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**Anisakis spp. larvae in different kinds of ready to eat products
made of anchovies (*Engraulis encrasicolus*) sold in Italian supermarkets.**

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(Article begins on next page)

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Abstract: In this study the occurrence of visible anisakid larvae in semi-preserved anchovy products sold on the Italian market was investigated. Totally, 107 ready to eat products (33 salted-ripened, 49 in oil and 25 marinated) were sampled. Each sample was digested, then the digested material was observed under natural and UV light. Parasites were counted, collected and microscopically identified to genus level. A representative subset was molecularly identified using the *cox2* gene. At least one visible *Anisakis* sp. larva was found in 54.2% of the total 107 products analysed. Totally 1283 dead larvae were collected. *Anisakis* sp. larvae were found in all the 33 salted products and 1139 (88.8%) larvae were collected, with a range of 1-105 parasites per product. Larval density per gram was 0.13. *Anisakis* sp. larvae were found in 49.0% of the products in oil and 143 (11.1%) larvae were isolated, with a range of 0-28 and a density of 0.03. Only 1 larva was found in the 25 marinated products (4.0%), the density was 0.00. A highly significant difference between all the product categories in respect of number of larvae per product, frequency of products contaminated by at least one larva and larval density per gram was found. Within the subset of larvae molecularly analysed (n=122), 92 larvae (75.4%) were identified as *A. pegreffii* and 30 (24.6%) as *A. simplex*. This study showed that semi-preserved anchovy products heavily contaminated with *Anisakis* spp. larvae reach the market. Beyond the negligible risk for anisakidosis, the presence of dead visible parasites may cause immediate rejection in consumers. In addition, the potential risk related to allergic reactions in sensitized individuals needs to be further assessed. In order to avoid commercialization of obviously contaminated products, fresh anchovies' batches intended for the production of such products should be accurately selected by the processing industry applying inspection methods.

Pisa, 14th July 2017

Dear Editor,

Please find enclosed the manuscript entitled “***Anisakis* spp. larvae in different kinds of ready to eat products made of anchovies: a defect or a hazard?**” to be considered for publication in the International Journal of Food Microbiology.

The European anchovy (*Engraulis encrasicolus*) is one of the most important fish resources of Mediterranean countries, where it is commonly used to produce traditional semi-preserved products, such as salted-ripened, in oil, marinated/pickled anchovies. Among the most important biohazards related to the consumption of raw anchovies is the presence of viable zoonotic nematode larvae belonging to the *Anisakis* genus. The parasitological risk associated to the presence of viable larvae in semi-processed seafood products can be prevented applying a freezing treatment or an appropriate brining or pickling process for a sufficient time. Nevertheless, the presence of dead visible parasites in processed products represents a defect that alters the overall quality, causes immediate consumers' rejection and may damage the reputation of the brand. In addition, although it is generally believed that sensitization with live *Anisakis* spp. larvae is required prior to the development of a clinical allergic responses, the allergenic potential of dead larvae is still debated.

Taking into account the increasing market request of ready to eat semi-preserved anchovies, their high prices and the scarcity of data on the presence of anisakid parasites in these preparations, the aim of this study was to assess the presence of visible anisakid larvae in different commercial categories of the most appreciated types of these semi-preserves on the Italian market.

Totally, 107 ready to eat products (33 salted-ripened, 49 in oil and 25 marinated) were sampled and separately submitted to artificial digestion. Parasites were counted, collected and microscopically identified to genus level. A subset was molecularly identified using the *cox2* gene.

Of the total 107 products analysed, 54.2% were positive for the presence of at least one visible *Anisakis* sp. larva and a total of 1283 larvae were collected. All the parasites found were dead. All the 33 salted products were positive and 1139 (88.8%) *Anisakis* spp. larvae were collected, with a range of 1-105 parasites per product. Among products in oil, 48.9% were positive with 143 (11.1%) *Anisakis* spp. larvae isolated and a range of 0-28. Only 1 out of the 25 marinated products (4%) was positive, with the presence of one larva. Within the larvae subset (n=122), 92 larvae (75.4%) were molecularly identified as *A. pegreffii* and 30 (24.6%) as *A. simplex*.

The present results showed that semi preserved anchovy products heavily contaminated with *Anisakis* spp. larvae can reach the market. In particular, the level of contamination was different

depending on the products typology, being linked to the processing procedure and to the preliminary preparation of the fish, especially depending on the removal of the viscera. Beyond the negligible risk for anisakidosis, the presence of dead parasites may cause immediate rejection in consumers. In addition, the risk related to allergic reactions in sensitized individuals is still an open issue.

The manuscript has not been published elsewhere nor is it being considered for publication elsewhere. All authors have approved this manuscript, agree to the order in which their names are listed, declare that no conflict of interests exists and disclose any commercial affiliation.

Yours sincerely,
Andrea Armani

Dear editor,

thank you very much for considering our manuscript for publication in International Journal of Food Microbiology.

Please find below our answers to the reviewers' comments. We would like to thank both reviewers for their constructive suggestions. We are sorry they were not completely satisfied by the first revision. Some of the issues were probably due to the fact that the reviewers' comments were partly contrasting.

We hope that we have now succeeded in making all the requested modifications and clarifications.

Reviewer #1:

Line 231. Sorry but this is still unclear to me. Does it mean that the MA threshold is calculated as $3/N$ where N is 10% of the batch, 10% of the samples collected for analysis or a maximum of 3 larvae in all the samples within 10% of the sample size? It is unclear what is the value of the MA threshold and how the MA is calculated at individual level to define the samples exceeding this threshold.

The mean abundance threshold was calculated on the basis of the Liguria Region Circular n. 1 of 1997. This regulation states that: "if when opening the coelomic cavity numerous viable larvae appear, giving a repellent aspect to the product, the batch is withdrawn from the market; ii) if the number of visible parasites is higher than 3 per anchovy in the 10 % of the examined specimens, or the number of parasitized specimens is higher than 10 % of the total, the batch should be submitted to decontamination by means of freezing, according on the existing law; iii) if the number of larvae is ≤ 3 per anchovy in maximum 10 % of the examined specimens, the batch is intended to free consumption.

