A comparative study of lipid composition of an under-valued crustacean (*Munida* spp.) captured in winter and summer

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ABSTRACT

This research was focused on the lipid fraction of an under-valued crustacean (lobster krill; *Munida* spp.), being its basic objective the comparative study of individuals captured at winter and summer seasons. For this purpose, seasonal variations were analysed in the muscle (i.e., tail meat) for proximate composition, lipid classes distribution and fatty acids profile. As a result, mean total lipids ranged from 0.75±0.08 % (summer) to 0.92±0.06 % (winter), moisture from 77.94±0.25 % (winter) to 78.62±0.38 % (summer) and protein from 17.93±0.46 % (summer) to 18.22±0.46 % (winter). Concerning lipid classes content (% of total lipids), phospholipids ranged from 64.85±1.29 (summer) to 67.85±2.56 (winter), sterols from 12.15±0.35 (winter) to 13.54±0.54 (summer), triacylglycerols from 0.04±0.02 (summer) to 1.25±0.88 (winter) and free fatty acids from 1.14±0.72 (winter) to 2.19±0.34 (summer). In both seasons, the most abundant fatty acids (FA) were C22:6ω3, C16:0, C18:1ω9 and C20:5ω3. PUFA were found as the most abundant group in individuals from both seasons (50.4-55.3 %). Higher PUFA values were determined in summer samples, while a highly-valuable ω3/ω6 ratio (from 9.11±1.12 in summer to 10.40±1.39 in winter) was observed. It is concluded that in spite of being a low-fat product, the lipid fraction of this under-utilised crustacean can provide highly-valuable constituents.

Running head: *Munida* spp. lipids in winter and summer

Key words: Lobster krill; tail muscle; seasonal variations; proximate composition; lipid classes; fatty acids

INTRODUCTION

Seafood products are known to provide great amounts of different beneficial nutrients such as highly-nutritional and digestible proteins, lipid-soluble vitamins, essential minerals and highly unsaturated fatty acids (Simopoulos, 1997; Ortiz et al., 2013). Marine lipids are now the subject of a great deal of attention due to their high content of ω3 polyunsaturated fatty acids (PUFA). Among such fatty acids, a great attention has been accorded to the two most abundant components, i.e., C22:6ω3 (docosahexaenoic acid, DHA) and C20:5ω3 (eicosapentaenoic acid, EPA) (Sveinsdóttir et al., 2016). Thus, C22:6ω3 has been reported to contribute to the development of certain physiological functions related to the nervous system and visual functions in human beings (Linko and Hayakawa, 1996), while C20:5ω3 has been reported to be beneficial for human health as it reduces the risk of cardiovascular diseases (Hall et al., 2008).

Marine species have shown wide lipid content variations as a result of endogenous and exogenous effects (Pearson et al., 1977; Piclet, 1987). On one hand, lipid matter has been described to exhibit a heterogeneous distribution throughout the body of marine species, probably affected by physiological factors (Sieiro et al., 2006). On the other hand, seasonal variation was considered to play a key role on temperature, feeding availability and other external factors affecting lipid content in different types of marine species (Bandarra et al., 2001). Consequently, an important effect of the seasonal variation on the level of lipid damage has been reported in processed marine species (Aubourg, 1999; Romotowska et al., 2016).

The marine food industry is suffering from dwindling stocks of traditional species as a result of drastic changes in their availability and legal limitations in their capture. Thus, seafood manufacturers and technologists are according an increasing

attention to new and non-conventional sources. Among them, lobster krill, also called squat lobster, a decapod crustacean belonging to the genus *Munida* (Family *Galatheidae*, Order *Decapoda*), represents a relevant and promising choice. Lobster krill lives mainly in the Atlantic Ocean, but is also abundant at deep Mediterranean bottoms. Biological and ecological items of different species belonging to this genus have been described previously (Freire et al., 1992; Company et al., 2003). Currently, lobster krill has no commercial value, but it is occasionally caught and discarded at sea during fishing targeted to other commercial fish species. Estimations from the Spanish Institute of Oceanography (IEO) for the period 2004-2008 have indicated that *Munida* spp. represent around 6 % of total discard weight in trawl fisheries targeting demersal species in the Northern Spanish coast (Pérez et al., 2008; García-López et al., 2016). Concerning previous technological studies, *Munida* spp. have shown a promising behaviour under chilling (García-Soto et al., 2015a) and frozen (García-Soto et al., 2015b) storage. Additionally, recent studies on their carotenoid composition (García-López et al., 2016) and proteolytic activity (D'Ambrosio et al., 2003) have opened the way to other issues of technological interest.

