Short communication

Inhibition of Shrinkage of Sea Cucumber *Stichopus japonicus* during Canning Using Sodium Phytate and Sodium Tripolyphosphate

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Shrinkage decreases the commercial value of the canned sea cucumber, and therefore size preservation during processing is the main objective of manufacturers. In this study, the efficacy of sodium phytate (SP) and sodium tripolyphosphate (ST) as a shrinkage inhibitor for use on sea cucumber was investigated. Shrinkage of the sea cucumber treated with SP and ST was monitored during processing. The canned sea cucumber treated with 10 volumes of 0.4% SP and 0.8% ST for 2 h had significantly lower shrinkage during processing compared with the control ($p < 0.05$). The pH of the broth of canned sea cucumbers *Stichopus japonicus* for the treatment was significantly higher than that for the control ($p < 0.05$). Results indicate that treatment with 0.4% SP and 0.8% ST is a promising way to inhibit sea cucumber from shrinking during canning.

Keywords: shrinkage, sodium phytate, sodium tripolyphosphate, sea cucumber

Introduction

Sea cucumbers have been used as a traditional food source in China and other Asian countries for thousands of years (Chen *et al.*, 2011). Among the hundreds of varieties of sea cucumbers, sea cucumber *Stichopus japonicus* is more loved by the consumers in China for its good nutritional value and taste.

Sea cucumber *S. japonicus* is highly perishable, and it starts deteriorating immediately after death. In view of its highly perishable nature, sea cucumber *S. japonicus* have to be processed to extend its shelf life. Among the various methods employed for preservation, canning could be one of the common methods used for sea cucumber *S. japonicus*. However, shrinkage in the canned sea cucumber *S. japonicus* happens after canning, and thus decreases the quality and commercial value of it.

It is known that shrinkage or contraction of sea cucumber could

be attributed to the free Ca^{2+} presented in the body of it (Suzuki, 1982; Thurmond, and Trotter, 1996). In addition, both sodium phytate (SP) and sodium tripolyphosphate (ST) are strong Ca^{2+} chelating agents (Lee *et al.*, 1998). Therefore, the aim of this study is to investigate the inhibitory effects of SP and ST on shrinkage of sea cucumber *S. japonicus* during canning. As far as we can know, few studies were focused on this subject.

Methods and Materials

Materials Live sea cucumbers *S. japonicus* were purchased from a local market (Lianyungang, Jiangsu, China). SP and ST were purchased from Fuchen Chemical reagents Co. (Tianjin, China). All other chemicals are of reagent grade and were used without further purification.

Preparation of canned sea cucumbers *A. japonicus* Sea

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cucumbers *S. japonicus* with uniform size were used for this study. The sea cucumbers *S. japonicus* were killed and dissected immediately thereafter. After removing the gut, the sea cucumbers *S. japonicus* were blanched in 90°C for 30 s, soaked in 10 volumes of SP + ST (run as treatment) or distilled water (run as control) for different time (0.5, 1, 1.5, 2, 2.5, and 3 h), canned in glass bottles, added SP + ST (run as treatment) or distilled water (run as control), exhausted, sealed, sterilized at 121°C for 20 min, cooled, and stored.

Weight loss The weight of sea cucumbers *S. japonicus* after canning was determined after caning to evaluate the efficacy of SP and ST as shrinkage inhibitor. The percent weight loss was calculated by weighing the samples.

pH Measurement The pH of the broth in canned sea cucumbers *S. japonicus* was recorded using a digital pH meter (Model: PHS-3C, CD Instruments, China).

Experimental design A Central-Composite Design (CCD) was carried out to optimize the concentrations of SP + ST and to fit a polynomial model:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{12} X_1 \times X_2 + \beta_{11} X_1^2 + \beta_{22} X_2^2 \quad \text{.....Eq. 1}$$

where Y was the weight loss of canned sea cucumbers *S. japonicus* (%), β_0 was the intercept term, β_1 and β_2 were linear coefficients, β_{12} was interaction coefficients, β_{11} and β_{22} were squared coefficients, and X_1 and X_2 were independent variables. The Design Expert (Version 7.1.6, State-Ease inc., Minneapolis; USA) software was used for the experimental design, data analysis, model building, and graph plotting.

Statistical analysis All data are presented as mean $\pm$ S.D. Statistical analysis was performed using Statgraphics Centurion XV Version 15.1.02. A multifactor ANOVA with posterior multiple range test was used to find significant differences of two groups.

Results and Discussion

Effect of SP and ST on shrinkage of canned sea cucumbers *S. japonicus* during canning The optimum combination of two variables, i.e., SP and ST, was further investigated for their optimum combination using a CCD. The design and results of the experiments conducted using a CCD are shown in Table 1. Results were analyzed using ANOVA, and the regression model was obtained as follows:

$$Y = 114.49631 - 165.49962 \times X_1 - 117.34308 \times X_2 + 24.93750 \times X_1 X_2 + 138.85000 \times X_1^2 + 57.16250 \times X_2^2 \quad \text{.....Eq. 2}$$

where Y is the weight loss of canned sea cucumbers *S. japonicus* (%), X_1 is the SP concentration (%), and X_2 is the ST concentration. The statistical significance of Eq. 1 was verified through ANOVA for the response surface quadratic model, and the results are summarized in Table 2. The data in Table 2 indicated that the model was highly significant, as demonstrated by the F-value and

Table 1. The Central-Composite Design for optimizing concentrations of sodium phytate (SP) and sodium tripolyphosphate (ST).