As regards the number of examined specimens, we referred to the Lombardy Region circular (Circular Letter VS8/C790/94) which states that: "knowing the total weight of the fish lot, it is possible to calculate the total number of specimens and then, by means of conversion rates and using an appropriate table, the number of subjects to be examined in each case. In the case of fish species caught in large batches (>600 specimens, such as anchovies), the number of subjects to collect is, at least, 29".

Therefore:

Number of examined specimens = 29

10% of 29 specimens = 2,9

3 (maximum number of tolerated parasites) * 2,9 = 8,7 maximum (theoretical) number of parasites in 29 specimens → 9 maximum (real) number of parasites in 29 specimens

$9/29 = 0.3$ mean abundance threshold

It derives that a MA of 0.3 corresponds to the threshold that allows to divide the batches in "non-marketable" ($MA > 0.3$) or "marketable" ($MA \leq 0.3$).

The combination of the described sampling plan and mean abundance threshold is the most applied approach in Italy (D'Amico et al., 2014 Food research international, 64, 348-362).

The proposed MA threshold was first used in a work comparing the performance of three different techniques (visual inspection, UV press method and digestion) (Guardone et al. 2016 Food Analytical Methods 9.5, 1418-1427) and subsequently in a work aimed at assessing the reliability of the digestion of a subsample of 150 g (± 30 g) of viscera and adjacent muscles, randomly collected from 29 specimens, in estimating the marketability of fresh anchovies' batch.

We added more details also in the text (lines 222-227). We really hope it is clear now. If you think it is necessary, we can add further explanations.

Finally, we would like to point out that, although we have used the MA threshold also in this publication, it was only applied to a part of the samples (those composed by whole specimens for which the MA could be calculated). The paper focuses on the number of larvae per product and on the contamination (presence of at least one larva). Following the suggestion of reviewer 2 we have also introduced another epidemiological index, the larval density per gram.

Discussion

In the discussion section, aspects related to batch selection and practical meaning of this study for food

industry has been removed from the previous version. I really think it would be important to discuss this and demonstrate how this work could be used in practice to inform decision making in fishery industry in long term.

Except for the above aspect of the MA, which I am sure will be clarified, the manuscript is well written but as presented, it remains a descriptive study. Considering the level of the journal, including some strong final remarks on the practical utility of the findings, would noticeably increase the quality of the work.

Therefore, I propose again what I wrote in the first revision:

"what 'a precautionary approach' would mean in practice for decision makers and the food industry? is it related to the batch selection reported in the conclusion? what options the food industry would have in practice to select the batches (e.g. fishing area?)? furthermore, from the results it appears that many samples are above the threshold in terms of MA. In the light of your results, it would be good to discuss the role of this threshold on the economic impact on the food industry if this value is used, as suggested, for batch selection."

We thank the reviewer for the suggestion. These points have been added to the discussion (lines 432-451).

Reviewer #2:

1. I think the title should be considered for revision; the title 'Anisakis spp~ a defect or a hazard ?' sounds like the authors investigated whether the Anisakis species in anchovy products are hazardous to humans. But the authors assessed the prevalence of anisakid larvae in different kinds of anchovy products, as mentioned in the end of the INTRODUCTION. Of course, the authors can mention the dead larvae have the potential risks of allergic reactions to humans in DISCUSSION. But this is not the main focus (aim) of this study (if the authors want to keep the aim of this study as described in the INTRODUCTION). So if the authors also want to emphasize the potential risk of the larvae (or want to keep the title), I suggest that they should at least raise enough evidence that dead Anisakis larvae are allergic to humans, particularly dead Anisakis larvae in ANCHOVIES can cause allergic reactions to humans, not in pink salmon.

The title has been changed, we preferred to maintain the aim as it is.

2. Please include the scientific name of anchovy in the title. **done**

3. Please make all percentage data round off to one decimal place (e.g., 88.8%, not 88.98%; 4.0%, not 4%) throughout the whole MS including Tables. **done**

4. 'positivity' and 'number of larvae' do not seem to be the terms generally used in parasitology. The authors should refer Bush et al. (1997)'s reference and select appropriate terms which fit into the definitions.

We are aware of the terminology defined in Bush et al., 1997. However, most of these terms refer to animal hosts, while in this study we have analysed seafood products which were composed of many individual hosts. This is the reason why we used the Mean Abundance, in the case of products composed of whole anchovies for which the number of individuals was countable. Now, we also added the larval density per gram as a further epidemiological index.

We have removed the term "positivity" and, where possible, we have replaced it with the term "contaminated", in accordance with the EU regulations, EFSA (<https://www.efsa.europa.eu/en/topics/topic/parasites-food>) and with previous works (Audicana & Kennedy 2008 *Clinical microbiology reviews*, 21(2), 360-379; Fæste et al., 2015 *Food Analytical Methods*, 8(6), 1390-1402; Llarena-Reino et al., 2012 *Food Control*, 23(1), 54-58).

The term "number of larvae" was kept since it is a measure and not a parasitological index and therefore it cannot be replaced. Besides, it has been used in similar recent studies:

- Cipriani, P., Acerra, V., Bellisario, B., Sbaraglia, G. L., Cheleschi, R., Nascetti, G., & Mattiucci, S. (2016). Larval migration of the zoonotic parasite *Anisakis pegreffii* (Nematoda: Anisakidae) in European anchovy, *Engraulis encrasicolus*: Implications to seafood safety. *Food Control*, 59, 148-157.
- Pierce, G. J., Bao, M., MacKenzie, K., Dunser, A., Giuliotti, L., Cipriani, P., ... & Hastie, L. C. (2017). Ascaridoid nematode infection in haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) in Northeast Atlantic waters. *Fisheries Research*, in press

5. Keywords in the MS should be selected for being detected by DB (e.g., PUBMED) as much as possible. I think the keywords in this MS are not useful for being detected in PUBMED or other DBs. I suggest that the keywords should be carefully selected again. **done**

