e-ISSN : 2621-9468

Type of the Paper (Article)

Effect of sodium alginate on the physicochemical and sensory properties of vegan surimi

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Abstract

This present study aimed to compare the effect of sodium alginate on the physicochemical and sensory properties of vegan surimi. Sodium alginate at different concentrations (0% - Control, 0.25% - F1, 0.50% - F2, and 0.75% - F3) were added to the vegan surimi, and the effect to the physicochemical and sensory properties of vegan surimi was assessed. The addition of 0.75% sodium alginate has significantly ($p<0.05$) improved the folding test score of F3 from 3.00 to 3.67. A significant ($p<0.05$) increase was observed in hardness, gumminess, and chewiness of F3 with the recorded value at 3.01, 2.56, and 2.43 kg, respectively. Besides, moisture content (70.82%), water holding capacity (78.36%), and lightness (quality indicator) of F3 were significantly ($p<0.05$) enhanced with the addition of sodium alginate. In sensory evaluation, the most preferred product was F1 (0.25% sodium alginate) in terms of texture (7.00), taste (7.17), and overall acceptability (7.17) based on the 9-point Hedonic testing. In conclusion, the results suggest the potential of sodium alginate in the improvement of physicochemical and sensory properties of vegan surimi.

Article History
Received June 7, 2023
Accepted December 20, 2023
Published December 29, 2023

Keywords
Hydrocolloid,
Plant-Based,
Sodium Alginate,
Vegan Surimi.

1. Introduction

Currently, there is a growing global need to shift away from animal-based diets for a variety of factors, including environmental or sustainable issues, animal welfare and human health. The goal is to supplant traditional animal-based foods with other options, primarily plant-based alternatives (1). Surimi is a useful raw material made from fish myofibrillar protein concentration. Due to the myofibrillar proteins' propensity to form gels, it is employed as a basis for the production of many analogue products, that there is a huge progress in the food industry.

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ISSN 2621-9468 online, DOI 10.20956/canrea.v6i2.1034

Surimi manufacturers have increased their manufacturing capacity in response to increased demand, which has unintentionally harmed the environment. The increasing surimi output was thought to be causing a decline in fish population. Surimi has a severe risk of toxicity and protein degradation because it is made from concentrated fish protein. In the surimi industry, frozen storage is frequently employed during manufacturing and extended storage. Nonetheless, biochemical modifications throughout cold storage seem linked to a decrease in surimi gelation capabilities, which is attributed to alteration of myofibrillar protein.

Through this perspective, the production of surimi goods in which myofibrillar proteins are substituted with proteins derived from other more manageable and available sources, such as pea protein, that gives intriguing opportunities for the surimi sector to produce different sorts of surimi equivalents from surimi gelation (2,3). Innovative mixed gels are healthier than surimi gels that are composed entirely of fish protein (4). It may be critical to examine the connections between separated pea proteins and myofibrillar proteins, as well as the functional significance of molecules of water as a probable cross linker involving fish and plant proteins, while creating an appropriate mixed surimi gel network. In this research, sodium alginate is added as alginates are hydrocolloids that contribute to the structural, stability, and functionality of a variety of refined foods.

Alginates are salts of alginic acid produced from kelp (*Laminaria* sp., *Macrocystis* sp) (5). The alginate is composed of 1, 4-linked α-L-guluronic acid (G) and β-D-mannuronic acid (M) residues as a polymeric acid (6). Alginates are excellent fish binding components because they combine with muscle fragments to generate thermo-stable gels under 30^{o}C (7). Sodium alginate is the most common type of alginate. Despite the prevalence use of alginates in food production as stabilizer or as a modifier in food rheological behaviour, one of its most intriguing features is gelation (8).

Alginate is unique among gel-shaping hydrocolloids due to its ability of producing thermo-stable gels without thermal processing. Polyvalent cations (mostly calcium) create intermolecular associations with diametrically linked guluronic acid block sections of the polysaccharide structure to form alginate gels (9). This gel is responsible for interacting between muscle proteins. This research uses alginate, owing to the alginate's capacity to retain water on surimi. The ability to retain water can influence the effects of setting on the gel's functions (7). Sodium alginate is a natural polysaccharide extracted from brown algae. Hence, it may facilitate protein degradation in gastrointestinal digestion due to the weak wraps between protein and anionic polysaccharides, thus improving digestibility and bioavailability of protein in vegan surimi (10). Therefore, this present study aimed to compare the effect of sodium alginate on the physicochemical and sensory properties of vegan surimi.

