COMPARISON OF THE PUNCH, TORSION, CONSTANT RATE DEFORMATION AND DYNAMIC FORCE DEFORMATION TESTS TO DETERMINE RHEOLOGICAL PROPERTIES OF SURIMI GELS.

FINAL REPORT

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Report on Comparison of the Punch, Torsion, Constant Rate Deformation and Dynamic Force Deformation Tests to Determine Rheological Properties of Surimi Gels.

I. Executive Summary

Eight rheological tests were performed on 25 surimi sample preparations under two different test conditions.

Constant rate deformation (compression) value of test samples ranged from 13,375 to 750 g. Adding 10% of ultra filtration concentrate (UFC) to 90% surimi uniformly increased stiffness and punch force. Expressible moisture level was inversely correlated with depression value. Salt at 1 to 3% increased gel strength and fold test score.

No one test measured all the desired attributes of surimi.

II. Introduction

Functional attribute of protein is often measured with cooked gel and the test is performed after the surimi is made.

A non-destructive test that would measure rheological properties of surimi, simply and conveniently, during its manufacture would allow considerable process flexibility. A probe that measures dynamic force deformation would accomplish this.

This report describes our findings on commonly employed rheological tests that were performed on surimi and surimi derivatives and their relationship to the constant rate deformation (compression) value.

III. Purpose

Battery of tests are employed to test rheological property of surimi. It ranges from the simple fold test to the compression test that measure the force required to induce gel failure.

It is desirable to select a test or a group of tests that closely identify the functional properties needed to make the best analog products.

We attempted to accomplish this by testing surimi of varying composition, under different test conditions, with conventional and unconventional methods.

IV. Approach

A. Sample preparation

Alaska pollock (*Theragra chalcogramma*), two to four days out of water, were filleted with a Baader 182, minced with a Baader 694, washed by a batch system and the excess wash water removed by a series of screens. The minced fish was refined and dehydrated using screw presses. The washed, refined, dehydrated fish flesh was finally mixed with 4% sucrose, 4% sorbitol, and 0.8% sodium tripolyphosphate and frozen. This is designated as 100% surimi or simply surimi. The process-water streams from the last wash screen and the dehydrator screens were combined and centrifuged with a decanter centrifuge (Sharples) to remove suspended particulates. The soluble protein fractions were concentrated on 36-2.25 pilot scale ultrafiltration unit (DDS). For this study the protein preparation was concentrated to 20% solids level. The yield from surimi processing is significantly improved (from 16-18% up to 18-23%) if the proteinaceous material passing through the refiners is refined a second time. Surimi-process-water ultra filtrate concentrate blocks were made by mixing 90 kg of this second grade surimi with 10 kg protein concentrate, adding sucrose, sorbitol and sodium tripolyphosphate as cryoprotectants, and freezing at -40°C as 10 kg blocks in a plate freezer. This is designated as 90% surimi or enriched surimi.

B. Preparation of Gels

Frozen surimi or enriched surimi were tempered for 16-18 hrs at 4°C and chopped in a Stephan Vacuum Chopper/Mixer (Model UM12) with the knife blade attachment at 1250 RPM until the temperature reached 0°C. Chopping was continued at 750 RPM (under a vacuum of 21 mm Hg) until the temperature of the batter reached 10°C (6-8 min). After stuffing, samples were cooked by immersing the stuffed casings in a 90°C water bath for 40 min, then cooled in ice water for 30 min and held overnight at 4°C. Some samples were "pre-set" by immersing in 40°C water bath for 20 min before proceeding to 90°C cook for 20 min.

In preparation of gels where salt was added, samples were tempered for 16-18 hours at 4°C. The samples were chopped in a Hobart Silent Cutter until the temperature reached 0°C, then fine salt was added to final concentration of 0, 1 and 3%, and chopping was continued until the temperature of the batter reached 10°C (5-7 min).

C. Functionality Tests

Punch Torsion tests were performed by the methods described in detail elsewhere (Reppond et al, 1987). Gel strength of the samples was determined using a Model 302-B Food checker rheometer equipped with a 5 mm spherical probe (Sun Kagaku Co., Ltd).

Constant rate deformation or the compression values was determined according to the method described by Lee et al (1987).

Expressible moisture was measured using an Instron Model 1000. A slice of the gel, 3.0 cm thick, was compressed between four sheets of Whatman No. 1 filter paper (2 on each side) to 90% deformation at a deformation rate of 50 mm/min. The percent expressible moisture was calculated as the weight of expressed fluid divided by the weight of the gel.

Flexibility of the samples was determined using the folding test.

Fold Test Score:
- 5= No cracking upon folding in quadrants.
- 4= Cracks upon folding in quadrants.
- 3= No cracking upon folding in half.
- 2= Cracks upon folding in half.
- 1= Breaks when handled.

