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Food and Life (2021) 2021(2):57–66
https://doi.org/10.5851/fl.2021.e6

Research Article Open Access

Effect of incorporating roasted sesame (*Sesamum indicum*) seeds on the quality parameters of chicken nuggets

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Abstract

The present study was aimed to develop a value-added chicken nugget by incorporating roasted sesame seeds (RSS) and elucidate its sensory and quality parameter changes during a 28-d frozen storage. Chicken nugget samples were processed to have four treatments as; 1) Nuggets with 0% RSS (w/w) [Control], 2) Nuggets with 5% RSS (w/w) [SN5], 3) Nuggets with 10% RSS (w/w) [SN10] and 4) Nuggets with 15% RSS (w/w) [SN15] with six replications per treatment. The two best nugget samples with RSSs were selected by a sensory panel and tested for physicochemical and microbial quality changes with the control sample during a 28-d frozen storage. Results revealed that SN10 had the highest ($p<0.05$) crude fat (8.84%), crude protein (14.24%) and ash (3.15%) contents compared to SN5 and the control. During the 28-d frozen storage, the pH of nuggets diminished gradually ($p<0.05$) in all treatments. SN10 had the highest ($p<0.05$) thiobarbituric acid reactive substance (TBARS) value compared with its counterparts throughout the 28-d frozen storage. The TBARS values and total plate count values increased ($p<0.05$) in all treatments during the frozen storage, but within the acceptable limits. The water holding capacity of nuggets in all treatments decreased ($p<0.05$) and cooking loss increased ($p<0.05$) during the frozen storage. In conclusion, RSSs could be mixed up to 10% to the nugget mixture to prepare nuggets with improved proximate composition, and physicochemical and sensory properties.

Keywords: chicken nuggets, proximate composition, thiobarbituric acid reactive substance, roasted sesame, sensory quality

Introduction

Processed foods are becoming popular, especially among urbanized societies, owing to their convenience in preparation, handling, and storage. In addition, consumers insist that such products possess high quality, freshness, nutritional value, and health benefits (Venugopal, 2005). Among processed foods, ready-to-eat or ready-to-cook meat products have become more desirable and can be consumed as a part of the main diet or as a snack (Magdelaine et al., 2008). Nugget is a ready- to-eat, convenient breaded product made of ground meat (Berry and Bigner, 1996; Deogade et al., 2008).

Sesame (*Sesamum indicum*) is a seed crop commonly used for confectionery and bakery products, milled to obtain high-grade edible "sesame oil," and contains a higher amount of nutritional and medicinal value (Bedigian, 2004; Borchani et al., 2010). In particular, roasted sesame seeds (RSS) are well known to have beneficial health effects, including anti-oxidative, anti-carcinogenic, hepatoprotective, hypocholesterolemic, and anti-hypertensive properties due to the presence of lignin isolates such as sesamin and sesamolin (Elleuch et al., 2007; Lee et al., 2008; Yakota et al., 2007). Sesamolin is converted to sesamol during roasting, which consists of phenolic and benzodioxide groups with antioxidant and anticancer activities (Hou et al., 2008; Kumar et al., 2009; Namiki, 1995). Moreover, sesame seeds add a pleasant aroma and flavor to foods in addition to nutritional and physiological benefits (Doblon-Merilles and Quimbo, 2019). Hence, many studies have attempted to improve the sensory and nutritional properties of meat-based products by incorporating sesame seeds or sesame products (Doblon-Merilles and Quimbo, 2019; Kang et al., 2017). Therefore, incorporation of RSS into meat-based foods such as nuggets may add value to the product in terms of taste and

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nutritional and medicinal values.

Previous studies have been conducted to evaluate the quality characteristics of nuggets by incorporating different additives such as pomegranate seed powder, grape seed extract with tomato powder, and grounded mustard (Kaur et al., 2015; Kumar and Tanwar, 2011). Nevertheless, few studies are available which focus on the addition of RSS to chicken nuggets or the additives effects on quality characteristics. Therefore, this study was designed to develop a value-added chicken nugget that incorporates RSS and to investigate its sensory and quality parameter changes during a 28-d frozen storage.