2. Materials and Methods

2.1. Vegan Surimi Gel Preparation

Vegan surimi was prepared according to Sinurat et al. (11) with modifications. The ingredients (Table 1) were mixed at 60 rpm for 5 min (at room temperature), using a food processor to produce a dough. Concentration of alginate incorporated was 0.25%, 0.5%, and 0.75%, for F1, F2, and F3, respectively. The dough was incubated at 60°C for an hour to properly hydrate the gluten. Then, the dough was divided into pieces and was placed in a food processor, where they were further cut into smaller fragments at 500 rpm for 1 min, followed by at 1200 rpm for another 2 min to make the secondary dough. Next, the dough was coated in baking paper and a layer of aluminum foil before being steamed for 1.5 h in a food steamer to an internal temperature of 80°C. It was kept at 4°C overnight before further analysis.

Table 1. Formulations of vegan surimi.

Ingredients (g)	Formulation			
	Control	F1	F2	F3
Soy protein isolate	57.00	56.75	56.50	56.25
Water	35.00	35.00	35.00	35.00
Potato starch	3.00	3.00	3.00	3.00
Sugar	3.00	3.00	3.00	3.00
Salt	1.00	1.00	1.00	1.00
Sodium Alginate	0.00	0.25	0.50	0.75
Paprika	0.50	0.50	0.50	0.50
MSG	0.50	0.50	0.50	0.50
Total	100	100	100	100

2.2. Colour

The colour of vegan surimi gel samples was measured using the CIE Lab Scale of colorimeter (Model Minolta Spectrophotometer CM-3500D, Osaka, Japan). The instrument was standardized with zero calibration (CM-A100) and followed by a white calibration plate (CM-A120). The L*, a*, b* values were used to determine the parameters. L* stands for lightness (L* = 100 for the lightest and L* = 0 for the darkest, a* for redness (red +60 to green -60), while b* for yellowness (yellow +60 to blue -60) (12).

2.3. Folding Test

Vegan surimi gel samples were cut into 3 mm thick sections for assessment of folding test. The slices were held between both the thumb and the forefinger folded to observe the pattern the slice broke. The scale used was: (1=cracks by finger pressure, 2=cracks quickly when folded in half, 3=cracks steadily when folded in half, 4=no cracks visible after folding in half, 5=no cracks visible after folding twice) (12).

2.4. Moisture Content

Approximately 5 g of vegan surimi paste was measured at 120°C using an oven drying method to determine the moisture content. The dried sample was weighed every 15 min until it maintained a steady final weight. The moisture content measurements for each sample were analyzed three times. Moisture content was calculated by following the formula:

$$\text{Moisture (\%)} = \frac{\text{Initial weight (g)} - \text{Final weight(g)}}{\text{Initial weight (g)}} \times 100\% \tag{1}$$

2.5. Expressible Moisture (EM) and Water Holding Capacity (WHC)

Evaluation of EM was carried out in accordance with the method of Hui et al. (13). The vegan surimi gel samples were sliced into 5 mm thick, weighed, and placed between two sheets of Whatman paper No. 41. A 5 kg standard weight was placed on top and maintained for about 2 min. The sample was weighed again after 2 min. The EM was calculated by following a formula below:

$$\mathrm{EM}\ (\%) = \frac{\text{Weight of pre−pressed sample (g)} - \text{Weight of pressed sample (g)}}{\text{Weight of pre−pressed sample (g)}} \times 100\% \quad (2)$$

Determination of WHC of vegan surimi was adapted from the method of Alakhrash et al. (14), and was calculated as follows:

$$\mathrm{WHC}\ (\%) = \frac{\text{Moisture content (\%)} - \text{EM (\%)}}{\text{Moisture content (\%)}} \times 100\% \quad (3)$$

2.6. Texture Profile Analysis (TPA)

TPA of vegan surimi gel was conducted according to the method of Walayat et al. (15) with slight modifications. Texture Analyzer TA-XT2 (Stable Micro Systems, Godalming, UK) with a compression platen (SMS P/75) was used to characterize the textural characteristics (i.e. hardness, springiness, cohesiveness, gumminess, and chewiness) of gels. The settings for TPA were as follows: load cell capacity (30 kg); speed (1.0 mm/sec); test speed (1.0 mm/sec); post-test speed (1.0 mm/sec); distance (15 mm); duration before second compression (2 sec) and trigger pressure (5 g).