6. Line 114~115: it has been supposed that also ingestion ~ -> it has been also suspected that ingestion ~ **done**

7. Line 121~ : Taking into ~EU. the high prices of ~ -> Taking into ~ EU and the high prices of ~ .

It is not possible to change the sentence, as we cannot substitute the comma with "and" because there is another element listed and there would be two "and" in the sentence

8. Line 144 : ~ University of Pisa, Department ~ -> Department of ~ University of Pisa **done**

9. Line 149: ~ their number -> their number of what? **The sentence has been modified**

10. Line 151: ~ rinsed in a glass beaker. -> rinsed with what ? **with tap water, the indication has been added**

11. Line 152: The oil was carefully removed also ~ -> The oil was also carefully removed **done**

12. Line 154: With the aim to test the recovery ~ -> To test the recovery ~ **done**

13. Line 159~162 : Considering that ~ per time -> I do not understand what the authors want to describe. Please revise this sentence. **Done**

14. Line 196~197: by the Experimental ~ (Turin, Italy) -> Delete **done**

15. Line 252: trials ->What trials ? **Those mentioned at line 156. However, the sentence has been modified to make it more clear.**

16. Line 261~264: All the parasites ~dead. In fact, even though ~and might be ~ treatment -> All the parasites ~dead. Although In fact, even though the emission of fluorescence are known to not always discriminate between live and dead larvae, might be related to ~ by the treatment spontaneous and stimulated movements of the larvae were absent in this study. **We found very hard to understand this point. However, we have modified the sentence hoping to have correctly interpreted the meaning.**

17. Among those ~ analyzed (n=122) 92 (75.4%) -> Among these ~ analyzed larvae (n=122), 92(75.4%)~ **we have modified the sentence trying to clarify it. However, we cannot use "these", instead of "those", because not all the larvae were molecularly analysed.**

18. Line 296~297: see section 3.2 -> delete **done**

19. Line 299: ~A. simplex (22.6%) -> A. simplex (22.6%) (Table 2). **Done**

20. Line 305: The MA~ 3.92 -> **Delete. The sentence was wrong and did not make sense. However, this sentence cannot be deleted because this information is not present elsewhere in the text. Therefore, the sentence was corrected.**

21. Line 313: corresponding to 11.1% of the ~ -> corresponding to 11.1% (00/00) of the ~ **Done**

22. Line 323: ~ for 15 product, in fact although other ~ -> ~ for 15 products. in fact although Other 3 products ~ **done**

23. Line 351: Analogously -> Similarly **done**

24. Line 353: As known, most anisakid larvae are located ~ -> As known, most anisakid larvae are known to be located ~? **The sentence has been modified assuming you wanted to move "known" from the beginning to the middle of the sentence. Otherwise it would be repeated.**

25. Line 357: ~ after the capture especially ~ -> ~ after the capture, especially ~ **done**

26. Line 364: ~ were positive. -> positive for what? **For the presence of at least one larva. The sentence has been modified.**

27. Line 389: ~ inactivates Anisakidae larvae -> inactivates anisakid larvae. **done**

28. Line 392~395: In addition, salted-ripened anchovies ~ for E. encrasicolus -> This sentence does not make sense; The scientific name of European anchovy is E. encrasicolus. Delete 'for E. encrasicolus'. **Done**

29. Line 417~418: ~ live larvae that can actively ~ the external surface. -> ~ live larvae which can actively move and become evident also on the external surface. **done**

30. Line 419: However, also the presence ~ -> However, also the presence ~ **we don't understand this point.**

31. Line 467~476: I think this paragraph is not helpful for discussion and better to be deleted. As mentioned in the INTRODUCTION, the aim of this study is that the assessment of the presence of visible anisakid larvae in different commercial categories of products. But this paragraph contains how the consumers and authorities should react with the presence of the larvae in fish products. And what is FBO? I suggest the authors should keep the MS clear, concise, readable, not too wordy.

Conclusions have been modified and shortened. FBO stands for Food Business Operators, as stated at line 96.

32. Line 478~479: I think the authors should make it clear what the aim of this study is. The authors described that 'The present work highlighted how semi-preserved anchovy products heavily ~ can reach the market'. I think the authors should discuss the distribution structure, marketing system regarding the fisheries products, to highlight the issue written in this sentence. But there is no mention regarding 'how ~ can reach the market' in this MS, and as in the INTRODUCTION, the authors assessed the prevalence of anisakid larvae in different kinds of anchovy products. Furthermore, the title also includes the debate about allergic issue of dead larvae. All of these make the readers confused and the MS difficult to understand.

We think the word "how" was probably misleading. We did not intend to describe the products' distribution on the market but to point out that highly contaminated products are already sold in Italian supermarkets. We have change the sentence hoping to clarify our idea and to better agree with the aim of our work.

33. I strongly suggest that the authors should replace the references which cannot be read nor accessed by international readers. If the references cannot be accessed or cannot be obtained by the readers who want to have a look, those references should not be referred. Unfortunately, there are so many references which I cannot read nor access in this MS.

The references have been revised. All the documents are now accessible to international readers.