Materials and Methods

Treatments

The RSS incorporated chicken nuggets were processed separetly to obtain four treatments as; 1) Nuggets with 0% RSS (w/w) [Control], 2) Nuggets with 5% RSS (w/w) [SN5], 3) Nuggets with 10% RSS (w/w) [SN10] and 4) Nuggets with 15% RSS (w/w) [SN15] with six replications per treatment.

Preparation of RSS incorporated chicken nuggets

Chicken nuggets were prepared following the commercial guidelines. Initially, chicken meat and skin were ground through an 8 mm grinding plate using a meat mincer (S32, Xianghou, Zhejiang, China) and the resultant minced meat mixture was finely chopped for 3 min. Then, the chopped meat mixture was mixed with other ingredients until a uniform blend occurs. The composition of meat emulsion (w/w) was 72% chicken meat, 12% chicken skin, 4% pepper, 3.5% garlic, 3.5% onion, 3% chilli flakes, and 2% salt.

The RSS were then separately top-dressed onto the nugget mixture to have the aforementioned treatments. Nugget mixture was moulded using a stainless steel moulder. Moulded nuggets were chilled (0℃–4℃) for 4 hours, dipped in a batter made up of whole eggs (85%), water (10%), wheat flour (4%), and turmeric powder (1%) and subsequently covered with bread crumbs. After that, the nuggets were flash-fried (160℃) in vegetable oil for 30 s, separately vacuum packed and stored under frozen condition (–18℃) until further analysis.

Sensory evaluation

A sensory evaluation was conducted using 30 untrained panellists aged between 21–27 representing each sex. A seven-point hedonic scale (1=Dislike very much, 4=Neither like nor a dislike, 7=Like very much) was used for the sensory evaluation and sensory attributes were appearances, colour, aroma, crispiness, juiciness, texture, flavour and overall acceptability. Nugget samples (4×4×1.5 cm) were deep fried (160℃ for 5 min) until the core temperature reached 72℃, and served in random order to panellists on coded (with random 3-digit numbers) white dishes with drinking water. After sensory evaluation, the two best RSS incorporated chicken nuggets were selected for further analysis over a 28-d frozen storage along with the control.

pH value

The pH values were determined according to the methodology reported by Jung et al. (2011) using a calibrated pH meter (pH 700, Eutech instrument, Ayer Rajah Crescent, Singapore) at room temperature. The mean value of three repeated measurements from each sample was used.

Lipid oxidation

Lipid oxidation was measured weekly as the thiobarbituric acid reactive substance (TBARS) value of each sample as described previously by Zeb and Ullah (2016) with slight modifications. Briefly, one gram of each nugget sample was added to 5 mL of glacial acetic acid (100%; Sigma-Aldrich, St. Louis, MO, USA) with 0.01% butylated hydroxytoluene (to prevent further oxidation; Sigma-Aldrich) and vigorously shaken for 1 h. The resultant hydrolysate was filtered (No. 4, Whatman International, Maidstone, UK) and then centrifuged at 2,100 rpm for 15 min. The filtrate (1 mL) was mixed with 1 mL of 4 mM 2-thiobarbituric acid (TBA) solution (Sigma-Aldrich), and the mixture was kept in a boiling water bath (LWB-IIID, Daihan Labtech, Namyangju, Korea) at 95℃ for 1 h. After cooled down to room temperature, the absorbance of the supernatant was measured at 532 nm wavelength by the spectrophotometer (DU 530, Beckman Instruments, Fullerton, CA, USA). The amount of malondialdehyde (MDA) was calculated in the nugget samples using a standard curve prepared from 1 mL of 4 mM TBA solution, and 1 mL of 1 mM MDA stock solution made out from MDA tetrabutylammonium salt (Sigma-Aldrich). TBARS value was reported as milligram of MDA per kilogram of nuggets.