The present research was focused on the study of the lipid fraction of *Munida* spp. The basic objective of this study was to carry out a comparative study between individuals captured at winter and summer seasons. Seasonal variations were analysed in the muscle (i.e., tail meat) in proximate composition, lipid classes distribution and fatty acids profile.

MATERIALS AND METHODS

Raw material and sampling

Lobster krill was caught near the Galician Atlantic coast (North-Western Spain) in winter (January 2013) and summer (July 2013), stored on-board and transported to the laboratory. Throughout this process (about ten hours), *Munida* individuals were kept in ice. *Munida* specimens were characterised in terms of species identification, length and weight. Thus, individuals employed in the study were catalogued as included in the following species: *M. sarsi, M. tenuimana, M. rugosa and M. microphtalma*, being *M. sarsi* the most abundant. Further, carapace length and total weight were included in the following ranges: 3.2-4.3 cm and 9.5-11.0 g, respectively. Then, the edible flesh (i.e., tail muscle) was separated and used to undertake the different chemical analyses. At each season, 1.5 kg of lobster krill specimens were divided into three different groups of 0.5 kg each (n=3). In each group, the edible flesh of all individuals was pooled together and analysed independently.

All chemical analyses were carried out on the lobster krill muscle in triplicate. All solvents and chemical reagents used were of reagent grade (Merck, Darmstadt, Germany).

General composition analysis

The total lipid fraction was extracted from the *Munida* muscle by the Bligh and Dyer (1959) method, which employs a single-phase solubilisation of the lipids using a chloroform-methanol (1:1) mixture. Results were expressed as % on wet muscle basis. Throughout the study, lipid extracts were kept at –40ºC under nitrogen atmosphere.

97 Moisture content was determined as the weight difference in the *Munida* muscle
98 (1-2 g) before and after 4 h at 105ºC (AOAC, 1990). Results were expressed as % on
99 wet muscle basis.
100 Protein content was determined in the *Munida* muscle using the Kjeldahl method
101 (AOAC, 1990) with a conversion factor of 6.25. Results were expressed as % on wet
102 muscle basis.
103
104 **Lipid classes analysis**
105 Phospholipids (PL) were determined by measuring the organic phosphorus in the
106 total lipid extracts according to the Raheja et al. (1973) method, which is based on a
107 complex formation with ammonium molybdate. Results were expressed as % of total
108 lipid.
109 Sterols (ST) were determined on total lipid extracts by the method of Huang et
110 al. (1961), based on the Liebermann-Buchardt reaction. Results were expressed as % of
111 total lipid.
112 To measure the triacylglycerols (TAG) content, the total lipid extracts were first
113 purified on 20 x 20 cm thin-layer chromatography plates coated with a 0.5 mm-layer of
114 silica gel G from Merck (Darmstadt, Germany) using a mixture of hexane-ethyl ether-
115 acetic acid (90:10:1, v:v:v; two times) as eluent (Álvarez et al., 2009). Once the TAG
116 fraction was purified, the method of Vioque and Holman (1962) was used to measure
117 the ester linkage content according to the conversion of the esters into hydroxamic acids
118 and subsequent complexion with Fe (III). Results were expressed as % of total lipid.
119 Free fatty acids (FFA) content was determined in the total lipid extracts
120 following the Lowry and Tinsley (1976) method, which is based on the formation of a