*Highlights (for review)

- Different kinds of anchovy ready to eat products were analysed by digestion
- 54.2% of the products were positive for at least one visible *Anisakis* spp. larva
- A total of 1283 dead larvae were collected
- The product category influenced the number of larvae and positivity rate
- Salted products were found to be the most contaminated (positivity 100%)

1 *Anisakis* spp. larvae in different kinds of ready to eat products made of anchovies
2 *(Engraulis encrasicolus)* sold in Italian supermarkets: a defect or a hazard?
3

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26 Abstract

27 ~~The aim of~~In this study ~~was to assess~~ the ~~presenece~~ occurrence of visible anisakid larvae in
28 semi-preserved anchovy products sold on the Italian market was investigated. Totally, 107
29 ready to eat products (33 salted-ripened, 49 in oil and 25 marinated) were sampled. Each
30 sample was digested, then the digested material was observed under natural and UV light.
31 Parasites were counted, collected and microscopically identified to genus level. A
32 representative subset was molecularly identified using the *cox2* gene. At least one visible
33 Anisakis sp. larva was found in 54.2% of the total 107 products analysed. ~~Of the total 107~~
34 ~~products analysed, 54.2% were positive for the presence of at least one visible Anisakis sp.~~
35 ~~larva and a total of~~ and ~~†~~ Totally 1283 dead larvae were collected. ~~All~~ Anisakis sp. larvae were
36 found in all the 33 salted products ~~were positive~~ and 1139 (88.8%) ~~Anisakis sp.~~ larvae were
37 collected, with a range of 1-105 parasites per product. Larval density per gram was 0.13.
38 Anisakis sp. larvae were found in 49.0% of the products in oil ~~Among products in oil,~~
39 ~~49.08.98% were positive~~ and 143 (11.1%) ~~Anisakis spp.~~ larvae were isolated, with a range of
40 0-28 and a density of 0.03. Only 1 larva was found in ~~out of~~ the 25 marinated products
41 (4.0%), the density was 0.00 ~~was positive, with the presence of one larva~~. A highly
42 significant difference between all the product categories in respect of ~~both~~ number of larvae
43 per product, frequency of products contaminated by at least one larva and larval density per
44 gram was found ~~and positivity was found~~. Within the subset of larvae molecularly ~~identified~~
45 analysed (n=122), 92 larvae (75.4%) were identified as *A. pegreffii* and 30 (24.6%) as *A.*
46 *simplex*. This study ~~highlighted how~~ showed that semi-preserved anchovy products heavily
47 contaminated with *Anisakis* spp. larvae ~~can~~ reach the market. Beyond the negligible risk for
48 anisakidosis, the presence of dead visible parasites may cause immediate rejection in
49 consumers. In addition, the potential risk related to allergic reactions in sensitized individuals
50 needs to be further assessed. In order to avoid commercialization of obviously contaminated

51 | ~~products~~ ~~corrective measures on the final products~~, fresh anchovies' batches intended for the
52 | production of such products should be accurately selected by the processing industry
53 | applying inspection methods.

54 | **Keywords**

55 | ~~Salted ripened~~ ~~Processed seafood products~~, ~~anchovies~~, ~~anchovies in oil~~, ~~marinated~~
56 | ~~anchovies~~, ~~visible parasite~~, ~~anisakid dead larvae~~, ~~product quality~~, ~~defect~~, ~~risk assessment~~
57 | Anisakid larvae, anchovies, *Engraulis encrasicolus*, artificial digestion, contamination,
58 | semi-preserved seafood products, Italy

60 | **1. Introduction**

61 | The European anchovy (*Engraulis encrasicolus*) is an economically important fish species
62 | particularly appreciated in Mediterranean countries, where it is commonly used to produce
63 | traditional salted-ripened, in oil and marinated/pickled products (Anastasio et al., 2016; Felix
64 | et al., 2016; Triqui and Reineccius, 1995).

65 | In the presence of salt, anchovies undergo physicochemical modifications giving origin to
66 | a product called “ripened” or “matured” (Codex Alimentarius, 2012). Usually, salting-
67 | ripening involves a preliminary operation of brining, where the whole fish is immersed in
68 | saturated brine. Following this, anchovies are beheaded and gutted, placed in barrels,
69 | alternating layers of fish and salt, and pressed (Czerner et al., 2011; Felix et al., 2016). In
70 | some cases, fish are beheaded and gutted immediately at the beginning of the process
71 | (Granata et al., 2012). The curing process takes several months and the final product is
72 | characterized by firm consistency, reddish colour, juicy texture and characteristic odour and
73 | flavour (Felix et al., 2016; Granata et al., 2012; Sospedra et al., 2015). Salted-ripened
74 | anchovies may be packed in brine or preserved in oil. For preservation in oil, fish are
75 | generally skinned, washed, dried and filleted (Mohamed et al., 2016).

76 The term “marinades” or “marinated fish” is used to define products consisting of fish
77 processed with an edible organic acid, usually acetic acid, and salt, which gives them a
78 characteristic white colour of the flesh, and put into brines, sauces, or oil (McLay, 1972).
79 Pickled anchovies are very popular in Spain as *boquerones en vinaigre* and in Italy as *alici*
80 *marinate*. Traditionally, homemade marinated anchovies are prepared with fresh fish
81 eviscerated and de-boned by hand, then pickled in lemon juice or vinegar and salt for less
82 than 24h before consumption. Although ~~the Italian and Spanish~~ legislation requires
83 preventive freezing treatment also in case of domestic preparation of raw, marinated or not
84 fully cooked fish (~~D’Amico et al., 2014~~~~Decreto Legislativo 17 Luglio 2013; Real Decreto~~
85 ~~1420/2006~~), this is frequently not applied (~~Serracca et al., 2014~~), because it alters the texture
86 and the taste of fish meat (Sánchez-Monsalvez et al., 2005; Vidaček et al., 2009).

87 Among the most important biohazards related to the consumption of raw anchovies is the
88 presence of viable zoonotic nematode larvae belonging to the genus *Anisakis*, as their
89 ingestion is responsible for a zoonotic disease known as anisakiasis (Mattiucci et al., 2013).
90 Of the nine genetically characterized species of the genus *Anisakis*, only *A. pegreffii* and *A.*
91 *simplex* (*s. s.*) have been reported as causative agents of human gastric, intestinal and gastro-
92 allergic anisakiasis (Cipriani et al., 2017). *A. simplex s.l.* and *A. pegreffii* are frequently found
93 in European anchovies (Bao et al., 2017; Costa et al., 2016).