Water holding capacity (WHC)

The WHC was determined by following the method stated by Hamm (1961) and Wilhelm et al. (2010) with slight modification. Initially, the nugget samples were made into 2.0±0.10 g cubes and placed between two pieces of filter paper (No. 4; Whatman International). Then, a standard weight of 10 kg was placed on top of the filter paper for 5 min separately for each sample and the final weights were recorded. Finally, WHC was calculated using the following equation, where W_i and W_f are the initial and final weights of the sample, respectively.

$$\text{Water holding capacity} = 100 - [(W_i - W_f) \times 100 / W_i]$$

Cooking loss

For the determination of cooking loss, vacuum-packed nugget samples (25 g) were cooked in a water bath (LWB-IIID, Daihan Labtech) at 80℃ for 20 min and allowed to cool down to room temperature. The cooking loss was calculated as the weight loss of the sample during cooking as a percentage of the initial weight (Bai et al., 2017; Onenc et al., 2004).

Color values

The surface color values of minced nugget samples without outer crust was determined by a calibrated colorimeter (CR-410, Konica Minolta, Osaka, Japan). The values of lightness (CIE L*), redness (CIE a*) and yellowness (CIE b*) were obtained using the average value of three repeated measurements taken from different locations on minced nugget samples.

Proximate composition

The proximate composition of nugget samples was determined separately by the methods of AOAC (2016). Briefly, the oven-drying method (102℃ for 15 h) and Kjeldahl method (KDN-103 F, Hua Ye, Shanghai, China) was followed to calculate the moisture content and crude protein content of nugget samples respectively. The Soxhlet extraction system (TT 12/A, Gerhardt, Königswinter, Germany) was occupied to measure the crude fat content of the nugget samples and crude ash content was determined by igniting the nugget samples (2 g) in a furnace set at 550℃ for 4 h.

Microbiological analysis of the product

Total Plate Count (TPC), *Escherichia coli* count and *Salmonella* count of nugget samples were measured according to the methodology of AOAC (2016).

Statistical analyses

The complete experiment was conducted according to a completely randomized design and experimental data except those from the sensory evaluation were analyzed using one-way ANOVA technique, General Linear Model (GLM) in the SPSS software package (Version 26; IBM SPSS 2019). Significant differences between mean values were determined by using Tukey's multiple range test at a significance level of $p<0.05$. Data from the sensory evaluation were subjected to Freidman non-parametric analysis in the Minitab 17 statistical software package (Minitab, State College, PA, USA, 2014) with 95% significance.

Results

Sensory evaluation

Sensory attributes of the chicken nuggets incorporated with RSS is shown in Table 1. The incorporation of RSS did not affect ($p>0.05$) the appearance, colour, and aroma of chicken nuggets, but on other sensory attributes ($p<0.05$). SN10 had higher ($p<0.05$) scores for juiciness, flavour and overall acceptability, whereas SN15 showed the lowest values ($p<0.05$) among the treatments. Moreover, the crispiness of SN15 was significantly higher ($p<0.05$) than other treatments and control nuggets had the highest score for texture. Accordingly, SN15 treatment was excluded due to the poor customer preference ($p<0.05$) and SN5 and SN10 were selected for subsequent analysis for keeping quality and proximate composition with the control over a 28-d frozen storage period.

pH value

During the frozen storage of 28 days, the pH of nuggets diminished gradually in all treatments (Table 2; $p<0.05$). The initial pH value was higher ($p<0.05$) in the control sample compared to RSS incorporated nuggets. However, it was comparable ($p>0.05$) among the treatments over the frozen storage period.

Lipid oxidation

The TBARS values of chicken nuggets as affected by different levels of RSS are presented in Table 3. SN10 had the highest ($p<0.05$) TBARS value compared with its counterparts throughout the 28-d frozen storage period. Besides, the TBARS value of each treatment increased significantly ($p<0.05$) with an

Table 1. Sensory evaluation of chicken nuggets incorporated with different levels of roasted sesame seeds[1)]

Parameter	Tratments[2)]			
	Control	SN5	SN10	SN15
Appearance	5.88±0.046	6.63±0.056	6.63±0.064	6.38±0.049
Color	6.12±0.034	6.28±0.061	6.22±0.044	6.17±0.059
Aroma	6.33±0.077	6.12±0.104	6.24±0.031	5.83±0.078
Crispiness	5.38±0.136^{a}	6.13±0.118^{b}	6.19±0.064^{bc}	6.22±0.093^{c}
Juiciness	5.78±0.033^{a}	6.08±0.041^{b}	6.27±0.026^{c}	5.94±0.036^{ab}
Texture	6.59±0.040^{d}	6.13±0.057^{b}	6.38±0.069^{c}	5.63±0.322^{a}
Flavor	6.39±0.025^{b}	6.21±0.036^{ab}	6.53±0.054^{c}	5.50±0.027^{a}
Overall acceptability	6.23±0.039^{c}	6.11±0.055^{b}	6.25±0.146^{c}	5.44±0.093^{a}