121 complex with cupric acetate-pyridine. In this study, benzene was replaced by toluene as
122 organic solvent. Results were expressed as % of total lipid.
123
124 **Fatty acid (FA) analysis**
125 Total lipid extracts were converted into fatty acid methyl esters (FAME) by
126 reaction with acetyl chloride. FAME were then analysed by Gas-Liquid
127 chromatography (Perkin-Elmer 8700 gas chromatograph). For it, a fused silica capillary
128 column SP-2330 (0.25 mm i.d. x 30 m, 0.20 μm film, Supelco Inc., Bellefonte, PA,
129 USA), using nitrogen at 10 psi as carrier gas (linear flow rate of 1.0 ml/min) and a flame
130 ionisation detector (FID) at 250ºC were employed (Prego et al., 2012).
131 Qualitative analysis was carried out by comparison with the retention times of
132 two standard mixtures (Qualmix Fish, Larodan, Malmo, Sweden; FAME Mix, Supelco
133 Inc., Bellefonte, PA, USA). Peak areas were automatically integrated, being C19:0 fatty
134 acid employed as the internal standard for quantification purposes. Results concerning
135 individual FA and FA groups were expressed as % of total FA. The polyene index (PI)
136 was calculated as the following FA ratio: (C20:5ω3 + C22:6ω3)/C16:0.
137
138 **Statistical analysis**
139 Data obtained from the different chemical analyses were subjected to the
140 ANOVA method to explore differences as a result of the season. For this purpose, the
141 PASW Statistics 18 software for Windows (SPSS Inc., Chicago, IL, USA) was
142 employed. The comparison of means was performed using the least-squares difference
143 (LSD) method. Differences between both seasons were considered significant for a
144 confidence interval at the 95 % level ($p<0.05$) in all cases.
145

RESULTS AND DISCUSSION

Chemical composition

Lipid content (%) (Table 1) ranged from 0.75±0.08 (summer) to 0.92±0.06 (winter), so that higher values than those previously reported for this marine product were obtained (García-Soto et al., 2015a, 2015b). This lipid content is also higher than those determined in other crustacean species such as Norwegian lobster (*Nephrops norvegicus*) (0.70 %; Tsape et al., 2010), pink shrimp (*Parapenaeus longirostris*) (0.35 %; Cadun et al., 2005), shrimp (0.36 %; *Penaeus brasiliensis*), crab (0.49 %; *Ucides cordatus*) and lobster (0.66 %; *Panulirus argus*) (Pedrosa and Cozzolino, 2001). However, other crustacean species such as lobster (1.00 %; *Palinurus vulgaris*), shrimp (1.30 %; *Penaeus kerathurus*) (Tsape et al., 2010) and Dungeness crab (1.00 %; *Cancer magister*) (King et al., 1990) have shown higher lipid contents. Concerning seasonal variation (Table 1), a higher lipid content ($p<0.05$) was obtained in winter specimens. This result is in agreement with previous studies related to other crustacean species such as seabob shrimp (*Xiphopenaeus kroyeri*) (Luzia et al., 2003) and pink shrimp (*Pandalus borealis* and *Pandalus jordani*) (King et al., 1990). A higher lipid content in marine species during relatively colder periods (such as autumn and winter) has been explained on the basis of the previous prolonged effect of a rich feeding time (Piclet, 1987).

Moisture content (%) (Table 1) ranged from 77.94±0.25 (winter) to 78.62±0.38 (summer), which can be considered slightly lower than those previously reported for such marine product (79-83 %; García-Soto et al., 2015a, 2015b). However, moisture levels determined in this study can be considered similar to other crustacean species such as lobster (*Panulirus argus*) (Pedrosa and Cozzolino, 2001) and Dungeness crab (*Cancer magister*) (King et al., 1990). Higher moisture values ($p<0.05$) were found in

171 specimens corresponding to the summer time when compared with those of winter
172 season (Table 1). This result can be explained on the basis of an inverse ratio between
173 moisture and lipid contents, so that higher moisture contents are found in individuals
174 corresponding to relatively warmer seasons (Piclet, 1987). Such differences between
175 individuals from winter and summer seasons had already been obtained in previous
176 studies on pink shrimp (*Pandalus borealis* and *Pandalus jordani*) and other invertebrate
177 species such as sea scallop (*Argopecten grandis*) and California squid (*Loligo*
178 *opalescens*) (King et al., 1990).