94 The ~~presenece-occurrence~~ of anisakid larvae in fish is a natural condition throughout the
95 supply chain and their complete elimination from fishery products is not feasible (EFSA,
96 2010). Food Business Operators (FBOs) must ensure that fishery products obviously
97 contaminated with visible parasites are not placed on the market for human consumption, by
98 conducting a visual inspection of fresh fish products (Commission Reg. EC No 2074/2005).
99 In addition, the parasitological risk associated to the presence of viable larvae in semi-
100 processed seafood products can be prevented by applying a freezing treatment or an

101 appropriate brining or pickling process for a sufficient time (AESAN, 2007; Anastasio et al.,
102 2016; Sánchez-Monsalvez et al, 2005). Nevertheless, the presence of dead visible parasites in
103 processed products represents a defect that alters the overall quality (Codex Alimentarius,
104 2012; Council Reg. EC No 2406/1996) making them unfit for human consumption (Reg. EC
105 No 178/2002). In fact, the finding of parasites in fish products causes immediate consumers'
106 rejection and may damage the reputation of the brand. Moreover, although it is generally
107 believed that sensitization with live *Anisakis* spp. larvae is required prior to the development
108 of a clinical allergic responses, it has been also suspected ~~supposed~~ that ~~also~~-ingestion (and
109 inhalation) of dead larvae or their allergens might induce allergic reactions (Bao et al., 2017;
110 EFSA, 2010; Mattiucci et al., 2017).

111 In a preliminary phase of this study 44 ready to eat products made of anchovies, herrings,
112 mackerel and sardines were analysed (Guardone et al., 2016a). Considering that all the
113 samples made of mackerel and sardines were negative, while larvae were found in 80.0% of
114 the products made of anchovies, the present study specifically addressed this type of product.
115 Taking into account the increasing request of ready to eat seafood products from the EU
116 (EUMOFA, 2017), the high prices of semi-preserved anchovies and the scarcity of data ~~on~~ ~~on~~
117 ~~the presence of~~ anisakid parasites ~~associated to~~ these kind of preparations (Fraulo et al.,
118 2014; Sospedra et al., 2015), the aim of this study was to assess the ~~presence~~ occurrence of
119 visible anisakid larvae in different commercial categories of products sold in Italian
120 supermarkets. The most appreciated types of semi-preserves on the national market, such as
121 salted-ripened, in oil and marinated anchovies, were collected and analyzed.

122 **2. Materials and methods**

123 **2.1 Sampling**

124 A total of 107 ready to eat products made of anchovies, belonging to 17 different brands
125 and to different lots were sampled between April 2015 and May 2017 in Tuscany (Northern

126 Italy), at different points of sale of a large national purchasing consortium. A convenience,
127 non-probabilistic sampling was conducted, structured to include a proportional number of
128 products per type and brand. Three different types of commercial products were collected:
129 salted-ripened, in oil and marinated (Fig. 1). In 51 products, the fishes were only beheaded
130 and (partially) gutted, but the bones were not removed and the structure of the body was
131 maintained unaltered (“whole” anchovies) (Fig. 1a), while in the remaining 56 products the
132 anchovies were deboned and opened to become flat (“fillets”) (Fig. 1b-c). Thirty-three
133 products were salted-ripened anchovies (all whole fishes), 49 products were in oil (18 whole
134 fishes and 31 fillets) and 25 products were marinated anchovies (all fillets). The samples
135 were then transferred to the FishLab, ~~University of Pisa,~~ Department of Veterinary Sciences,
136 University of Pisa, and analysed.

137 *2.2 Parasitological analysis*

138 *2.2.1 Digestion procedure.* Each sample was registered with an internal unique code.
139 Photos of the external packaging with the labelling information and of the internal content
140 were taken. In the case of whole ~~specimens anchovies~~, their number of specimens was re
141 counted, ~~and the Mean Abundance (MA) was calculated (see Section 2.4)~~. Salt, brine and oil
142 were carefully removed from the products. Salted products were also lightly rinsed with tap
143 water in a glass beaker. The oil was also carefully removed ~~also~~ with the aid of absorbent
144 paper. Then, the edible part was weighted. Considering that the whole content of the
145 collected products is edible, the full weight of each sample was digested. ~~With the aim of~~ To
146 test the recovery rate of parasites from semi-preserved anchovy products, preliminary trials
147 were performed. Larvae collected from products s analysed in the preliminary phase of this
148 study (Guardone et al., 2016a) were submitted to artificial digestion using the Trichineasy[®].
149 according to the manufacturer’s instructions (CTSV, 2007). ~~according to the procedure~~
150 ~~described in Guardone et al., (2017)~~. ~~Considering that a~~ All the larvae were recovered with

151 | ~~thisset~~ procedure, ~~which~~ was ~~then~~ applied to all the samples. ~~digesting~~. A ~~a~~ maximum of
152 | 200 g of tissue ~~was digested~~ per time. ~~was digested according to the manufacturer's~~
153 | ~~instructions (CTSV, 2007~~http://www.etsv.biz/image_etsv/PDF/TrichinEasy_anisakis.pdf~~).~~

154 | At the end of the digestion the material retained in the filter was rinsed with water and
155 | divided in Petri dishes to create a thin layer of a few mm. The Petri dishes were observed
156 | under natural and UV light (UltraBright UV Transilluminator, 302/365 nm, Maestrogen, Las
157 | Vegas, USA) for the detection of anisakid larvae. During this step, spontaneous and
158 | stimulated movements of the larvae were assessed to evaluate viability. In consideration of
159 | the provisions of the Regulation EC No 853/2004 and subsequent amendments, only the
160 | visible larvae (non-encapsulated nematodes longer than 1 cm or parasites with a capsular
161 | diameter of at least 3 mm according to the definition given by the Codex Alimentarius
162 | Commission, 1971) were counted and collected. The residual salt ~~and oil~~ and the water used
163 | to rinse the anchovies were inspected as described above. The larvae found during this step
164 | were collected and summed to those found after the complete digestion. All the larvae were
165 | identified to genus level following Sakanari and McKerrow (1989) and Berland (1989) by
166 | observation under a microscope (Nikon Eclipse E200) and then stored in 70% alcohol for
167 | molecular analysis.