2.7. Sensory Evaluation

Hedonic testing is the organoleptic test that was used in this study to determine the consumer preference of vegan surimi. A total of 30 untrained participants aged 18 years and above, were recruited among the students and staff from UiTM, Shah Alam to evaluate the samples using the 9-point Hedonic scale, where 9 indicates like extremely and 1 indicates dislike extremely, respectively. Sensory evaluation was conducted at the sensory laboratory, Faculty of Applied Sciences, Universiti Teknologi MARA, whereby the sensory booths are partitioned and equipped with lighting unit to minimize bias. Five sensory attributes assessed were colour, odour, texture, taste, and overall acceptability. Panellists were presented with the samples (randomly coded as three-digit number) served on a plastic plate, a cup of plain water, an empty cup, a piece of tissue paper, a pen, and an evaluation sheet. Sufficient space and evaluation time were allocated and all residual samples were discarded upon completion of evaluation.

2.8. Statistical Analysis

Experimental data obtained were subjected to one way analysis of variance (One-way ANOVA) at a 95% confidence level, followed by Tukey's test for multiple comparisons, using IBM SPSS v28 for Windows (IBM SPSS Inc., Chicago, IL). The data were presented as the average of triplicates (n = 3) ± standard deviation (SD). A significance level of 5% was maintained throughout the study.

3. Results and Discussion

3.1. Colour

Colour is one of the most important factors that customers consider during evaluation of product quality. The tristimulus (L* a* b*) colour test findings reported in Table 2 indicate that the addition of sodium alginate altered the colour of vegan surimi ($p<0.05$) significantly. As the concentration of sodium alginate increased, L*, a*, and b* values generally rose. Lightness, or L* values of F1, F2, and F3 were statistically distinct ($p<0.05$) from those of control samples. Higher L* values suggest a more intense lightness, a feature that is highly valued by the consumers (16,17). On a scale from black = 0 to white = 100, L* values define the amount of light absorbed and reflected by a sample's surface. The hydrocolloids addition in production of a translucent gel matrix was likely responsible for the colour differences across the different surimi formulations (18). According to Pérez-Mateos et al. (19), the protein suspension in the surimi gel scatters light, resulting in an increase in light reflection and L* values.

The vegan surimi had a redder and more yellowish hue (an increasing a* and b* values with the increasing concentration of sodium alginate), which are characteristics of commercially available surimi derived from fish. The increasing a* and b* could be an indicative that Maillard reaction happens as sodium alginate consists of 0.65% protein and 0.77% carbohydrates (20). Considering that surimi is normally white, it is evident that seasonings and flavourings (such as the paprika utilised in this example) were the primary colourants. There were significant differences ($p<0.05$) between vegan surimi with the addition of sodium alginate from the control. However, in general, but there were no significant differences ($p>0.05$) between the vegan surimi (F1-F3) despite the increasing concentration of sodium alginate incorporated. The random distribution of additional substances in samples and their capacity to alter colour readings can be used to explain the variation in measurement.

Table 2. Colour analysis of vegan surimi with/without the addition of sodium alginate.

Samples	L*	a*	b*
Control	51.16±2.66^{b}	6.45±0.12^{c}	16.38±0.89^{b}
F1	58.73±1.55^{a}	8.51±0.73^{b}	22.17±2.12^{a}
F2	63.07±1.19^{a}	9.53±0.32^{ab}	24.36±0.90^{a}
F3	62.63±3.26^{a}	10.71±0.75^{a}	25.21±1.96^{a}

^{a,b,c} Values are mean ± standard deviation. Different letters in the same column indicate significant differences ($p<0.05$).

3.2. Folding Test

Folding test is a straightforward and speedy approach that can objectively measure the quantity of elasticity present in surimi (21). When there is no evidence of fracture in the sample test, this is an indication of high-quality surimi (22). Folding tests of vegan surimi with addition of varying amounts of sodium alginate and control were scored on a scale from 1-5 (cracked when squeezed with the finger to no visible crack after two folds). Table 3 displays the score of folding tests performed on vegan surimi with varying quantities of sodium alginate and the control sample.