179 The protein content (%) (Table 1) ranged from 17.93±0.46 (summer) to
180 18.22±0.46 (winter), which can allow us to conclude that *Munida* spp. represent an
181 interesting source of this valuable nutritional constituent (Simopoulos, 1997; Ortiz et
182 al., 2013). Compared to other crustacean species, protein values can be considered
183 similar to species such as Dungeness crab (*Cancer magister*) and pink shrimp
184 (*Pandalus borealis* and *Pandalus jordani*) (King et al., 1990), higher than shrimp
185 (*Penaeus brasiliensis*) and crab (*Ucides cordatus*) (Pedrosa and Cozzolino, 2001), but
186 lower than Norway lobster (*Nephrops norvegicus*) (Lourenço et al., 2009) and lobster
187 (*Panulirus argus*) (Pedrosa and Cozzolino, 2001). No differences between the protein
188 content of summer and winter specimens ($p>0.05$) were found (Table 1). No seasonal
189 effect has also been reported for other marine species throughout the different seasons
190 of the year (Piclet, 1987).

191

192 **Lipid class composition**

193 PL content (% of total lipid) ranged from 64.85±1.29 (summer) to 67.85±2.56
194 (winter) and showed no difference between seasons ($p>0.05$, Table 2). The
195 predominance of PL in total lipids is in agreement with previous reports on other

196 crustacean, mollusc and lean fish species (Pearson et al., 1977; Sieiro et al., 2006; Prego
197 et al., 2012). PL are known to be important constituents of cell membranes providing a
198 structural role in living bodies, so its presence in muscle is hardly affected by internal
199 anatomical and physiological factors. Although FA content and composition in PL has
200 been shown to be affected by the diet, the changes have shown to be relatively small
201 when compared with those of depot fats (Pearson et al., 1977).

202 ST content (% of total lipid) ranged from 12.15±0.35 (winter) to 13.54±0.54
203 (summer) (Table 2), similar to those reported for other crustacean species such as
204 Norway lobster (*Nephrops norvegicus*), lobster (*Palinurus vulgaris*) and shrimp
205 (*Penaeus kerathurus*) (Tsape et al., 2010). ST have been reported to contribute to
206 functional properties and play structural roles in living bodies (Pearson et al., 1977).
207 Previous studies on ST composition have shown that cholesterol is by far the
208 predominant sterol in species such as Norway lobster (*Nephrops norvegicus*), lobster
209 (*Palinurus vulgaris*), shrimp (*Penaeus kerathurus*) (Tsape et al., 2010), Dungeness crab
210 (*Cancer magister*) and pink shrimp (*Pandalus borealis* and *Pandalus jordani*) (King et
211 al., 1990). The results of the present study show a higher ST proportion in lipid matter
212 when considering the summer specimens. In agreement with the above-mentioned
213 structural role, no significant differences ($p>0.05$) were found between individuals
214 corresponding to both seasons when considering the ST content referred to wet muscle
215 basis (0.11 vs. 0.10 % for winter and summer specimens, respectively). No significant
216 ($p>0.05$) differences due to seasonal variability had also been found by Luzia et al.
217 (2003) when comparing seabob shrimp (*Xiphopenaeus kroyeri*) caught in summer and
218 winter seasons.

219 Results are very different when a depot lipid class like TAG is concerned. TAG
220 concentrations were remarkably lower than those obtained for ST and PL, with values

221 ranged from 0.04±0.02 (summer) to 1.25±0.88 (winter) (% of total lipid, Table 2). Such
222 lipid class distribution is in agreement with that observed in invertebrates (Sieiro et al.,
223 2006) and lean fish (Álvarez et al., 2009; Prego et al., 2012) species, but is considerably
224 different to that found in fatty fish species (Pearson et al., 1977). Contrary to the results
225 of this study, Tsape et al. (2010) found a higher TAG content in the lipid fraction of
226 crustacean species such as Norway lobster (*Nephrops norvegicus*), lobster (*Palinurus*
227 *vulgaris*) and shrimp (*Penaeus kerathurus*). In the current study, a significantly lower
228 TAG content ($p<0.05$) was observed in summer specimens when compared to the
229 winter season batch, this being in agreement with the lower lipid content found in
230 specimens belonging to the latter season. In this sense, a direct ratio between TAG and
231 total lipids contents has been reported in different kinds of marine species (Sieiro et al.,
232 2006; Álvarez et al., 2009).

