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FOOD SCIENCE & TECHNOLOGY | SHORT COMMUNICATION

Seasonal effects on proximal composition of male and female giant squid (*Dosidicus gigas*) and its rheological properties of surimi

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Abstract: Giant squid adults of both sexes were used in different seasons. Grounded meat of each one were used to determine proximate composition, ammonia-nitrogen, trimethyl amine contents, and viscosity. Simultaneously, surimi was prepared from each specimen to measure its gel strength. The moisture and protein values were between 81.2–86.9 and 10.5–16.4% respectively. They showed significant variations during summer in both sexes. The moisture: protein ratio was significantly lower in summer, showing greater variability among males. When protein is transformed to a dry basis, differences between sexes are observed in winter and spring. Ammonia nitrogen was about 310.0 mg% and trimethylamine content was below 3.0 mg%. The apparent viscosity and gel strength values were significantly lower during winter, presenting males the lowest average values.

Subjects: Food Science & Technology; Food Chemistry; Seafood; Food Analysis

Keywords: cephalopods gender difference; proximal composition; myofibrillar protein; gel strength; ammonia nitrogen

1. Introduction

Giant squid (*Dosidicus gigas*) is a cephalopod widely distributed in Oriental Pacific Ocean (latitude between 35° and 47° S); it has a short life cycle and high metabolic rate related to a fast growth (Nigmatullin, Nesis, & Arkhipkin, 2001). In Peru, its capture increased during that last decade (reaching 556 156 MT), which represents 17.3% of total unloaded capture of fishery resources in the country (Ministerio de la Producción, 2014).

Given the white color of its meat, the giant squid is a high protein resource that can be used to prepare preformed products based on surimi (Campo-Deaño, Tovar, Jesús Pombo, Teresa Solas, & Javier Borderías, 2009; Sánchez-Alonso, Careche, & Borderías, 2007). Surimi is a Japanese term that

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PUBLIC INTEREST STATEMENT

Giant squid surimi is a myofibrillar protein (flesh) washed and separated from other soluble compounds and then stored under freezing conditions, which is used to prepare several imitation products taking advantage principally of its white color and its rheological properties. It has been observed in some processing plants of giant squid surimi, considerable quality variations having a negative effect on production costs. This work demonstrates that both genders as seasonal variation may interfere with the properties of surimi prepared from giant squid.

defines the myofibrillar protein washed and/or separated from other soluble compounds to which sugar is added as crioprotectors, and then stored under freezing conditions; it is used to elaborate several imitation products taking advantage of its rheological properties (Park, 2005, p. 35).

There are quantitative and qualitative meat protein variations in cephalopods, these are associated with seasonal changes and rheological properties. Ozogul, Duysak, Ozogul, Özkütük, and Türeli (2008) reported slight seasonal variations in the total protein content of *Sepia officinalis*, *Loligo vulgaris*, *Octopus vulgaris* and *Eledone moschata*. Thereafter, this group reported higher differences in *S. officinalis* when included gender and sexual maturity in a different season (Ayas, Ozogul, Ozogul, & Uçar, 2012). Moreover, Kilada and Riad (2008, 2010) showed also these differences in *Loligo forbesi* y *Uroteuthis duvauceli*.

Freshness, sexual maturity and seasonal factors have effects on surimi quality (Morrisey & Park, 2000). It has been observed in some processing factories of giant squid surimi, considerable variations of gel strength, which is the parameter most commonly used to measure the surimi quality; all this can have a negative effect on the production costs. These variations have been associated with capture season

Under these terms, Ezquerro-Brauer, Haard, Ramírez-Olivas, Olivas-Burrola, and Velazquez-Sánchez (2002) reported differences in the amount of protein and proteolytic activity among squid captured in different time periods (April and November). Likewise, Moreno, Cardoso, Solas, and Borderías (2009) found differences in the strength of surimi gel obtained by isoelectric precipitation of species captured in different seasons. Apparently, seasonal changes affect the proteolytic activity of muscle and subsequently affect surimi during storage.

The objective of this study was to measure the proximal composition and rheological properties of giant squid to relate with seasonal variation and gender.

2. Materials and methods

Male and female adult giant squid specimens were used (three of each), obtained from Matarani port (Peru, 16°59' LS), during the four seasons of the year. Once captured, specimens were eviscerated and submerged on ice (<4°C). Biometric measurements were taken from the mantle with no heads, nor tentacles. Physical and chemical assays were performed in the central part of each specimen 24–30 h of being captured.

Proximal composition was determined on samples of all muscles according to FAO manuals (1986) with minor modifications; fat content was determined with Soxhlet extractor with ethylic ether as solvent, ash content by igniting a ca. 3–5 g test sample in a furnace at 550°C until light grey, moisture content by oven drying a ca. 3–5 g test sample at 102°C to a constant weight; total nitrogen was quantified by Kjeldhal. Ammonia nitrogen was measured by adding Nessler reactive (ASTM, 2008) to trichloroacetic acid - deproteinized samples. Total protein content was obtained by multiplying by 6.25 the difference between total nitrogen and ammonia nitrogen. Trimethylamine (N-TMA) content was evaluated by micro diffusion in a Conway chamber (Clancy, Beames, Higgs, & Donsanjh, 1995). Apparent viscosity was measured to mincemeat (50 g) dissolved with 200 mL of sodium phosphate buffer [0.2 M, pH 7.0] cold (2–4°C); the solution contained NaCl 5% (wt/vol). The measures were realized with a rotational viscometer Tokio-Rikukai and the values were expressed in centipoises (cp) (Gomez-Guillen, Martinez-Alvarez, & Montero, 2003).