Table 3. Folding test score, moisture content, expressible moisture (EM) content, and water holding capacity (WHC) of vegan surimi with/without the addition of sodium alginate.

Samples	Folding Test	Moisture Content (%)	EM (%)	WHC (%)
Control	3.00±0.00^{b}	68.14±1.60^{b}	32.86±0.45^{a}	52.07±0.40^{c}
F1	3.67±0.58^{a}	66.63±0.53^{b}	32.93±0.73^{a}	50.51±0.28^{c}
F2	3.67±0.58^{a}	71.74±0.49^{a}	23.65±0.20^{b}	67.00±0.91^{b}
F3	3.67±0.58^{a}	70.82±0.25^{a}	15.32±0.72^{c}	78.36±0.27^{a}

^{a,b,c} Values are mean ± standard deviation. Different letters in the same column indicate significant differences ($p<0.05$).

According to the findings of the analysis of variance, the control vegan surimi with the score 3.00 was found to be of a significantly lower grade (p<0.05) than other vegan surimi (F1-F3) with the addition of sodium alginate. Furthermore, there was no significant difference (p<0.05) between F1, F2, and F3 despite the increasing concentration of sodium alginate. The results demonstrated that the incorporation of hydrocolloid led to an improvement in the folding test score of vegan surimi. In addition, the greatest folding test score that could be attained on fish surimi (*Pangasius hypophthalmus*) with a soy protein isolate was a score value that was greater than 3 (slightly cracked when folded in half) (23). In the present study, the control vegan surimi sample provides a score that is comparable to that of the fish surimi. Moreover, the vegan surimi with the addition of sodium alginate were generally of a better quality with the score of 3.67. It is because soy protein isolate and sodium alginate play a significant part in the process of making surimi gel and able to reduce the amount of water produced. The results of folding test are generally more accurate when the texture of the surimi is more compact. Folding test results correlated well with the actual texture and mouthfeel perceived by the consumers, as evidenced by the significantly higher (p<0.05) hardness, gumminess, and chewiness of surimi incorporated with 0.75% sodium alginate than that of control and other vegan surimi with the addition of lower sodium alginate concentration (Table 4). Surimi gel that did not crack easily showed better sensory attributes, that were harder, gummier and chewier.

3.3. Moisture Content

Water is the most important component of food since it affects texture, appearance, and flavour (24). The difference in weight between the sample before and after drying in an oven is used as a foundation for assessing moisture content (expressed in percentage). The moisture content of the vegan surimi ranged from 66.63 to 71.74%. Table 3 depicts that the increment of moisture content in vegan surimi was significant (p<0.05) as the sodium alginate was added at 0.50 and 0.75%. Moisture content of F2 and F3 were recorded at 71.74 and 71.28%, respectively. By referring to the SNI No. 01-2694-2013, the maximum water content listed in the quality and safety requirement for surimi is 80%. In the present study, the combination use of sodium alginate and soy protein isolate enhanced the moisture content of vegan surimi, although it is still considered low as compared to the moisture content of fish surimi.

3.4. Expressible Moisture (EM) and Water Holding Capacity (WHC)

EM is indicated by the amount of liquid extracted from a protein system by the force exerted (25). The effects of adding different concentration of sodium alginate on EM of surimi are shown in Table 3. According to Niwa (26), the relationship between EM and WHC is inversely correlated. It is determined that the amount of imprisoned water reduces as EM increases (27). There was no significant difference (p>0.05) on the EM of F1 when sodium alginate was added at 0.25%. Nevertheless, the EM of F2 (23.65%) and F3 (15.32%) were significantly reduced (p<0.05) when sodium alginate was added at 0.50 and 0.75%, respectively. Addition of 0.75% sodium alginate into surimi gel resulted in the lowest EM, demonstrating that water loss had been minimized. The result was also in agreement with Nicomrat et al. (28), who discovered that a lower EM content was achieved with the addition of alginate in fish surimi samples. This may be due to the functional groups of each hydrocolloid's capacity to connect with water. Several carboxyl groups in the structure of alginate can bind with water and provide a strong electrostatic repulsion between the chains, resulting in a rapid hydration.