A score of 5 indicates an extremely elastic gel while a score of 1 indicates a complete loss of elasticity.

V. Findings

Table 1 is a compilation of data obtained from 25 surimi sample preparations. Standard deviation from 6 to 10 replicate samples are also given in parentheses. Data are listed in the order of descending compression test score of 13,375 to 750 g. The No. 1 ranking sample was also identified as the enriched surimi (90% surimi plus 10% ultra filtration concentrate), with no salt added and the gel was set by immersion at 40°C for 20 min followed by 90°C for 20 min. The 25th sample was 100% ultra filtration concentrate (UFC) with 3% salt and the gel cooked at 90°C for 40 min.

It is clear, form Table 1, that addition of 10% UFC concentrate has the overall effect of increasing the force required to induce gel failure, or the compression score. The enriched surimi occupied the first 10 positions with one exception (No. 8 sample).

The effects of 40°C presetting and salt are not as clear. The enriched surimi, with no salt, and cooked at 40 and 90°C ranked No. 1 but its 90°C cooked counter part ranked No. 7. In between these samples were one no salt, two 3% salt, and three 1% salt added enriched surimi samples. The effect of salt on gel strength of surimi is detailed elsewhere (French, 1990).

Salt definitely had an effect on fold test score with no salt sample scoring no higher than 1. Gel strength value closely paralleled the fold test score. The gel strength of around 500 g. cm revealed 5 in fold test and the gel strength of 1 in fold test was around 200 g. cm.

Depression, on the other hand appeared to be the function of moisture with more moist product showing the least depression score.

Stiffness and punch force score tended to follow that of the compression. Thus, the constant rate deformation (compression) the punch and the stiffness measurements might have been measuring a portion or the whole of the same attribute.

VI. Evaluation

Our aims were to examine the sensitivity and variability of punch, torsion and dynamic and constant rate deformation measurement data and to establish their relationship in expressing rheological property of surimi.

By examining surimi and surimi enriched with UFC by torsion, punch and compression measurement, we have accumulated data on surimi functionality sufficient to develop correlation among all commonly employed tests. Although this information is useful in identifying the most relevant yet simple test that can be routinely employed by the surimi industry, we failed to develope the dynamic deformation measuring system.

Our initial idea was to develop a simple and non-destructive test that could measure the dynamic force needed to induce reversible deformation on elastic surface. The system, however, was too complicated to design and we were unable to fabricate such a machine in the time frame allotted. We have not abandoned this concept, however, and work is in progress to develop machinery that can simply and reliably measure the rheological properties of surimi.

Our findings are the next best thing to help stream-line the surimi testing protocol.

Influence on test results by the moisture level, salt, protein content, and the nature of the protein were examined under two test conditions (90°C or 40/90°C).

Adding back soluble proteins that were washed away during surimi processing had improved the compression score of the gel indicating some functionally unique and/or valuable proteins might have been lost under present surimi processing regime.

If our finding will improve the overall yield of the surimi industry by reducing the washing process, the added protein recovered will supply more surimi to the consumer without increased harvest. At least 10% increase in yield is possible by adding back the protein, without loss of any functional attribute of surimi.

VII. Conclusion

Constant rate deformation (compression) test best measured the overall rheological properties of fish protein gel. Stiffness, however, was more closely related to compression value.

Gel strength can be measured simply by the fold test. Depression value was inversely correlated with expressible moisture score.

Statistical analysis of data is needed to further confirm above observation.

VIII. References

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TABLE 1.
RELATIONSHIP AMONG RHEOLOGICAL MEASURMENT OF SURIMI
– RANKED BY CONSTANT RATE DEFORMATION (COMPRESSION) –