168 | *2.2.2 Molecular identification.* A subset of *Anisakis* larvae (from 1 to 4 larvae per product)
169 | was submitted to molecular identification. Total DNA extraction was performed according to
170 | the protocol used in Guardone et al., (2016b). DNA concentration and purity were determined
171 | by a NanoDrop ND-1000 spectrophotometer (NanoDrop Technologies, Wilmington, DE,
172 | USA).

173 | A 629-bp fragment of the mitochondrial cytochrome *c* oxidase subunit II (*cox2*) gene was
174 | amplified using the primers 211F (5'-TTT TCT AGT TAT ATA GAT TGR TTY AT-3') and
175 | 210R (5'-CAC CAA CTC TTA AAA TTA TC-3') (Nadler & Hudspeth, 2000). PCR

176 amplifications were set up in a 20 µl reaction volume containing 2 µl of a 10× buffer
177 (biotechrabbit GmbH, Hennigsdorf, Germany), 200 µM of each dNTP (dNTPmix,
178 EurocloneS.p.A-Life Sciences Division, Pavia, Italy), 200 nM primers, 1.25 U PerfectTaq
179 DNA Polymerase (biotechrabbit GmbH, Hennigsdorf, Germany), and 50-100 ng of DNA and
180 DNase free water (Water Mol. Bio. Grade, DNase-RNase and Protease free, 5Prime GmbH,
181 Hamburg, Germany) with the following cycling program: initial denaturation at 94 °C for 3
182 min; 40 cycles at 94 °C for 20 s, 45 °C for 20 s, 72 °C for 25 s; final extension at 72 °C for 10
183 min, as in Guardone et al., (2016b).

184 PCR products were checked by gel electrophoresis and the presence of fragments of the
185 expected length was assessed by comparison with the marker SharpMass™50-DNA ladder
186 (Euroclone, Wetherby, UK). PCR products were purified with EuroSAP PCR Enzymatic
187 Clean-up kit (EuroClone Spa, Milano) and stored at -80°C prior to the sequencing. ~~The~~
188 ~~sequencing of the~~ PCR products were sequenced ~~was carried out by the Experimental~~
189 ~~Institute of Zooprophyllaxis of Piedmont, Liguria and Aosta Valley (Turin, Italy)~~ to obtain
190 forward and reverse direction sequences for each PCR product. The sequencing reaction was
191 performed by the use of a 4-capillary 3130 Genetic Analyzer (Applied Biosystems) and the
192 BigDye® Terminator v3.1 Cycle Sequencing kit (Life Technology, Thermo Fisher Scientific
193 Inc.).

194 All the obtained sequences were analyzed using Bioedit version 7.0.9 (Hall, 1999).
195 Adjustments were made after visual checking and the sequences were analysed on GenBank
196 by using the Basic Local Alignment Search Tool (BLAST) (Altschul et al., 1990).

197 ***2.4 Statistical analysis***

198 *2.4.1 Comparison of the three product categories.* Salted, in oil and marinated products
199 were compared in respect to: ~~positivity (presence of at least one larva, (nominal variable) and~~
200 ~~number of total larvae in each analysed sample (counting variable).~~ presence of at least one

201 larva (nominal variable), number of larvae per product and density (larvae/gram)
202 (quantitative variables). To assess differences among groups two tests were applied: the χ^2
203 test for the nominal variable and the Kruskal-Wallis test for the counting variable. The non-
204 parametric tests were chosen given the unequal sample size, the presence of categories with
205 less than 30 products and, not least, the violation of the ANOVA assumptions, mostly the
206 homogeneity of variance. For all the analyses, significant results were those associated with
207 $p < 0.05$. If overall significance was observed, pair-wise comparisons were analysed using χ^2
208 (for nominal variables) and Mann-Whitney (for quantitative data) tests. In these comparisons,
209 in order to protect for type I error increase, a threshold of $\alpha = 0.01$ was chosen for the
210 interpretation of the results. Analyses were performed using SPSS v 15^(R).

211 *2.4.2 Comparison between products made of fillets and whole anchovies.* Differences in
212 positive samples the number of larvae per product, frequency of products contaminated by at
213 least one larva and larval density per gram were also analysed the occurrence, in the number
214 of larvae detected whereas also analyzed in respect to the product being composed by whole
215 anchovies or by fillets. The analyses were carried out using χ^2 (for nominal variables) and
216 Mann-Whitney (for quantitative data) tests. These comparisons were performed only for
217 products preserved in oil, the only category containing both fillets and whole fishes.

218 *2.4.3 Mean abundance (MA).* The mean abundance (MA) (total number of individuals of a
219 particular parasite species in a sample of a particular host species divided by the total number
220 of hosts of that species examined, Bush et al., 1997) was calculated after the complete
221 digestion of products made of whole specimens whole products and the value obtained was
222 used to issue a marketability judgement. The MA threshold was calculated by applying an
223 approach regional law widely used throughout Italy (D'Amico et al., 2014) which defines the
224 maximum number of tolerated larvae in fresh batches of anchovies (~~three~~ 3 larvae in 10% of
225 the sampled fish). Considering that in the case of fish species caught in large batches, such as

226 anchovies, the number of subjects to collect for a significant sampling is, at least, 29, the
227 maximum number of parasites tolerated is 9 and therefore the MA threshold is 0.3 (Guardone
228 et al., 2016b, Guardone et al., 2017).

229 **3. Results and discussion**

230 ***3.1 Parasitological analysis***

231 The official method for the detection of parasites in fish is the visual inspection
232 (Commission Reg. EC 2074/2005). The pressing method of frozen fillets followed by the
233 examination under ultraviolet light is also frequently used (Gómez-Morales et al., 2017).
234 Moreover, the artificial digestion may also be applied to isolate larvae from fish and it is
235 considered the gold standard for its higher sensitivity (Guardone et al., 2016b; Llarena-Reino
236 et al., 2013). The cuticle of parasitic nematodes has been reported as highly resistant to strong
237 acids and digestive enzymes, regardless of whether the nematodes are live or have been killed
238 by freezing or conventional heating (Tejada et al., 2006). However, damages to the cuticle
239 occurring during processing (Anastasio et al., 2016; Tejada et al., 2006; Vidacek et al., 2009)
240 can affect the resistance of the larvae to the artificial digestion. ~~For this reason~~ As mentioned,
241 trials were performed using dead *Anisakis* spp. larvae ~~collected from products (salted and in~~
242 ~~oil) analysed in a preliminary phase of this study (Guardone et al., 2016a).~~ Since A ~~all the~~
243 ~~larvae were recovered after the digestion, therefore, the procedure applied to fresh anchovies~~
244 ~~(Guardone et al., 2017), already proven to be able to recover live larvae, the procedure~~ was
245 considered suitable ~~also~~ for semi-preserved products.

