

# Improvement of Surimi Gel from Frozen-Stored Silver Carp

## Supplementary Materials

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**Table S1.** Effect of MMF on the gel quality of FSC with various MMF dosages and without MMF (control).

	Control	0.1 wt% MMF	0.5 wt% MMF	1.0 wt% MMF
Breaking Force(N)	1.40 ± 0.13 <sup>a</sup>	1.60 ± 0.18 <sup>ab</sup>	1.97 ± 0.26 <sup>bc</sup>	2.38 ± 0.30 <sup>c</sup>
Deformation(m)	0.0075 ± 0.0007 <sup>a</sup>	0.0092 ± 0.0011 <sup>a</sup>	0.0091 ± 0.0010 <sup>a</sup>	0.0087 ± 0.0012 <sup>a</sup>
Gel Strength (N-m)	0.0105 ± 0.0003 <sup>a</sup>	0.0148 ± 0.0027 <sup>ab</sup>	0.0182 ± 0.0044 <sup>b</sup>	0.0209 ± 0.0049 <sup>b</sup>
Hardness(N)	42.0 ± 6.5 <sup>ab</sup>	34.5 ± 3.5 <sup>a</sup>	54.5 ± 9.8 <sup>b</sup>	48.9 ± 10.0 <sup>b</sup>
Cohesiveness	0.29 ± 0.02 <sup>a</sup>	0.24 ± 0.03 <sup>a</sup>	0.29 ± 0.02 <sup>a</sup>	0.28 ± 0.04 <sup>a</sup>
Springiness	0.78 ± 0.04 <sup>a</sup>	0.70 ± 0.10 <sup>a</sup>	0.74 ± 0.06 <sup>a</sup>	0.67 ± 0.05 <sup>a</sup>
Chewiness(N)	9.58 ± 1.96 <sup>ab</sup>	6.02 ± 1.72 <sup>a</sup>	11.9 ± 3.72 <sup>b</sup>	9.14 ± 2.98 <sup>a</sup>
Resilience	0.087 ± 0.003 <sup>a</sup>	0.073 ± 0.005 <sup>a</sup>	0.085 ± 0.014 <sup>a</sup>	0.079 ± 0.010 <sup>a</sup>

Each value is expressed as means ± S.D. ( $n=5$ ); Different lowercase letters in a row indicate significant differences ( $p < 0.05$ ) between treatments.

**Table S2.** Effect of TG on the gel quality of FSC with various TG dosages and without TG (control).

	Control	0.1 wt% TG	0.5 wt% TG	1.0 wt% TG
Breaking Force(N)	1.03 ± 0.11 <sup>a</sup>	1.89 ± 0.05 <sup>b</sup>	2.36 ± 0.16 <sup>c</sup>	3.49 ± 0.24 <sup>d</sup>
Deformation(m)	0.0098 ± 0.0006 <sup>a</sup>	0.0107 ± 0.0010 <sup>a</sup>	0.0107 ± 0.0007 <sup>a</sup>	0.0110 ± 0.0004 <sup>a</sup>
Gel Strength (N-m)	0.0101 ± 0.0010 <sup>a</sup>	0.0202 ± 0.0022 <sup>b</sup>	0.0254 ± 0.0034 <sup>b</sup>	0.0383 ± 0.0033 <sup>c</sup>
Hardness(N)	22.8 ± 3.5 <sup>a</sup>	42.6 ± 2.3 <sup>b</sup>	37.1 ± 2.8 <sup>b</sup>	69.8 ± 2.8 <sup>c</sup>
Cohesiveness	0.159 ± 0.017 <sup>a</sup>	0.224 ± 0.023 <sup>b</sup>	0.251 ± 0.019 <sup>b</sup>	0.228 ± 0.025 <sup>b</sup>
Springiness	0.777 ± 0.059 <sup>a</sup>	0.779 ± 0.173 <sup>a</sup>	0.783 ± 0.014 <sup>a</sup>	0.789 ± 0.177 <sup>a</sup>
Chewiness(N)	2.12 ± 0.54 <sup>a</sup>	10.1 ± 2.6 <sup>b</sup>	7.31 ± 1.06 <sup>b</sup>	16.4 ± 1.9 <sup>c</sup>
Resilience	0.050 ± 0.002 <sup>a</sup>	0.048 ± 0.48 <sup>a</sup>	0.082 ± 0.006 <sup>a</sup>	0.042 ± 0.43 <sup>a</sup>