WHC is the capacity of a protein to bind water from both within and outside the sample. WHC is a crucial factor in gel formation (29) and it has a close relationship with the amount of free water released. WHC of vegan surimi which ranged from 50.51 to 78.36% are tabulated in Table 3. Analysis of variance revealed that the addition of varied concentrations of sodium alginate to vegan surimi had a significant effect ($p<0.05$) on the WHC. According to the results, the addition of 0.50 and 0.75% of sodium alginate increased the WHC value of F2 (67.00%) and F3 (78.36%), respectively. Sodium alginate is one of the hydrocolloids used in surimi production to enhance the binding energy of water by inhibiting the interchange of water molecules from proteins, thereby stabilizing the proteins. Fore degraded proteins, a drop in WHC is observed due to the diminishment of their water binding capacity. In relation to EM, the lower the EM, the greater the vegan surimi's water retaining capacity. In other words, the addition of sodium alginate could increase the capacity of surimi to retain water.

3.5. Texture Profile Analysis (TPA)

Table 4 illustrates the effect of different sodium alginate concentrations on the textural properties of vegan surimi. Five TPA characteristics determined in this study are: hardness, springiness, cohesiveness, gumminess, and chewiness. According to Lee and Chung (30), these five TPA features are more effective for evaluating the overall binding qualities of surimi gel, whether it contains additional compounds or not. Nonetheless, a higher value for these five criteria may not be always indicating a higher quality. When sodium alginate was added up to 0.75%, the hardness value of the surimi samples increased significantly ($p<0.05$), and a similar pattern was also observed for gumminess and chewiness. Specifically, addition of 0.75% sodium alginate into surimi caused the hardness, gumminess, and chewiness of surimi to be significantly higher ($p<0.05$) than that of control and other vegan surimi with the addition of lower sodium alginate concentration. It was in agreement with the study by Fu et al. (31), that a higher molecular weight and apparent viscosity of sodium alginate resulted in a higher gel strength. Nopianti et al. (32), also reported that hardness and chewiness are correlated, and in the present study, vegan surimi incorporated with 0.75% sodium alginate had the highest values for both hardness and chewiness. There was no significant difference ($p>0.05$) in springiness and cohesiveness of all surimi samples.

Table 4. Texture profile analysis of vegan surimi with/without the addition of sodium alginate.

Samples	Hardness (kg)	Springiness (mm)	Cohesiveness	Gumminess (kg)	Chewiness (kg.mm)
Control	2.37 ± 0.15^{b}	0.94 ± 0.02^{a}	0.87 ± 0.04^{a}	2.05 ± 0.04^{b}	1.94 ± 0.02^{b}
F1	2.45 ± 0.09^{b}	0.95 ± 0.02^{a}	0.89 ± 0.03^{a}	2.07 ± 0.08^{b}	1.99 ± 0.08^{b}
F2	2.19 ± 0.02^{b}	0.97 ± 0.01^{a}	0.88 ± 0.01^{a}	1.92 ± 0.02^{b}	1.86 ± 0.02^{b}
F3	3.01 ± 0.28^{a}	0.95 ± 0.01^{a}	0.85 ± 0.01^{a}	2.56 ± 0.02^{a}	2.43 ± 0.22^{a}

[a,b,c] Values are mean ± standard deviation. Different letters in the same column indicate significant differences ($p<0.05$).

The amount of protein in processed muscle foods has a substantial effect on hardness. The addition of hydrocolloids altered the texture of muscle protein (33). According to Kazir et al. (1), the protein content of vegan seafood analogs is likely due to the structure of the raw material, such as the soy protein isolate. These findings are congruent with those of Yong et al. (34), who discovered that adding soy protein isolate to hog gel made it tougher. The hardness of the samples was also affected by salt. Additionally, Pérez-Mateos and Montero (33) found that fish gels containing hydrocolloids such as alginate were more durable than those without. Values of springiness and cohesiveness were higher in vegan surimi added with 0.50% sodium alginate than that of control although there were no significant differences (p>0.05) among all vegan surimi samples.