Surimi was prepared according to Maza, Solari, and Albrecht-Ruiz (2008), squid pieces were grounded and washed initially with a saline solution with citric acid (pH 4.0) and then with a bicarbonate solution to neutralize it. After that it was washed with cold water and pressed until reaching approximately 75% moisture; it was homogenized in mixer/cutter adding 4% sugar, 4% sorbitol and 0.3% polyphosphate. It was frozen at below –20°C during one week. Gel strength of surimi from each specimen, was evaluated by the puncture test, using a Rheo Tex SD-700 reometer, with a spindle penetration of 5 mm at 60 mm/min.

Physical and chemical analysis were conducted in specimens one by one. Proximal composition, ammonia nitrogen, N-TMA and apparent viscosity were done by replicate; strength force was measured in twelve jellified samples.

Statistical analysis: Linear regression was done for results of length vs. weight and moisture vs. protein. Data was analyzed with multifactorial ANOVA procedure and Fisher's Least Significant Difference (LSD) test ($p < 0.05$) using STATGRAPHICS Centurion program version XVI.

3. Results and discussion

Length and weight of mantles were lineally related [Y (cm) = 2.599 X (kg) + 52.386; $R^2 = 0.867$], supporting the fact that the specimens sampled were adults (Nigmatullin et al., 2001). The weight of mantles was found between 4.70 and 12.95 kg and the length between 61 and 87 cm.

The fat content of giant squid was found to be very low ($0.46 \pm 0.06\%$) and there was no relation with gender nor capture season. These results differ with Ozogul et al. (2008) and Ayas et al. (2012) who reported lipid contents of males higher than females for all seasons. No differences were observed between the levels of ash of males and females during all seasons, its content was $1.20 \pm 0.13\%$.

Moisture and protein content in mantles were inversely related [Y (% protein) = $-0.968 X$ (% moisture) + 94.573; $R^2 = 0.809$] moisture content was found between 81.1 and 86.9%, while protein content varied between 10.1 and 16.4%. Independently of genus or season, weight had direct relation with moisture and an inverse relation with protein content ($p < 0.05$).

Nitrogen ammonia (N-NH₃) was found around 310 ± 83 mg/100 g and showed no significant variations, with no relation to weight or the length mantle. Those results do not correspond with Iida, Nakamura, and Tokunaga (1992) and Yamanaka, Matsumoto, Hatae, and Nakaya (1995), who reported a direct relation between length and CINH₃ content.

Table 1. Proximal composition, ammonia nitrogen and trimethylamine content of male and female Giant squid in different seasons

Assay	Winter	Spring	Summer	Autuum	Sex
Moisture (%)	84.24 ± 1.43^{abc}	84.52 ± 1.57^{ab}	82.89 ± 0.80^{bc}	85.06 ± 1.63^{ab}	F
	85.53 ± 0.98^a	85.49 ± 1.58^a	81.97 ± 0.71^c	85.13 ± 1.73^{ab}	M
Protein (%)	12.79 ± 1.42^{abc}	12.90 ± 1.61^{abc}	14.31 ± 1.00^{ab}	12.34 ± 1.75^{bc}	F
	11.11 ± 0.85^c	11.46 ± 1.71^c	15.04 ± 1.21^a	12.45 ± 1.81^{abc}	M
Protein (dry basis) (%)	81.02 ± 1.68^{ab}	83.25 ± 2.47^{ab}	83.60 ± 3.04^{ab}	82.42 ± 3.46^{ab}	F
	76.74 ± 0.69^b	78.78 ± 3.47^{ab}	83.34 ± 3.37^{ab}	83.72 ± 6.37^a	M
Crude fat (%)	0.44 ± 0.02^b	0.48 ± 0.05^{ab}	0.42 ± 0.05^b	0.46 ± 0.04^b	F
	0.57 ± 0.02^a	0.41 ± 0.06^b	0.42 ± 0.09^b	0.48 ± 0.02^{ab}	M
Ash (%)	1.13 ± 0.05	1.34 ± 0.06	1.25 ± 0.06	1.08 ± 0.13	F
	1.08 ± 0.02	1.31 ± 0.10	1.30 ± 0.08	1.09 ± 0.13	M
Ammonia nitrogen (mg N/100 g)	330 ± 50	211 ± 53	369 ± 97	318 ± 54	F
	414 ± 7	255 ± 63	326 ± 34	293 ± 127	M
Trimethylamine (mg N-TMA/100 g)	1.17 ± 0.20	1.39 ± 0.01	1.39 ± 0.02	2.20 ± 0.04	F
	1.42 ± 0.53	1.84 ± 0.45	1.81 ± 0.42	2.22 ± 0.47	M