[1)] Values represented as mean±SD of six replicates per treatment.
[2)] Control, nuggets with 0% RSS (w/w); SN5, nuggets with 5% RSS (w/w); SN10, nuggets with 10% RSS (w/w); SN15, nuggets with 15% RSS (w/w).
[a-d]Values in a row with different superscripts differ significantly ($p<0.05$).
RSS, roasted sesame seeds.

Table 2. pH values of chicken nuggets as affected by different levels of roasted sesame seeds and frozen storage period[1)]

Period	Treatments[2)]		
	Control	SN5	SN10
Day 0	6.73±0.015^{Ay}	6.68±0.010^{Axy}	6.67±0.306^{Ax}
Day 7	6.33±0.050^{B}	6.36±0.051^{B}	6.37±0.021^{B}
Day 14	6.34±0.030^{B}	6.35±0.006^{B}	6.34±0.026^{B}
Day 21	6.29±0.025^{B}	6.34±0.035^{B}	6.30±0.057^{B}
Day 28	6.26±0.017^{B}	6.29±0.032^{B}	6.26±0.053^{B}

[1)] Values represented as mean±SD of six replicates per treatment.
[2)] Control, nuggets with 0% RSS (w/w); SN5, nuggets with 5% RSS (w/w); SN10, nuggets with 10% RSS (w/w).
[A,B]Values in the same column with different superscripts differ significantly ($p<0.05$).
[x,y]Values in the same row with different superscripts differ significantly ($p<0.05$).
RSS, roasted sesame seeds.

increasing frozen storage period.

Water holding capacity and cooking loss

The WHC of chicken nuggets were affected by the incorporation of different levels of RSS (Table 4; $p<0.05$). During the 28 days of frozen storage, the WHC of chicken nuggets were decreased ($p<0.05$) irrespective of the level of RSS incorporated and a higher overall reduction was shown by the control compared to SN5 and SN10. Table 5 indicates that the cooking loss values increased ($p<0.05$) during the 28-d frozen storage irrespective of the level of RSS incorporated. Significantly higher ($p<0.05$) WHC values were shown by SN10 compared to SN5 every week.

Color values

The influence of incorporation of RSS on color values of chicken nuggets is shown in Table 6. CIE a*, CIE b*, and CIE L* values of all three nugget types fluctuated from d 1 to d 28 of the frozen storage. The level of RSS did not affect ($p>0.05$) CIE a* and CIE b* values until 2 wks and 3 wks, respectively.

Microbiological stability

The changes observed in the TPC of chicken nuggets

Table 3. Thiobarbituric acid reactive substance values (MDA; mg/kg) of chicken nuggets as affected by different levels of roasted sesame seeds and frozen storage period[1)]

Period	Treatments[2)]		
	Control	SN5	SN10
Day 0	0.04±0.004^{Ax}	0.04±0.005^{Ax}	0.05±0.004^{Ay}
Day 7	0.09±0.012^{Bx}	0.11±0.018^{By}	0.13±0.011^{Bz}
Day 14	0.18±0.015^{Cx}	0.49±0.049^{Cy}	0.63±0.062^{Cz}
Day 21	0.45±0.054^{Dx}	0.65±0.062^{Dy}	0.83±0.077^{Dz}
Day 28	0.55±0.063^{Ex}	0.79±0.072^{Ey}	1.01±0.094^{Ez}

[1)] Values represented as mean±SD of six replicates per treatment.
[2)] Control, nuggets with 0% RSS (w/w); SN5, nuggets with 5% RSS (w/w); SN10, nuggets with 10% RSS (w/w).
$^{A–E}$Values in the same column with different superscripts differ significantly ($p<0.05$).
$^{x–z}$Values in the same row with different superscripts differ significantly ($p<0.05$).
MDA, malondialdehyde; RSS, roasted sesame seeds.