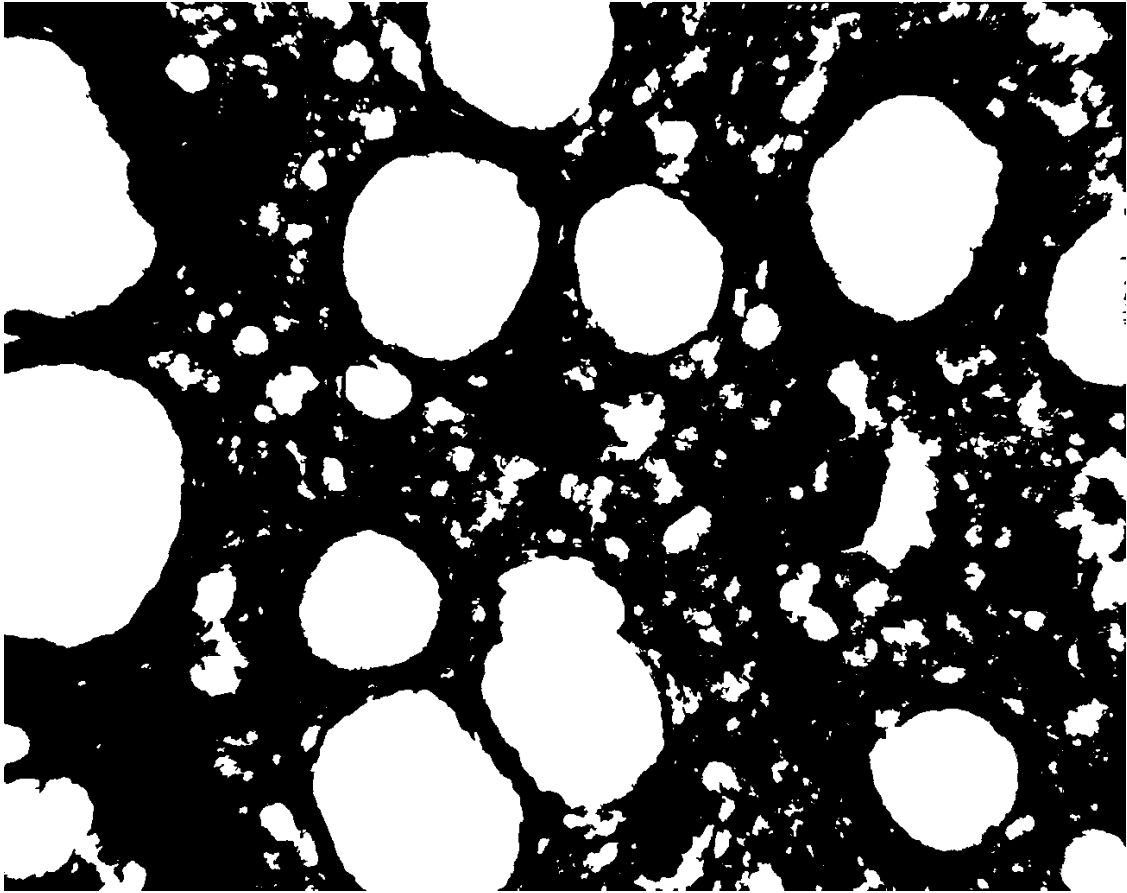
Each value is expressed as means ± S.D. ( $n=5$ ); Different lowercase letters in a row indicate significant differences ( $p < 0.05$ ) between treatments.

**Table S3.** Effect of MMF & TG on the gel quality of FSC with the same TG dosage (0.5 wt%) and various MMF dosages and without MMF (control).