233 The FFA content (% of total lipid) was ranged from 1.14±0.72 (winter) to
234 2.19±0.34 (summer) (Table 2), being such values similar to those determined in fresh
235 *Munida* spp. in previous studies (1.14-2.12 %; García-Soto et al., 2015a, 2015b). Lower
236 FFA values were reported, however, for other crustacean species such as Norway
237 lobster (*Nephrops norvegicus),* lobster (*Palinurus vulgaris*) and shrimp (*Penaeus*
238 *kerathurus*) (Tsape et al., 2010). A higher average FFA concentration was determined in
239 summer specimens when compared with the winter season counterparts (Table 2).
240 However, the differences were not significant ($p>0.05$). Such slight differences are in
241 agreement with the well-known inverse ratio between total lipid and FFA contents,
242 which has been described in fatty (Pearson et al., 1977) and lean (Álvarez et al., 2009;
243 Prego et al., 2012) fish species. The FFA values found in the current study correspond
244 to a very low development of lipid hydrolysis since analysis was carried out after the
245 catching/slaughtering steps. Accordingly, the FFA values observed would correspond to

246 the *in vivo* metabolic action of lipases and phospholipases on high-molecular-weight
247 lipids such as TAG and PL, respectively (Sikorski and Kolakowski, 2000).
248
249 **Fatty acids composition**
250 Although the same four acids were found as the most abundant (Table 3), a
251 different trend was observed when considering the percentaged share of these FA in the
252 total FA of winter specimen (C22:6ω3 > C16:0 > C18:1ω9 > C20:5ω3) and summer
253 specimen (C22:6ω3 > C20:5ω3 > C18:1ω9 > C16:0). Other remarkable FA were C18:0,
254 C18:1ω7 and C20:4ω6. Some significant differences ($p<0.05$) could be observed
255 between individuals from both seasons (Table 3). Thus, a higher content ($p<0.05$) of
256 C18:1ω7 was determined in winter specimens, while C20:4ω6, C20:5ω3 and C22:5ω3
257 FA contents proved to be higher ($p<0.05$) in the summer counterparts. With respect to
258 other fatty acids, higher average values of saturated (SFA) and monounsaturated
259 (MUFA) fatty acids were found in winter season specimens, while higher average
260 PUFA concentrations were found in summer counterparts. A previous study
261 investigated the FA composition of a cold acetone extract of *Munida* muscle (García-
262 López et al., 2016). Thus, C18:1ω9 was the most abundant FA, followed by C22:6ω3
263 and C16:0; other remarkable FA were C16:1ω7, C23:0 and C20:5ω3. The differences
264 between such results and those found in the present study can be explained on the basis
265 that different lipid extraction procedures were employed in both studies.
266 The results of the present study are in agreement with previous reports on the FA
267 profiles of the lipid fraction of other crustacean species. Tsape et al. (2010) found the
268 following decreasing percentaged share for the average values of the most abundant FA
269 of Norway lobster (*Nephrops norvegicus*) (C16:0 > C18:1ω9 > C22:6ω3 > C20:5ω3 >
270 C18:0), lobster (*Palinurus vulgaris*) (C16:0 > C18:1ω9 > C22:6ω3 > C20:5ω3 > C18:0)

271 and shrimp (*Penaeus kerathurus*) (C20:5ω3 > C16:0 > C22:6ω3 > C18:1ω9 >
272 C20:4ω6). Likewise, King et al. (1990) reported the following decreasing tendency for
273 Dungeness crab (*Cancer magister*) (C20:5ω3 > C22:6ω3 > C16:0 > C18:1ω9) and pink
274 shrimp (*Pandalus borealis* and *Pandalus jordani*) (C20:5ω3 > C16:0, C22:6ω3 >
275 C18:1ω9).

276 Previous reports on the effect of season on FA composition, such as Luzia et al.
277 (2003), did not show differences between seabob shrimp (*Xiphopenaeus kroyeri*)
278 specimens from summer and winter, being in all cases C16:0, C18:1ω9, C18:0,
279 C22:6ω3, C16:1 and C20:5ω3 the most abundant FA. However, Yanar and Çelik (2005)
280 found different FA concentration sequences for wild shrimp (*Penaeus semisulcatus*)
281 from January (C16:0 > C20:5ω3, C22:6ω3, C18:1ω9 > C18:0 > C16:1ω7) and July
282 (C18:1ω9 > C16:0 > C18:0 > C20:5ω3 > C16:1ω7 > C20:4ω6 > C22:6ω3), as well as
283 for the shrimp *Metapenaeus monoceros* when comparing specimens caught in January
284 (C20:4ω6 > C20:5ω3 > C16:0 > C22:6ω3 > C18:0) and July (C16:0 > C18:1ω9 >
285 C20:5ω3 > C18:0 > C16:1ω7).