246 At least one visible larva was found in 58 (54.2%) of ~~Of~~ the total 107 products analysed;
247 58 (54.2%) were positive for the presence of at least one visible larva. A total of 1283 visible
248 larvae were collected, which were all morphologically identified as *Anisakis* sp. ~~Overall a~~
249 ~~total of 1283 anisakid larvae were collected.~~ Strong differences were observed between the
250 various categories of products and also between whole and filleted products (Table 1). All the

251 parasites found during the analysis were dead. In fact, ~~even~~ Although emission of
252 fluorescence is known ~~did to~~ not always ~~allow to~~ discriminate between live and dead larvae
253 ~~and might be related to the stress produced in the larvae by the treatment~~ (Tejada et al., 2006;
254 Vidaček et al., 2009), spontaneous and stimulated movements of the larvae were absent in
255 this study. ~~All the visible parasites were morphologically identified as Anisakis sp.~~ Among
256 the subset of ~~ose~~ molecularly analysed larvae (n=122), 92 (75.4%) were identified as *A.*
257 *pegreffii* and 30 (24.6%) as *A. simplex* (Table 2). Larvae of the genus *Hysterothylacium* were
258 found very rarely (4 samples) and were always shorter than 1 cm, ~~and~~ thus they were not
259 counted as visible larvae. The low prevalence of *Hysterothylacium* spp. may be due to the
260 fact that these parasites are generally smaller and thinner than *Anisakis* spp. and might be less
261 resistant to processing techniques.

262 The complete elimination of parasites from fishery products is not feasible (EFSA, 2010),
263 therefore it is necessary to establish a threshold to discriminate between fit and unfit products
264 (Reg. EC 178/2002). In particular, it is essential to identify the number of larvae that can be
265 tolerated in a product and to adopt a criterion for taking decisions on the marketability of
266 fishery products. According to the “*Guidance document on the implementation of certain*
267 *provisions of Regulation (EC) No 853/2004 on the hygiene of food of animal origin*”
268 (European Commission, 2014) a fishery product is considered obviously contaminated if
269 visible parasites are detected in edible portions. However, such document does not define a
270 maximum number of parasites. Therefore, in a previous work (Guardone et al., 2016b), a MA
271 threshold ~~calculated as described above~~, was used to assess the marketability of fresh batches
272 of anchovies. Especially in the case of small fish, which are not sold individually, the MA
273 could be used to estimate the degree of infestation.

274 *3.1.1 Salted anchovies.* At least one visible *Anisakis* sp. larva was found in all ~~All~~ the 33
275 products (100%) ~~were found positive for the presence of at least one larvae~~. Totally, 1139

276 larvae ~~of *Anisakis* sp.~~ were collected in this category, corresponding to 88.8% of the total
277 collected larvae. The mean number of larvae per product was 34.52 (± 29.33 standard
278 deviation), with great variability (range: 1- 105). The mean density (larvae per gram) was
279 0.13 (Table 1). The highest number of larvae (439) was found in the products belonging to
280 brand 5 (Table 2). The results show that salted anchovies are the most contaminated type of
281 products, which is likely due to the type of processing (~~see Section 3.2~~).

282 Parasites recovered from these products were molecularly identified as *A. pegreffii*
283 (77.4%) and *A. simplex* (22.6%) (Table 2). The majority of the larvae of *A. simplex* found in
284 these samples was collected from anchovies declared to be fished in the Cantabrian sea (FAO
285 area 27), while *A. pegreffii* was the dominant species in samples declared as fished in the
286 Mediterranean Sea, confirming previous epidemiological data (Costa et al., 2016 and
287 references therein).

288 ~~The MA, which~~ varied from 0.04 to 3.92. Twenty-nine products (87.98%) exceeded the
289 MA threshold of positivity previously set for fresh anchovies. No differences in MA values
290 were observed ~~in the distribution of the positivity to the MA threshold~~ in relation to the
291 different brands (Table 2).

292 *3.1.2 Products in oil.* Among the 49 products, 18 were made of whole anchovies and the
293 remaining 31 of fillets. The 18 whole products belonged to 4 different brands. Two of them
294 consisted of previously salted anchovies (red flesh, brand 2 and 7), while the other two
295 presented a white meat (brand 1 and 8) (Table 2).

296 At least one *Anisakis* sp. larva was found in Overall 24 (49.08.98%) products in oil ~~were~~
297 ~~found positive for the presence of at least one larva~~ and a total of 143 larvae ~~of *Anisakis* sp.~~
298 were collected, corresponding to 11.1% (143/1283) of the total larvae collected. A mean
299 number of 2.9 larvae per product was detected (± 5.80 standard deviation) with a great
300 variability (range: 0-28 larvae). The larval density per gram was 0.03 (Table 1 and 2).

301 Parasites recovered from products in oil were molecularly identified as *A. pegreffii* (70.3%)
302 and *A. simplex* (29.7%). The geographical origin is not compulsory for fishery products in oil
303 (D'Amico et al., 2016) and it was not reported for 5 of the 14 brands. All the larvae
304 molecularly identified from these products were *A. pegreffii*. Most of the remaining indicated
305 FAO 37 or FAO 37.2.1 and the dominant species was *A. pegreffii*. Only the products of one
306 brand were claimed to originate from FAO area 27. In these samples the majority of the
307 identified larvae were *A. simplex*.

