specific numbers of phosphorous components designated by the "P" and a corresponding number of oxygen molecules designated by the "O." Therefore, a monophosphate is a one-phosphorous chain length product, di- or pyrophosphate has two phosphorous units, and so forth. Each chain length product has specific activities (Table 3). Phosphate products and their characteristics are shown in Table 4.

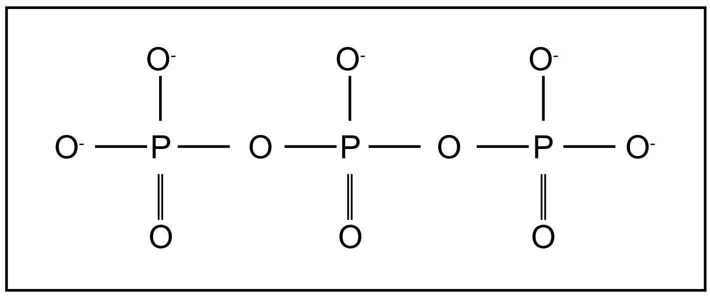

Figure 1. Representation of the structure of tripolyphosphate.

Highlights of Research Conducted at Mississippi State University

Catfish fillets were provided by a local catfish processor. For each treatment, 5 kg of fillets were either placed in a vacuum meat tumbler or injected with a multineedle injector and then marinated with a brine solution formulated for a 15% pick-up over green weight. The finished marinated product contained approximately 0.45% phosphates and 0.5% salt. Therefore, each solution included water, salt, and phosphate at 92.72%, 3.83%, and 3.45 %, respectively.

Example: 5 kg catfish fillets and 15% brine = 5 kg fish + 5kg fish x 0.15 = 5.75 kg

0.75 kg brine = (0.5 % salt x 5.75 kg = 0.02875 kg) + (0.45% phosphate x 5.75 kg = 0.025875 kg) + (0.75 kg -0.02875 - 0.025875 kg = 0.6954 kg water)

0.75 kg brine = 0.02875 kg salt, 0.025875 kg phosphate, and 0.6954 kg water

The fillets were either vacuum-tumbled (4°C, 20 mm Hg, 20 minutes, 18 rpm) or injected using a multineedle injector (2 mm needles, 21 cycles per minute, 0.28 Mpa pressure). The following phosphate products were used as treatment variables: (1) sodium tripolyphosphate (STPP), (2) agglomerated blend of sodium phosphates (ASPOP), (3) agglomerated blend of poly- and pyrophosphates (ASPPP), (4) agglomerated blend of polyphosphates (ASP), and (5) agglomerated blend of potassium and sodium polyphosphates (APSP). The marinated fillets were placed on polyethylene trays, overwrapped with stretch film, and stored at 4°C throughout the shelf life of the product. The following attributes were evaluated to determine yields, quality, and shelf life: pH, tenderness, pick-up percentages, protein exudates, cooking loss, and yield based on green weight.

Research Findings at Mississippi State University

ASPOP had the least protein exudate in vacuum-tumbled catfish fillets when compared with other phosphates, with the exception of ASP (Table 5). This is likely because ASPOP contains orthophosphate but no pyrophosphate or tripolyphosphate, which are known to be the most optimal forms of phosphate for extracting protein (Xiong, 1998). Too much protein exudate on the surface of marinated catfish fillets is undesirable for surface appearance. In addition, all phosphates decreased cooking loss when compared with the nonmarinated control, except for STPP (Table 5). This is likely because STPP is less soluble than the other phosphates and does not contain the orthophosphates or polyphosphates that are present in some of the other phosphate samples. In addition, ASPOP and APSP resulted in more tender (total energy) fillets than the STPP treatment, but no other differences existed among phosphate treatments (Table 5). All agglomerated phosphates improved the quality of catfish fillets when compared with STPP. Though not statistically different from some other treatments, ASPOP may be the best choice for vacuum-tumbled catfish fillets because it had high yields that are similar to those of ASPPP and APSP, and it had the lowest numerical amount of protein exudates. These characteristics are both important in vacuum-tumbled catfish fillets

For catfish fillets marinated through multineedle injection, ASPOP optimized pick-up and yield based on green weight (Table 6). In addition, all other agglomerated phosphates and STPP improved yield based on green weight and quality (shear force and total energy) when compared with the nonmarinated controls (Table 6). ASPOP was the most effective phosphate at increasing pick-up and yields (with the exception of ASP) due to the pH effect and increased ionic strength that would cause more water to be trapped within the food system. Major quality differences may not have occurred between STPP and agglomerated phosphates (other than ASPOP) in the injected catfish fillets because injection relies solely on pH and ionic strength for marinade pickup. Tumbling also relies on mechanical action and the presence of various phosphate chain lengths and solubility to affect yields. Additional research is currently under way at MSU to determine optimal strategies for shelf life for a distribution system for fresh fish.