286 A wide majority of the Western population does not consume adequate levels of
287 ω3 FA through natural dietary sources, such as marine species. Accordingly, great
288 attention has been paid to the ω3/ω6 ratio of foods included in the human diet. The
289 value of this ratio has shown to exert great effect on the development of certain health
290 problems (Knoch et al., 2009), being the recommended ratio for the whole diet near 1/6
291 (Simopoulos, 1994). In spite of being a low-fat product, it should be noted that in the
292 present study, specimens from both seasons exhibited ω3/ω6 ratios that could be
293 considered beneficial for fulfilling the recommended nutritional values.

294 FA groups and ratios are shown in Table 4. Higher average PUFA values were
295 found in summer specimens, while *Munida* specimens from winter season exhibited

296 higher SFA and MUFA average values. Differences in the PUFA and SFA
297 concentrations were found significant ($p<0.05$). PUFA were the major group in
298 individuals corresponding to both seasons, reaching values ranged from 50.46±0.44
299 (winter) to 55.25±0.16 (summer). Average total ω3- and ω6-PUFA contents were found
300 higher in summer specimens, being differences significant ($p<0.05$) when considering
301 the ω3 group. Moreover, the ω3/ω6 ratio ranged from 9.11±1.12 (summer) to
302 10.40±1.39 (winter), with higher average values in winter specimens. Finally, all kinds
303 of samples revealed a high PI score, being average values higher in summer specimens,
304 although differences were not significant ($p>0.05$). Present PI values are in agreement
305 with those previously described in previous research concerning this marine product
306 (2.49-2.56; García-Soto et al., 2015a, 2015b).

307 Previous studies focused on the lipid extract of different crustacean species
308 revealed a similar trend for the FA groups. Thus, Tsape et al. (2010) found PUFA to be
309 predominant in Norway lobster (*Nephrops norvegicus*), lobster (*Palinurus vulgaris*) and
310 shrimp (*Penaeus kerathurus*) muscle; in such study, different ω3/ω6 ratio values (4.74,
311 0.83 and 2.34, respectively) were obtained that could be explained on the basis of
312 internal (anatomical, physiological, etc.) and external (water temperature, feeding
313 availability, season, etc.) factors. A similar distribution of FA groups was obtained by
314 King et al. (1990) for Dungeness crab (*Cancer magister*), and pink shrimp (*Pandalus*
315 *borealis* and *Pandalus jordani*), being ω3 FA the most abundant PUFA in all species.
316 Finally, Yanar and Çelik (2005) studied the seasonal variability of the FA groups
317 distribution in two kinds of shrimp species (*Penaeus semisulcatus* and *Metapenaeus*
318 *monoceros*). As a result, both species showed a higher PUFA content in specimens
319 corresponding to January when compared with individuals from July.
320

CONCLUSIONS

Present results have provided a first approach about the proximate and lipid compositions of this under-valued crustacean product, with a special focussing on the comparative study of individuals caught in winter and summer seasons. Thus, total lipids, moisture and protein contents ranged from 0.75 to 0.92, 77.94 to 78.62 and 17.93 to 18.22 (% on wet muscle basis), respectively; winter specimens showed a higher ($p<0.05$) lipid content and a lower ($p<0.05$) moisture value. With respect to lipid classes, PL, ST, TAG and FFA contents ranged from 64.85 to 67.85, 12.15 to 13.54, 0.04 to 1.25 and 1.14 to 2.19 % of total lipid; the summer batch exhibited higher ($p<0.05$) ST and lower ($p<0.05$) TAG values. The most abundant FA were C22:6ω3, C16:0, C18:1ω9 and C20:5ω3 in all kinds of individuals. The PUFA group was by far the most abundant in individuals from both seasons (from 50.46±0.44 % in winter to 55.25±0.16 % in summer). Additionally, higher PUFA values were found in summer specimens, while winter *Munida* spp. specimens exhibited higher saturated FA values ($p<0.05$). A highly-valuable ω3/ω6 ratio (from 9.11±1.12 in summer to 10.40±1.39 in winter) was observed; further, all specimens exhibited a high PI score, being average values higher in summer specimens.