Table 4. Water holding capacity (%) of chicken nuggets as affected by different levels of roasted sesame seeds and frozen storage period[1)]

Period	Treatments[2)]		
	Control	SN5	SN10
Day 0	97.58±0.318^{Dy}	95.38±0.215^{Bx}	97.22±0.456^{Cy}
Day 7	94.30±0.883^{C}	94.35±0.613^{B}	93.87±0.522^{BC}
Day 14	91.38±0.259^{Bx}	93.64±0.167^{By}	92.50±0.724^{By}
Day 21	91.10±0.816^{Bxy}	89.36±0.947^{Ax}	91.89±0.804^{By}
Day 28	82.77±1.395^{A}	87.27±1.921^{A}	84.16±1.589^{A}

[1)] Values represented as mean±SD of six replicates per treatment.
[2)] Control, nuggets with 0% RSS (w/w); SN5, nuggets with 5% RSS (w/w); SN10, nuggets with 10% RSS (w/w).
$^{A–D}$Values in the same column with different superscripts differ significantly ($p<0.05$).
$^{x–y}$Values in the same row with different superscripts differ significantly ($p<0.05$).
RSS, roasted sesame seeds.

Table 5. Cooking loss (%) of chicken nuggets as affected by different levels of roasted sesame seeds and frozen storage period[1)]

Period	Treatments[2)]		
	Control	SN5	SN10
Day 0	1.38±0.085^{Ax}	1.42±0.032^{Ax}	2.00±0.036^{Ay}
Day 7	2.00±0.116^{Bx}	2.32±0.069^{By}	3.17±0.033^{Bz}
Day 14	2.47±0.249^{BCx}	2.97±0.050^{Cy}	3.45±0.119^{Cz}
Day 21	2.75±0.075^{Cx}	3.34±0.291^{Cy}	4.11±0.129^{Dz}
Day 28	4.22±0.297^{D}	3.96±0.155^{D}	4.24±0.116^{D}

[1)] Values represented as mean±SD of six replicates per treatment.
[2)] Control, nuggets with 0% RSS (w/w); SN5, nuggets with 5% RSS (w/w); SN10, nuggets with 10% RSS (w/w).
$^{A–D}$Values in the same column with different superscripts differ significantly ($p<0.05$).
$^{x–z}$Values in the same row with different superscripts differ significantly ($p<0.05$).
RSS, roasted sesame seeds.

Table 6. Colour values of chicken nuggets as affected by different levels of roasted sesame seeds and frozen storage period[1)]

Period	Treatments[2)]		
	Control	SN5	SN10
CIE L*			
Day 0	50.56±0.235^{Ay}	49.02±0.520^{Ax}	50.29±0.838^{ABxy}
Day 7	52.23±0.555^{B}	52.30±0.776^{B}	52.27±0.594^{B}
Day 14	54.55±0.225^{Cz}	50.83±0.303^{ABy}	48.63±0.746^{Ax}
Day 21	53.46±0.600^{BCy}	53.22±0.483^{Cy}	50.24±0.656^{ABx}
Day 28	52.30±0.691^{B}	52.46±1.178^{BC}	51.06±0.392^{AB}
CIE a*			
Day 0	11.54±0418^{C}	11.59±0.322^{C}	10.88±0.209^{B}
Day 7	10.27±0.211^{B}	10.24±0.225^{AB}	10.69±0.347^{B}
Day 14	9.95±0.166^{ABx}	10.55±0.0985^{By}	9.78±0.121^{Ax}
Day 21	9.73±0.102^{ABx}	9.71±0.085^{Ax}	10.33±0.135^{ABy}
Day 28	9.48±0.243^{A}	9.39±0.165^{A}	9.76±0.116^{A}
CIE b*			
Day 0	27.80±0.314^{B}	28.71±0.533	27.73±0.608^{AB}
Day 7	27.20±0.487^{AB}	27.70±0.681	28.20±0.830^{AB}
Day 14	28.80±0.049^{C}	28.33±0.929	27.93±0.153^{AB}
Day 21	26.43±0.380^{Ax}	27.91±0.066^{y}	28.51±0.387^{By}
Day 28	26.48±0.475^{A}	27.60±0.534	27.06±0.326^{A}