Table 5. Yields and quality attributes of vacuum-tumbled catfish fillets enhanced with various phosphate treatments.[1–3]

Treatment[4]	Pick-up	Exudate	Cook loss	Yield based on green weight	pH	Shear force	Total energy
	%	%	%	%			
Control	NA	NA	17.8[a]	82.2[c]	6.56[bc]	17.7[a]	0.24[a]
STPP	9.1	3.8[a]	16.9[ab]	90.1[b]	6.50[c]	13.2[b]	0.16[b]
ASPOP	8.6	3.3[b]	15.4[bc]	92.2[ab]	6.68[a]	11.6[b]	0.14[c]
ASPPP	9.0	3.8[a]	15.0[c]	92.7[ab]	6.63[ab]	12.4[b]	0.15[bc]
ASP	9.1	3.6[ab]	16.1[bc]	93.0[a]	6.52[c]	12.1[b]	0.15[bc]
APSP	8.6	3.9[a]	15.2[bc]	93.4[a]	6.55[c]	11.5[b]	0.14[c]

[1]Yields = pick-up, exudate, cook loss, and yield based on green weight. Quality attributes = pH and tenderness (shear force and total energy).
[2]abc = Means with the same letter within each column are not significantly different ($P<0.05$)
[3]NA = Not applicable because the control treatment was not marinated
[4]Control = no phosphate and salt; STPP = sodium tripolyphosphate; ASPOP = agglomerated blend of sodium phosphates; ASPPP = agglomerated blend of poly- and pyrophosphates; ASP = agglomerated blend of polyphosphates; APSP = agglomerated blend of potassium and sodium polyphosphates.

Table 6. Yields and quality attributes of multineedle-injected catfish fillets enhanced with various phosphate treatments.[1–3]

Treatment[4]	Pick-up	Cook loss	Yield based on green weight	pH	Shear force	Total energy
	%	%	%			
Control	NA[1]	15.7[ab]	84.3[c]	6.40[b]	17.2[a]	0.24[a]
STPP	12.5[b]	16.6[ab]	95.9[b]	6.48[b]	14.3[b]	0.17[b]
ASPOP	15.2[a]	14.3[b]	100.9[a]	6.99[a]	13.7[b]	0.15[b]
ASPPP	11.9[b]	17.4[a]	94.5[b]	6.35[b]	14.2[b]	0.16[b]
ASP	13.3[ab]	16.5[ab]	96.6[b]	6.42[b]	15.0[b]	0.16[b]
APSP	13.2[b]	17.2[ab]	96.0[b]	6.44[b]	13.9[b]	0.16[b]

[1]Yields = pick-up, exudate, cook loss, and yield based on green weight. Quality attributes = pH and tenderness (shear force and total energy).
[2]abc = Means with the same letter within each column are not significantly different ($P<0.05$)
[3]NA = Not applicable because the control treatment was not marinated
[4]Control = no phosphate and salt; STPP = sodium tripolyphosphate; ASPOP = agglomerated blend of sodium phosphates; ASPPP = agglomerated blend of poly- and pyrophosphates; ASP = agglomerated blend of polyphosphates; APSP = agglomerated blend of potassium and sodium polyphosphates.

Summary and Conclusions

- Use of agglomerated phosphates optimized yields in vacuum-tumbled catfish fillets when compared with STPP because of the presence of variable phosphate chain lengths and enhanced solubility.

- Use of ASPOP optimized yields based on green weight and quality of catfish fillets marinated through multineedle injection because of the treatment's high pH and ionic strength. This finding demonstrates that when all quality characteristics are evaluated, a highly soluble phosphate blend with a high pH is optimal for injector systems. Such a phosphate would be characterized as a blend of sodium polyphosphates and orthophosphates.

References

Bendell, J.R. 1954. The swelling effect of polyphosphates on lean meat. J. Sci. Food and Agric. 5:468.

Brouillette, M. 2007. Salt and phosphate as functional ingredients for meat, poultry, and seafood. Muscle Foods and Functional Ingredients Workshop. Proceedings. Mississippi State Univ. Starkville, Mississippi. Aug 29-30.

Smith, B.S. 2007. Salt and carbohydrate roles in meat processing. Marination 101. March 28-30, 2007. Mississippi State University, Starkville, Mississippi.

USDA-FSIS. 2007. Code of Federal Regulations. 9CFR424.21.

Xiong, Y.L. 1998. Phosphate-mediated water uptake, swelling, and functionality of the myofibrillar architecture. *In* Quality Attribute of Muscle Foods. Xiong, X.L., Ho, C.-T., and Shahidi, F. eds. Kluwer Academic, New York. p. 319.

Acknowledgements

Superior Fish Products of Macon, Mississippi, allowed us to use their processing equipment. This report was approved for publication as MAFES Research Report 24:7 of the Mississippi Agricultural and Forestry Experiment Station under the following projects: MIS-371270 and MIS-501080.

MISSISSIPPI STATE UNIVERSITY

Printed on Recycled Paper

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the Mississippi Agricultural and Forestry Experiment Station and does not imply its approval to the exclusion of other products that also may be suitable.