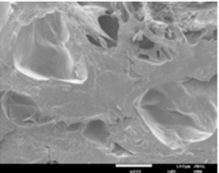
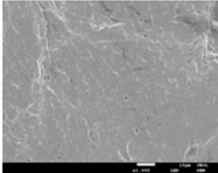
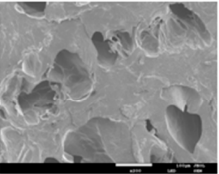
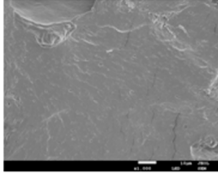
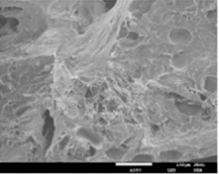
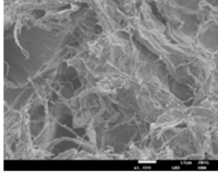
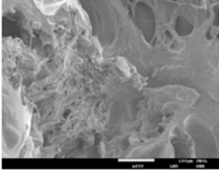
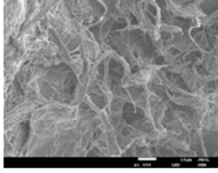
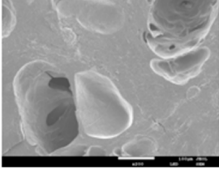
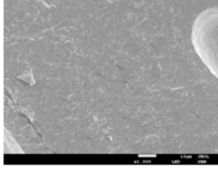
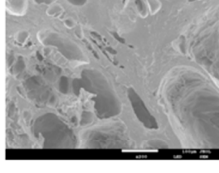
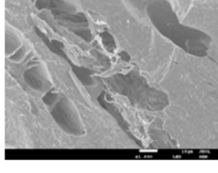
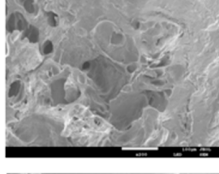
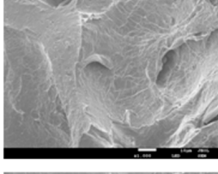
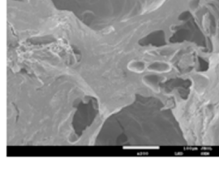
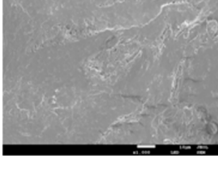
	0.5 wt% TG	0.5 wt% TG 0.1 wt% MMF	0.5 wt% TG 0.5 wt% MMF	0.5 wt% TG 1.0 wt% MMF
Breaking Force(N)	2.36 ± 0.16 <sup>a</sup>	3.44 ± 0.20 <sup>b</sup>	3.88 ± 0.24 <sup>c</sup>	4.21 ± 0.14 <sup>c</sup>
Deformation(m)	0.0107 ± 0.0007 <sup>a</sup>	0.0118 ± 0.0005 <sup>a</sup>	0.0114 ± 0.0006 <sup>a</sup>	0.0118 ± 0.0006 <sup>a</sup>
Gel Strength(N-m)	0.0254 ± 0.0034 <sup>a</sup>	0.0406 ± 0.0038 <sup>b</sup>	0.0443 ± 0.0045 <sup>b</sup>	0.0498 ± 0.0037 <sup>c</sup>
Hardness(N)	37.1 ± 2.8 <sup>a</sup>	71.4 ± 4.7 <sup>b</sup>	81.7 ± 6.0 <sup>c</sup>	77.6 ± 3.2 <sup>bc</sup>
Cohesiveness	0.251 ± 0.019 <sup>a</sup>	0.228 ± 0.039 <sup>a</sup>	0.272 ± 0.016 <sup>a</sup>	0.262 ± 0.018 <sup>a</sup>
Springiness	0.783 ± 0.014 <sup>a</sup>	0.826 ± 0.142 <sup>a</sup>	0.870 ± 0.017 <sup>a</sup>	0.851 ± 0.014 <sup>a</sup>
Chewiness(N)	7.31 ± 1.06 <sup>a</sup>	18.1 ± 2.7 <sup>b</sup>	19.4 ± 2.27 <sup>b</sup>	17.4 ± 1.74 <sup>b</sup>
Resilience	0.082 ± 0.006 <sup>a</sup>	0.093 ± 0.325 <sup>a</sup>	0.101 ± 0.004 <sup>a</sup>	0.097 ± 0.002 <sup>a</sup>

Each value is expressed as means ± S.D. ( $n=5$ ); Different lowercase letters in a row indicate significant differences ( $p < 0.05$ ) between treatments.