1) Values represented as mean±SD of six replicates per treatment.
2) Control, nuggets with 0% RSS (w/w); SN5, nuggets with 5% RSS (w/w); SN10, nuggets with 10% RSS (w/w).
A–C Values in the same column with different superscripts differ significantly (p〈0.05).
x–z Values in the same row with different superscripts differ significantly (p〈0.05).
RSS, roasted sesame seeds.

prepared with or without incorporation of selected levels of RSS during 28 d of frozen storage period under frozen condition (−18℃) are presented in Table 7. TPC values increased (p<0.05) over the frozen storage period irrespective of the level of RSS incorporated. However, no significant effect (p>0.05) was found among the treatments at individual test dates. *Salmonella* and *E. coli* were not detected in any chicken nugget during the frozen storage period.

Proximate composition

The proximate composition of chicken nuggets as affected by different levels of RSS are presented in Table 8. SN10 had higher (p<0.05) ash, crude fat and crude protein contents compared to control and SN5. Nonetheless, nuggets free from RSS had obtained a greater (p<0.05) moisture content than did SN5 and SN10.

Discussion

Enhancement of some sensory properties, especially flavor, was achieved by the incorporation of RSS at moderate levels into the nuggets. Borchani et al. (2010) reported that sesame seeds release sesame oil during frying and contain a high amount of unsaturated fats. Tangkham and LeMieux (2017) stated that higher levels of unsaturated fats affect the flavor of a product. The significantly higher crispiness and juiciness of RSS-incorporated nuggets may be due to the lower moisture and higher fat contents reported in the RSS-incorporated nuggets, respectively (Table 8).

The present study revealed that the incorporation of different levels of RSS had a significant effect on the pH of chicken nuggets. This could be attributed to the fact that the release of free amino groups from the sesame oils (free SH groups) may increase the pH of RSS-incorporated nuggets at high temperatures compared with sesame-free nuggets (Lawrie, 1998).

Table 7. Total plate count (log CFU/g) of chicken nuggets as affected by different levels of roasted sesame seeds and frozen storage period[1)]

Period	Treatments[2)]		
	Control	SN5	SN10
Day 0	5.77±0.133^{A}	5.77±0.097^{A}	5.69±0.088^{A}
Day 7	5.99±0.056^{B}	5.92±0.042^{A}	6.02±0.036^{B}
Day 14	6.10±0.035^{BC}	6.11±0.043^{B}	6.12±0.055^{B}
Day 21	6.27±0.049^{C}	6.25±0.054^{BC}	6.31±0.065^{C}
Day 28	6.29±0.031^{C}	6.31±0.027^{C}	6.33±0.012^{C}

[1)] Values represented as mean±SD of six replicates per treatment.
[2)] Control, nuggets with 0% RSS (w/w); SN5, nuggets with 5% RSS (w/w); SN10, nuggets with 10% RSS (w/w).
[A–C]Values in the same column with different superscripts differ significantly ($p<0.05$).
[x–z]Values in the same row with different superscripts differ significantly ($p<0.05$).
RSS, roasted sesame seeds.

Table 8. Proximate composition of chicken nuggets as affected by different levels of roasted sesame seeds[1)]

Parameter (%)	Treatments[2)]		
	Control	SN5	SN10
Moisture	50.12±0.032^{z}	47.17±0.299^{y}	42.78±0.423^{x}
Ash	2.72±0.045^{x}	2.86±0.061^{y}	3.15±0.091^{z}
Crude fat	6.75±0.077^{x}	8.02±0.111^{y}	8.84±0.130^{z}
Crude protein	12.01±0.167^{x}	13.25±0.206^{y}	14.24±0.276^{z}

[1)] Values represented as mean±SD of six replicates per treatment.
[2)] Control, nuggets with 0% RSS (w/w); SN5, nuggets with 5% RSS (w/w); SN10, nuggets with 10% RSS (w/w).
[x–z]Values in the same row with different superscripts differ significantly ($p<0.05$).
RSS, roasted sesame seeds.