3.6. Sensory Evaluation

As shown in Table 5, five sensory parameters included in the Hedonic evaluation were colour, odour, texture, taste, and overall acceptability. The average rating for the colour of vegan surimi varied between 6.37 and 6.90. This means that the opinions of the respondents regarding the colour of the vegan surimi ranged from "like slightly" to "like moderately". The addition of 0.25%, 0.50%, and 0.75% sodium alginate did not significantly (p>0.05) affect the colour of the vegan surimi as there was no discernible variation in colour between the samples. Although there was a significant difference (p<0.05) in colour between control and vegan surimi with the addition of sodium alginate (Table 2), the variation was probably minor that was not detected by the panellists. A product's marketability depends on how consumers interpret the colour of food items. If the colour did not fulfil their expectations, the consumers would not purchase that particular product (35). Similarly, there was no significant difference (p>0.05) in the scores of odour among vegan surimi. This trend was expected, given the odourless alginate used in this product may not contribute to the vegan surimi's odour. Vegan surimi obtained an average score for odour which ranged from 6.57 to 7.20, suggesting that they "liked moderately" the aroma.

Table 5. Sensory evaluation of vegan surimi with/without the addition of sodium alginate.

Samples	Colour	Odour	Texture	Taste	Overall Acceptability
Control	6.90±1.27^{a}	6.57±1.28^{a}	6.43±1.41^{ab}	7.00±1.20^{a}	6.68±1.19^{a}
F1	6.53±1.38^{a}	6.63±1.19^{a}	7.00 ±1.37^{a}	7.17±1.15^{a}	7.17±0.99^{a}
F2	6.77±1.76^{a}	7.20±1.40^{a}	6.23±1.14^{ab}	6.73±1.14^{a}	6.63±1.03^{ab}
F3	6.37±1.61^{a}	6.77±1.41^{a}	5.83±1.56^{b}	5.83±1.49^{b}	5.90±1.19^{b}

[a,b,c] Values are mean ± standard deviation. Different letters in the same column indicate significant differences (p<0.05).

Interestingly, vegan surimi (F3) with the addition of 0.75% sodium alginate received the lowest score for texture (5.83), taste (5.83), and overall acceptability (5.90), respectively. These hedonic scores obtained for F3 were significantly lower (p<0.05) than that of other vegan surimi (control, F1, and F2). This implies that the panellists remained neutral (point 5) or "like slightly" (point 6) to the texture, taste, and overall acceptability of F3. The score of preference also decreased with the increasing of sodium alginate concentration. In general, the scores for F1 were the highest and it was most preferred by the panellists despite its insignificant differences (p>0.05) than the other vegan surimi. The outcome of the taste sensory evaluation followed a similar pattern to that of the texture sensory evaluation. This result indicated how texture affected panellists' approval of a taste, and therefore the overall acceptability. According to studies, taste and smell perception are frequently diminished when the concentration of hydrocolloids rises, and texture impacts how tastes are perceived. This hypothesis may be substantiated by the fact that the texture score decreased as the alginate concentration increased (36), which could be associated to the decreased elasticity with increasing concentration of sodium alginate (37). Nevertheless, addition of sodium alginate at low level may enhance the gel strength and hedonic score for texture of surimi (38). This justifies the reason for the use of low level of sodium alginate in vegan surimi in the present study, owing to the insignificant differences ($p>0.05$) in physicochemical properties and the significantly unfavoured ($p<0.05$) hedonic score with the increasing concentration of sodium alginate.

4. Conclusions

This study demonstrates the role of sodium alginate as a binding agent in the preparation of vegan surimi. The proposed level of use was 0.50%, as the addition beyond this level makes no significant differences for the physicochemical properties of vegan surimi in general, and causes a significant low hedonic score in sensory properties and consumer acceptability. Incorporation of sodium alginate had considerably improved the water holding capacity and gel strength (i.e. hardness, gumminess, and chewiness) of vegan surimi gel. With the growing demand of plant-based products, these results are promising for the future implications of manufacturing and marketing of a vegan surimi product.

Acknowledgements

The authors wish to thank the Faculty of Applied Sciences, Universiti Teknologi MARA especially the laboratory assistants for their excellent assistance in making this research a success. The authors are grateful for the sponsorship of ingredients by DKSH Performance Materials Malaysia Sdn. Bhd. in this research.

Author Contributions

E.K.S. and N.A.A.R. conceived and designed the experiments; A.M.S. performed the experiments; L.J.S. and U.I. analyzed the data; E.K.S. and N.A.A.R. contributed reagents/materials/analysis tools; E.K.S., N.H. and A.M.S. wrote the paper.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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