ATTRIBUTE / RANK	1	2	3	4	5	6	7	8	9	10	11	11	13
SAMPLE													
COMPOSITION[1]	80/10	90/10	90/10	90/10	90/10	90/10	90/10	100	90/10	90/10	100	100	100
NaCl (%)	0	3+[3]	3+	1	1	1	0	2	1	2	3+	3+	2
TEST (40/90 or 90)[2]	40/90	90	90	40/90	40/90	90	90	90	90	90	90	40/90	40/90
PUNCH													
FORCE (g)	410	585	569	512	492	498	378	533	484	460	525	523	391
	(17)	(33)	(17)	(33)	(40)	(46)	(13)	(19)	(313)	(27)	(41)	(52)	(35)
DEPRESSION (mm)	5.80	11.62	9.68	11.50	10.80	10.33	6.22	10.95	9.90	10.76	14.28	12.15	12.94
	(0.82)	(0.49)	(1.67)	(1.58)	(1.36)	(1.39)	(1.58)	(1.86)	(1.55)	(1.50)	(0.18)	(1.14)	(1.43)
GEL STRENGTH (g. cm)	238.22	679.24	550.30	584.94	533.83	513.34	234.70	581.45	479.02	493.36	749.83	634.81	504.70
	(38.43)	(37.09)	(96.96)	(50.00)	(104.76)	(83.90)	(58.05)	(87.07)	(78.29)	(56.03)	(63.02)	(82.28)	(58.62)
STIFFNESS (g/cm)	71.82	50.46	60.15	45.54	46.09	48.99	63.88	49.15	49.81	43.44	36.77	43.26	30.80
	(8.52)	(4.34)	(10.63)	(9.35)	(5.80)	(7.34)	(15.35)	(9.60)	(8.11)	(7.05)	(2.78)	(5.83)	(5.17)
COMPRESSION (FORCE AT FAILURE IN g)	13,375	13,250	12,344	10,281	9,969	9,500	9,188	8,833	8,667	8,400	8,188	8,188	7,781
	(2,773)	(826)	(1,875)	(1,092)	(1,445)	(1,354)	1,853	(629)	(890)	(479)	(599)	(315)	(926)
COMPRESSION (%)	74	65	65	65	65	65	65	65	65	65	65	65	65
	(1)	(?)[4]	(?)	(?)	(5)	(?)	(5)	(?)	(?)	(?)	(?)	(?)	(?)
FOLD	1	5	5	5	5	5	1	5	5	5	5	5	5
EXPRESSIBLE MOISTURE (%)	1.29	0.38	0.31	0.45	0.25	0.18	1.20	0.47	0.32	0.26	0.28	0.22	0.29
	(0.48)	(0.05)	(0.07)	(0.25)	(0.03)	(0.20)	(0.17)	(0.12)	(0.08)	(0.01)	(0.01)	(0.01)	(0.03)

(1) Composition (surimi / ultra filtration concentrate) in %. Standard deviations in ( ).
(2) Gel cooking regimes of 40°C for 20 min followed by 90°C for 20 min (40/90), cooking at 90°C for 40 min (90).
(3) 3+ indicates 3% salt plus 3% starch.
(4) Standard deviation not calculated due to lack of clear point of failure.

TABLE 1. (CONTINUED)
RELATIONSHIP AMONG RHEOLOGICAL MEASURMENT OF SURIMI
– RANKED BY CONSTANT RATE DEFORMATION (COMPRESSION) –

ATTRIBUTE / RANK	14	15	16	16	18	19	20	21	22	23	24	25
SAMPLE												
COMPOSITION[1]	100	100	100	100	100	100	0/100	0/100	0/100	0/100	0/100	0/100
NaCl (%)	0	1	2	2	2	0	3+	3+	0	0	3	0
TEST (40/90 or 90)[2]	90	40/90	90	40/90	90	40/90	90	40/90	40/90	90	40/90	90
PUNCH												
FORCE (g)	302	495	435	460	436	295	-	-	-	-	-	-
	(5)	(23)	(23)	(40)	(25)	(-)						
DEPRESSION (mm)	8.08	12.63	11.63	13.92	10.93	8.28	-	-	-	-	-	-
	(0.22)	(1.67)	(1.22)	(1.99)	(0.32)	(-)						
GEL STRENGTH (g. cm)	243.86	613.36	504.31	643.40	477.10	244.86	-	-	-	-	-	-
	(10.35)	(96.71)	(43.72)	(123.15)	(40.30)	(-)						
STIFFNESS (g/cm)	37.40	38.92	37.89	33.51	39.92	37.40	-	-	-	-	-	-
	(?)	(5.45)	(6.12)	(4.65)	(1.47)	(-)						
COMPRESSION (FORCE AT FAILURE IN g)	7,688	7,250	6,063	6,063	5,938	5,063	1,125	1,063	1,000	938	875	750
	(-)	(1,275)	(916)	(1,087)	(944)	(1,962)	(177)	(442)	(-)	(88)	(0)	(0)
COMPRESSION (%)	69	65	65	65	65	55	65	65	65	65	65	65
	(11)	(?)	(0)	(?)	(?)	(11)	(?)	(?)	(?)	(?)	(?)	(?)
FOLD	1	5	4	5	5	1	5	5	0	0	0	0
EXPRESSIBLE MOISTURE (%)	1.35	-0.02	0.28	0.37	0.32	0.82	12.02	11.34	16.46	12.62	18.40	20.74
	(0.91)	(0.52)	(0.32)	(0.10)	(0.03)	(0.22)	(0.51)	(0.99)	(?)	(0.75)	(0.95)	(1.52)

(1) Composition (surimi / ultra filtration concentrate) in %. Standard deviations in ( ).
(2) Gel cooking regimes of 40°C for 20 min followed by 90°C for 20 min (40/90), cooking at 90°C for 40 min (90).
(3) 3+ indicates 3% salt plus 3% starch.
(4) Standard deviation not calculated due to lack of clear point of failure.