Similarly, Korkeala et al. (1990) and Teruel et al. (2015) reported a gradual decrease in pH in chicken nuggets and ring sausages due to the growth of microorganisms and acid formation, respectively. However, the pH decrement observed in the current study was within the permitted range (4.8 to 6.8) for meat products (Lengkey and Lobo, 2016).

The increase in TBARS values of RSS-incorporated nuggets, compared to the control, can be attributed to the presence of a high amount of unstable and loosely bound polyunsaturated fatty acids in the sesame oil that initiate and facilitate lipid oxidation (Borchani et al., 2010). However, all TBARS values reported in the study during the 28-d frozen storage were within the permitted levels in which no rancidity in meat and meat products would be observed, i.e., MDA 2.0–2.5 mg/kg (Domínguez et al., 2019).

The results of the current study concerning WHC can be explained by the findings of Confrades et al. (2000), who showed that the physical structure and pH value of a meat product directly affects the WHC and cooking loss. With the frozen storage, the structure becomes denatured and the water-binding ability of the product is reduced, resulting in a lower WHC and increased cooking loss. Ice crystal formation at −18℃ may damage the tissue structure and result in drip loss during thawing (Teruel et al., 2015; Totosaus, 2012). However, the results of the present study are not in agreement with those of Confrades et al. (2000), who explained that the WHC of nuggets could be enhanced by the incorporation of RSS because of the higher water and fat binding properties of dietary fibers in sesame seeds.

The loss of redness in nugget samples over the frozen storage period can be attributed to the formation of metmyoglobin in meat products (Suckow et al., 2016; Teruel et al., 2015). The higher fiber content in plant ingredients can enhance the CIE L* of meat products (Bhosale et al., 2011). However, this was not observed in the present study with the incorporation of RSS into chicken nuggets. In addition, previous studies by Yasarlar et al. (2007) and Yadav et al. (2016) reported similar uneven changes in the CIE L*, CIE a*, and CIE b* of meat products after the incorporation of different cereals.

The total plate count of nuggets was well below the permitted levels (i.e., 30-300 colonies), which can be attributed to good manufacturing and handling practices applied in commercial manufacturing facilities. The cleanliness of the raw materials and hygienic practices used during the preparation and packaging of chicken nuggets led to zero *Salmonella* and *E. coli* counts. The results of the present study were comparable to the findings of Nag et al. (1998), who reported an increase in the TPC of chicken nuggets supplemented with rice flour during the frozen storage period. In addition, deep-frying of nuggets at higher temperatures could eliminate the coliform count (Bhat et al., 2011).

Serdaroğlu and Değırmencioğlu (2004) observed a significant reduction in moisture content with increased fat levels in beef sausages. This was in line with the results of the current study, in which SN5 and SN10 had high-fat content had lower moisture levels. Fat and moisture compete for space in the protein matrices in the product, and a higher portion of the protein binds with fat, while a small amount of protein binds with water (Warriss, 2001; Xiong, 1997). This could have resulted in lower moisture content in the higher-fat-containing products. The increase in fat, protein and ash contents of SN5 and SN10 compared to the control nuggets can be attributed to the fact that sesame seeds are rich in oils (43.3%–44.3%), protein (18.3%–25.4%), and minerals (5.2%–6.2%) (Anilakumar et al., 2010; Borchani et al., 2010).

Conclusion

The sensory properties of nuggets can be improved by the incorporation of up to 10% of RSS in the nugget mixture. The incorporation of RSS enhanced the ash, crude fat, and crude protein content of chicken nuggets. In addition, RSS increased the TBARS values of chicken nuggets, although they were within acceptable levels.

Conflicts of Interest

The authors declare no potential conflict of interest.

Acknowledgments

The authors are grateful to Nelna Farm (Pvt) Ltd, Sri Lanka for providing facilities to conduct this study. The authors would like to acknowledge, Ms. Sarangi Karunarathna and Mr. Thilina Jayasinghe from the Meat Science and Research Laboratory, Uva Wellassa University, Sri Lanka.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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Date Received Jun. 30, 2021
Date Revised Jul. 12, 2021
Date Accepted Jul. 13, 2021