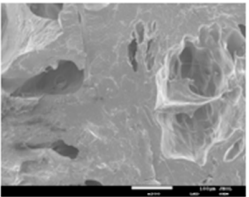
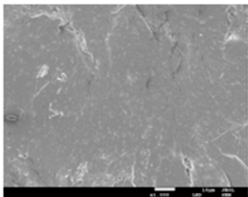
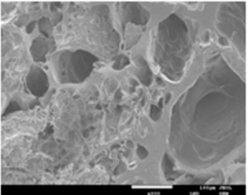
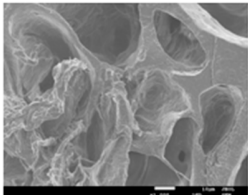
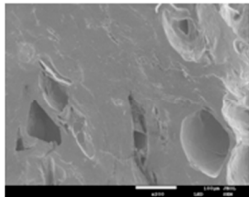
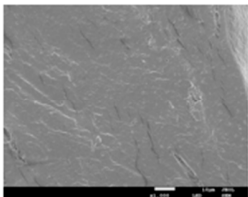
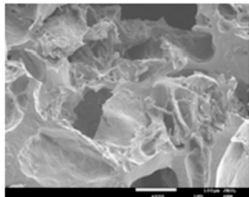
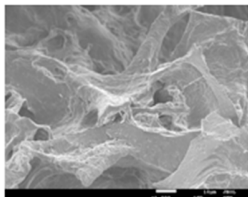
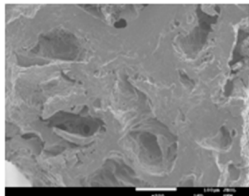
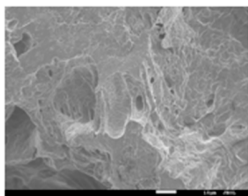
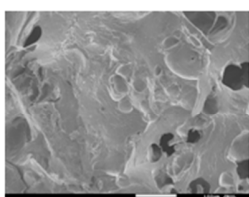
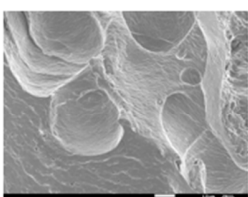
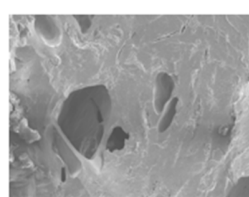
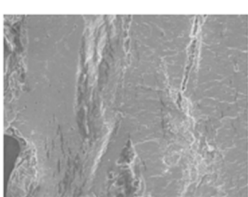
**Figure S1.** Example of binary-processed microscopic image of 0.5 wt% TG sample.



**Figure S2.** SEM images for BBD treatments of FSC surimi

Observation	MMF wt%	TG wt%	CLG wt%	200×	1000×
1	0.1	0.1	3		
2	1	0.1	3		
3	0.1	1	3		
4	1	1	3		
5	0.1	0.5	1		
6	1	0.5	1		
7	0.1	0.5	5		
8	1	0.5	5		

**Figure S2.** SEM images for BBD treatments of FSC surimi Continue

Observation	MMF wt%	TG wt%	CLG wt%	200×	1000×
9	0.5	0.1	1		
10	0.5	1	1		
11	0.5	0.1	5		
12	0.5	1	5		
13	0.5	0.5	3		
14	0.5	0.5	3		
15	0.5	0.5	3		

**Figure S3. RStudio ANOVA Results**

(a) Gel Strength:

```
Residuals:
    Min       1Q   Median       3Q      Max
-0.0215044 -0.0086878 -0.0001213  0.0078207  0.0270529

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.225838   0.050200   4.499 4.09e-05 ***
MMF          -0.213515   0.076022  -2.809  0.00708 **
TG           -0.080941   0.076022  -1.065  0.29212
CLG          -0.065695   0.024338  -2.699  0.00945 **
I(MMF^2)      0.173838   0.067540   2.574  0.01307 *
I(TG^2)       0.092279   0.067540   1.366  0.17796
I(CLG^2)      0.010096   0.003943   2.560  0.01353 *
MMF:TG        0.019723   0.014962   1.318  0.19344
MMF:CLG       0.006494   0.003377   1.923  0.06017 .
TG:CLG        0.003255   0.003377   0.964  0.33973
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.01219 on 50 degrees of freedom
Multiple R-squared:  0.6749,    Adjusted R-squared:  0.6164
F-statistic: 11.53 on 9 and 50 DF,  p-value: 1.542e-09
```