	X_1	X_2	Y
1	0.20	1.00	31.23
2	0.40	0.80	20.98
3	0.40	0.52	28.11
4	0.68	0.80	20.04
5	0.60	0.60	27.15
6	0.40	0.80	3.14
7	0.20	0.60	41.03
8	0.40	0.80	20.68
9	0.40	0.80	20.57
10	0.12	0.80	42.26
11	0.40	0.80	20.64
12	0.60	1.00	21.34
13	0.40	1.08	21.15

X_1 , sodium phytate concentration (%); X_2 , sodium tripolyphosphate concentration (%); Y , weight loss (%).

the probability value [$(P > F) < 0.0001$]. The accuracy of fit was proven by the high multiple correlation coefficient ($R^2 = 96.31\%$), indicating that the response model can explain 96.31% of the total variations. Generally, a regression model having an R^2 value greater than 0.9 is considered to have a very high correlation (Haaland, 1989). The value of the adjusted multiple correlation coefficient ($R^2_{\text{Adj}} = 93.68\%$) was also sufficiently high to indicate the significance of the model.

The interaction between SP and ST is not significant (Table 2). The optimal concentrations for the minimum weight loss based on the model were calculated as 0.4% and 0.8% for SP and ST, respectively. By substituting levels of the factors into the regression equation, the maximum predictable response for weight loss was calculated and was experimentally verified. The minimum weight loss obtained experimentally using the optimized concentrations of SP and ST was 21.27%, which was consistent with the predicted value of 21.20% obtained using a response surface methodology regression study and significantly lower than that of the control (43.61%; $p < 0.05$).

Time course of soaking The time courses for the weight loss of canned sea cucumbers *S. japonicus* under the optimal conditions obtained from RSM were monitored for 3 h. As shown in Fig. 1, it is interesting that for both treatment and control samples, the weight loss of canned sea cucumbers *S. japonicus* decreased firstly and then leveled off after 2 h. However, the resulting weight loss of canned sea cucumbers *S. japonicus* for the treatment was significantly lower than that for the control (43.61%; $p < 0.05$). The decreased weight loss of canned sea cucumbers *S. japonicus* for the treatment could be partly due to the chelating effect of Ca^{2+} with SP and ST (Lee *et al.*, 1998).

Effect of SP + ST on pH of the broth of canned sea cucumbers *S. japonicus* Changes in pH of the broth of canned sea cucumbers *S. japonicus* with and without treatment are shown in Fig. 2. The

Table 2. Analysis of variance for the experimental results of the Central Composite Design

Factor	Sum of square	Degree of freedom	F value	$P > F$	Significance
X_1	380.21	1	99.75	<0.0001	aa
X_2	80.98	1	21.25	0.0025	a
X_1^2	214.59	1	56.30	0.0001	aa
X_2^2	36.37	1	9.54	0.0176	a
$X_1 \times X_2$	3.98	1	1.04	0.3409	
Model	697.03	5	36.58	<0.0001	aa
Lack of Fit	21.89	3	6.09	0.0568	
Pure Error	4.79	4			

^aStatistically significant at 95% of probability level.

^{aa}Statistically significant at 99% of probability level.

Fig. 1. Effect of soaking time on shrinkage of canned sea cucumbers *S. japonicus* **Fig. 2.** The pH of the broth of canned sea cucumbers *S. japonicus*.

pH of the broth of canned sea cucumbers *S. japonicus* for the treatment (9.81) was significantly higher than that for the control (6.51; $p < 0.05$). The higher of pH of the broth of canned sea cucumbers *S. japonicus* for the treatment could be ascribed to the alkalinity of SP and ST. The water binding capacity of protein could increase at higher pH, and this may partly lead to the lower

weight loss of canned sea cucumbers *S. japonicus*. However, at too higher pH, some proteins could dissolve in water, and thus increase the weight loss of canned sea cucumbers *S. japonicus*. The higher pH of the broth led to a higher pH (~9.37) of the muscle of canned sea cucumber. However, the higher pH of both the broth and muscle of canned sea cucumber did not affect the taste of it very

much.

Conclusions

This study demonstrated that SP + ST could be used to effectively prevent shrinkage of canned sea cucumbers *S. japonicus*, and the efficacy was associated with dose and soaking time. The higher pH of the broth of canned sea cucumbers *S. japonicus* for the treatment contributed to lower weight loss of canned sea cucumbers *S. japonicus*. Therefore, treatment with SP + ST increased the commercial value of canned sea cucumbers *S. japonicus*.

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