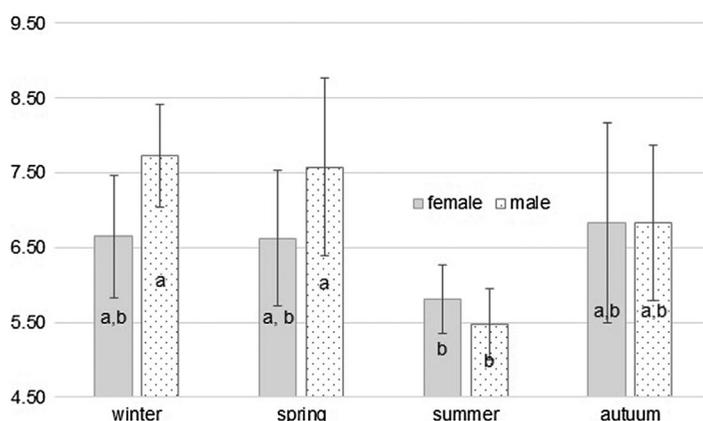
Notes: Means of 3 determinations \pm standard deviation.

For each assay, values different letters (are significantly different ($p < 0.05$) according to LSD test.

Results of crude fat, ash, ammonia nitrogen and trimethylamine didn't presented significant differences by seasonal nor by gender.

Figure 1. Seasonal influence on moisture:protein ratio (M:P) in giant squid’s mincemeat.

Notes: Values represent the mean of at least three replicates; whisker lines indicate SD; different letters indicate significant differences at $p < 0.05$.



Lower moisture contents were observed during the summer, although only males presented significant differences ($p < 0.05$). Likewise, higher protein contents were observed in the summer but without significant differences (Table 1); when protein values are converted to dry basis, males of winter and spring presented lower values although with no significant differences.

Also, when moisture: protein ratio (M:P) is compared by gender, no significant differences between them were observed, however, this relation was more constant in females (Figure 1), it could be the cause to more consistence doughy. It is noteworthy that in summer M:P ratio shows a significantly lower value in both sexes; possibly as a result of spawning period, as indicated Tafur, Villegas, Rabí, and Yamashiro (2001) who suggest that this occurs between spring and summer in the southern hemisphere.

N-TMA content was around 1.7 ± 0.5 mg/100 g. N-TMA was always less 3.0 mg N/100 g, these results were similar to those reported by Yamanaka et al. (1995) and Márquez-Ríos, Morán-Palacio, Lugo-Sánchez, Ocano-Higuera, and Pacheco-Aguilar (2007), supporting its freshness microbiological condition.

Gender had an influence on apparent viscosity values and gel strength. Always appearing higher values in females ($p < 0.05$). Likewise, seasonality significantly influenced ($p < 0.05$) on apparent viscosity and gel strength, presenting the lowest values in winter compared to summer and autumn (Table 2).

Apparent viscosity and gel strength were always higher in females than males but the variability of results did not allow a definitive statistical conclusion (Figure 1). The relationship between viscosity and gel strength was linear [Y (gr.cm) = $0.149 X$ (cp) + 94.785 ; $R^2 = 0.885$], this may also serve as quality criteria of raw material in the process of surimi squid (Borderías, Jimenez-Colmenero, &

Table 2. Apparent viscosity in homogenates of male and female giant squid and gel straight of corresponding surimi

	Viscosity (cp)		Gel straight (g.cm)	
	Female	Male	Female	Male
Winter	589 ± 61 ^{de}	373 ± 50 ^e	191 ± 22 ^{cd}	160 ± 51 ^d
Spring	1,087 ± 246 ^{cde}	702 ± 321 ^{ab}	238 ± 29 ^{bc}	197 ± 48 ^{cd}
Summer	1,424 ± 234 ^{ab}	1,095 ± 250 ^a	228 ± 46 ^{bc}	209 ± 12 ^{cd}
Autuum	1,078 ± 19 ^{bcd}	858 ± 306 ^{abc}	326 ± 25 ^a	280 ± 47 ^{ab}

Notes: Viscosity Means of 3 determinations ± standard deviation; results are expressed in centipoises (cp).

Gel straight Means of 12 determinations ± standard deviation, results are expressed in grams per centimeter (g.cm).

For each assay, values different letters are significantly different ($p < 0.05$) according to LSD test.

Tejada, 1985). When linking protein to viscosity or gel strength no significant variation was found, although it is remarkable to note lower protein content and lower values of apparent viscosity and gel strength in winter.

4. Conclusions

Surimi processing from giant squid appears to be affected by their functional properties by seasonal variation and gender. We have observed lower moisture, higher protein and lower M:P ratio during summer. Homogenized meat females had a consistency more viscous paste than males, which presented greater variability of results. The content of N-TMA in fresh squid that was less than 3 mg% and may be a possible indicator of quality for this species. The apparent viscosity of the meat solution and corresponding gel strength of surimi showed the lowest values in winter and they have no correlation between them, being males the ones that had lower and more variable values than females.

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Competing Interest

The authors declare no competing interests.

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