(b) Hardness:

```
Residuals:
    Min       1Q   Median       3Q      Max
-57.860  -9.581  -0.088   13.269   46.169

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  411.964    95.504   4.314 7.56e-05 ***
MMF          -252.248   144.629  -1.744  0.087287 .
TG           59.735    144.629   0.413  0.681355
CLG          -116.191    46.302  -2.509  0.015378 *
I(MMF^2)     251.432    128.493   1.957  0.055969 .
I(TG^2)       57.480    128.493   0.447  0.656563
I(CLG^2)      18.721     7.502   2.496  0.015922 *
MMF:TG       -117.828    28.464  -4.140  0.000134 ***
MMF:CLG       15.170     6.424   2.361  0.022142 *
TG:CLG        2.277     6.424   0.354  0.724467
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 23.2 on 50 degrees of freedom
Multiple R-squared:  0.7402,    Adjusted R-squared:  0.6934
F-statistic: 15.83 on 9 and 50 DF,  p-value: 7.698e-12
```

**Figure S3. RStudio ANOVA Results Continue.**

**(c) Springiness**

```

Residuals:
    Min       1Q   Median       3Q      Max
-0.061539 -0.012385  0.003396  0.013473  0.065606

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.7245822  0.1006060   7.202  2.9e-09 ***
MMF           0.0185799  0.1523559   0.122  0.90343
TG            0.4157687  0.1523559   2.729  0.00875 **
CLG           0.0561464  0.0487758   1.151  0.25516
I(MMF^2)     -0.0636731  0.1353571  -0.470  0.64011
I(TG^2)      -0.3274684  0.1353571  -2.419  0.01923 *
I(CLG^2)     -0.0088390  0.0079027  -1.118  0.26871
MMF:TG        0.0627145  0.0299849   2.092  0.04158 *
MMF:CLG      -0.0008403  0.0067674  -0.124  0.90168
TG:CLG        0.0040117  0.0067674   0.593  0.55599
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.02444 on 50 degrees of freedom
Multiple R-squared:  0.7548,    Adjusted R-squared:  0.7107
F-statistic: 17.1 on 9 and 50 DF,  p-value: 1.934e-12

```

**(d) Cohesiveness**

```

Residuals:
    Min       1Q   Median       3Q      Max
-0.157625 -0.032700  0.008351  0.048317  0.112687

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.178846  0.284084   4.150 0.000129 ***
MMF          -0.398681  0.430212  -0.927 0.358529
TG           -0.660390  0.430212  -1.535 0.131080
CLG          -0.285507  0.137730  -2.073 0.043350 *
I(MMF^2)      0.342797  0.382212   0.897 0.374082
I(TG^2)       0.442016  0.382212   1.156 0.252985
I(CLG^2)      0.044977  0.022315   2.016 0.049238 *
MMF:TG        0.041702  0.084669   0.493 0.624503
MMF:CLG      -0.003409  0.019109  -0.178 0.859119
TG:CLG        0.019134  0.019109   1.001 0.321495
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.069 on 50 degrees of freedom
Multiple R-squared:  0.5123,    Adjusted R-squared:  0.4245
F-statistic: 5.835 on 9 and 50 DF,  p-value: 1.593e-05

```

**(d) Resilience**

```

Residuals:
    Min       1Q   Median       3Q      Max
-0.135138 -0.014345  0.003236  0.016389  0.068699

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.339136  0.148523   2.283 0.02669 *
MMF           0.193229  0.224920   0.859 0.39439
TG            0.149941  0.224920   0.667 0.50807
CLG          -0.045021  0.072007  -0.625 0.53466
I(MMF^2)     -0.070236  0.199825  -0.351 0.72670
I(TG^2)      -0.089805  0.199825  -0.449 0.65507
I(CLG^2)      0.010711  0.011667   0.918 0.36299
MMF:TG       -0.032543  0.044266  -0.735 0.46567
MMF:CLG      -0.028397  0.009991  -2.842 0.00647 **
TG:CLG        0.005263  0.009991   0.527 0.60065
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03608 on 50 degrees of freedom
Multiple R-squared:  0.5652,    Adjusted R-squared:  0.4869
F-statistic:  7.22 on 9 and 50 DF,  p-value: 1.242e-06

```



**Figure S4.** Frozen silver carp fillet with skin and bone (around 18 cm length and 6 cm width).



**Figure S5.** Example of our samples (right) and the plastic casing (left).