It is concluded that proximate and lipid composition of this under-valued product can be considered relatively similar to other crustacean products. In spite of being a low-fat product, the lipid fraction of this crustacean has shown to provide high proportions of highly-valuable constituents like PUFA, ω3-PUFA and highly-profitable FA ratios (i.e., ω3/ω6 and PI), which showed no seasonal variation. Additionally, this under-utilised product has shown a profitable protein content in order to be included in the human diet as such or in combination with other food components. Further research focused on compositional issues of lobster krill is needed to explore the practical

346 commercial and technological potential of this marine product as a new, attractive and
347 nutritious crustacean product for human consumption.
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461

TABLE 1

Chemical composition* of *Munida* caught at winter and summer seasons**

Constituent	Season	
	Winter	**Summer**
Lipids	0.92 b (0.06)	0.75 a (0.08)
Moisture	77.94 a (0.25)	78.62 b (0.38)
Proteins	18.22 a (0.46)	17.93 a (0.46)

* Average values of three (n=3) replicates. Standard deviations are indicated in brackets. For each constituent, average values followed by different letters (a, b) denote significant differences ($p<0.05$) as a result of season.

** Values expressed as % wet muscle weight.

TABLE 2

Content of lipid classes* of *Munida* caught at winter and summer seasons**

Lipid class	Season	
	Winter	**Summer**
Phospholipids	67.85 a (2.56)	64.85 a (1.29)
Sterols	12.15 a (0.35)	13.54 b (0.54)
Triacylglycerides	1.25 b (0.88)	0.04 a (0.02)
Free fatty acids	1.14 a (0.72)	2.19 a (0.34)

* Average values of three (n=3) replicates. Standard deviations are indicated in brackets. For each lipid class or group, average values followed by different letters (a, b) denote significant differences ($p<0.05$) as a result of season.

** Values expressed as % on lipid basis.

TABLE 3

Fatty acid composition* of *Munida* caught at winter and summer seasons**

Fatty acid (FA)	Season	
	Winter	**Summer**
C 14:0	0.32 a (0.08)	0.29 a (0.03)
C 16:0	18.20 a (0.76)	16.00 a (1.40)
C 16:1 ω7	2.43 a (0.44)	1.98 a (0.16)
C 18:0	5.56 a (0.08)	5.40 a (0.48)
C 18:1 ω9	17.11 a (0.62)	16.06 a (1.22)
C 18:1 ω7	5.39 b (0.29)	4.49 a (0.42)
C 18:2 ω6	1.01 a (0.06)	1.17 a (0.08)
C 20:1 ω9	0.53 a (0.09)	0.53 a (0.04)
C 20:4 ω6	3.42 a (0.11)	4.30 b (0.32)
C 20:5 ω3	16.87 a (0.16)	19.95 b (1.72)
C 22:5 ω3	0.37 a (0.04)	0.45 b (0.01)
C 22:6 ω3	28.79 a (0.30)	29.38 a (3.11)

* Average values of three (n=3) replicates. Standard deviations are indicated in brackets. For each FA, average values followed by different letters (a, b) denote significant differences ($p<0.05$) as a result of season.

** Values expressed as % of total FA.

TABLE 4

Content and ratios* of fatty acid groups of *Munida* caught at winter and summer seasons**

Fatty acid group	Season	
	Winter	**Summer**
Total saturated fatty acids	24.08 b (0.08)	21.69 a (0.03)
Total monounsaturated fatty acids	25.46 a (0.83)	23.06 a (1.40)
Total polyunsaturated fatty acids	50.46 a (0.44)	55.25 b (0.16)
Total ω3 fatty acids	46.03 a (0.08)	49.78 b (0.47)
Total ω6 fatty acids	4.43 a (0.62)	5.47 a (1.22)
ω3/ω6 ratio	10.40 a (1.39)	9.11 a (1.12)
Polyene index	2.51 a (0.27)	3.09 a (0.22)

* Average values of three (n=3) replicates. Standard deviations are indicated in brackets. For each fatty acid group or ratio, average values followed by different letters (a, b) denote significant differences ($p<0.05$) as a result of season.

** Values of fatty acids groups expressed as % on total FA.