308 It was possible to calculate the MA for 15 products. ~~In fact,~~ although other 3 products
309 (brand 8) were originally prepared with whole anchovies it was not possible to count them
310 due to the loss of integrity of the specimens induced by the processing (Table 2). Of these 15
311 samples, all the 10 products made of salted anchovies (brand 2 and 7) exceeded the set MA
312 threshold. On the contrary, ~~no larvae were found in all~~ the 5 products of brand 1 ~~were~~
313 ~~negative~~. The high ~~positivity-contamination level~~ in whole salted in oil anchovies confirms
314 the results obtained for salted-ripened anchovies. The MA varied from 0.0 to 2.8.

315 Different ~~levels of contamination ees in positivity~~ were observed in ~~relation to the~~ whole
316 and filleted products (~~at least one larva was found in~~ 61.14% of the whole products and
317 41.94% of the fillets ~~was positive for at least one larvae~~). Within whole products, differences
318 were also observed between red and white fish: 83.92% of the parasites (n=120) were found
319 in the 2 products made of red whole anchovies.

320 *3.1.3 Marinated anchovies.* Only 1 ~~visible Anisakis spp. larva was found in out of~~ the 25
321 marinated products (4.0%). ~~The larva was found positive with the presence of one Anisakis~~
322 ~~spp. larva that~~ was subsequently molecularly identified as *A. pegreffii*. ~~The larval density per~~
323 ~~gram was 0.00~~ (Table 1 and Table 2). Considering that all these products consisted in filleted
324 anchovies it was not possible to calculate the MA.

325 *3.2 Comparison between product categories: influence of the processing technology on*
326 *the presence-occurrence and viability of anisakid larvae*

327 The processing technology can influence the presence of parasites in the final products.
328 The present study showed a significant difference between all the product categories in
329 respect of both number of larvae per product (Kruskal-Wallis' $\chi^2=69.95$; $p<0.001$), ~~and~~
330 ~~positivity number of contaminated products ($\chi^2=50.34$; $p<0.001$).~~ frequency of contaminated
331 products ($\chi^2=50.34$; $p<0.001$) and density of larvae per gram ($\chi^2=58.89$; $p<0.001$).

332 The average number of larvae per product was ~~about around~~ 35, 3 and 0 for salted, in oil
333 and marinated products, respectively (Table 1). ~~Analogously Similarly,~~ the frequency of
334 contaminated products ~~being positive~~ in each category was 100.0%, 49.0% and 4.0% (Table
335 1). In addition the density was different across products: mean density of 0.13 (s.d.= 0.09) in
336 salted products, 0.03 (s.d.=0.06) in products conserved in oil and 0.0 (s.d.=0.001) in marinated
337 products.

338 ~~As known, for other fish species, also in the case of anchovies most a~~Anisakid larvae are
339 known to be located in the fish visceral cavity and/or embedded in the visceral organs and in
340 the adjacent muscles (belly flap) (EFSA, 2010). Larval migration to the muscles may occur
341 after the capture, especially in the case of an inappropriate refrigeration (Cipriani et al.,
342 2016). When visible parasites are only found in non-edible parts of the fishery product,
343 processing procedures, such as gutting, ensure that the raw materials are not obviously
344 contaminated (European Commission, 2014). On the contrary, when the viscera removal is
345 not complete, the final product may harbour a high number of parasites. This is the case of
346 salted-ripened anchovies, where the gut is not completely removed as intestinal enzymes
347 seem to play an essential role in ripening (Czerner et al., 2011). In fact, at least one larva was
348 found in all the each analysed salted products ~~were positive.~~ Similarly, all the whole salted
349 anchovies in oil were positive contaminated with for a high number of larvae ~~and exceeded all~~

350 ~~thresholds~~. Overall 1259 larvae were found in whole salted anchovies in brine and in oil these
351 ~~products (1139 in 33 salted products and 120 in 2 salted whole anchovies in oil)~~. Another
352 ~~larva was found in one of the “white” whole anchovies in oil~~ (Table 1 and 2). As concerns the
353 fillets in oil, these are generally previously treated as whole salted anchovies for the
354 maturation process, and only after this phase they are filleted and put under oil. The lower
355 presence of parasites in this kind of products can be explained by the fact that parasites are
356 removed together with the gut residual during filleting. Statistical analyses revealed the
357 significance of the differences ($Z=-2.98$; $p<0.01$) observed between whole and filleted
358 anchovies in oil. The same differences were found when the larval density was evaluated
359 ($Z=-2.98$; $p<0.02$), with a value of 0.07 (s.d.=0.08) in whole fish compared to 0.01 (s.d=0.02)
360 in fish fillets. The analyses were performed only in products preserved in oil considering that
361 the salted products were all whole fish and the marinated ones were all filleted.- The presence
362 of very low positivity found for marinated products (only one larva in the 25 marinated
363 products) analysed may be explained by the fact that this kind of products are usually filleted
364 as fresh, hampering the parasitic migration from the viscera to the muscle. The very low
365 contamination of industrially marinated anchovies sampled in this study agrees with the
366 results of Sospedra et al., (2015) who analysed the same products from Spanish restaurants,
367 while it is well known that domestically prepared marinated anchovies are one of the
368 products most at risk for human anisakiasis (Bao et al., 2017; Mattiucci et al., 2013).

369 As concerns the viability of the larvae in semi processed anchovy products, it is known
370 that salting may reduce the parasite hazard by killing anisakid larvae if salt content and time
371 are adequate (Codex Alimentarius, 2012; Karl et al., 1994). Recently, the opinion No. 2007-
372 SA-0379 of the French Food Safety Agency (AFSSA, 2007), reported that salting inactivates
373 Anisakidae larvae within 21 or 28 days depending on the final salt concentration in fish. In a
374 recent work, all the larvae collected from anchovies salted according to a traditional Italian

375 procedure (final salt concentration of 24.5%) were found dead after 15 days (Anastasio et al.,
376 2016). ~~In addition, s~~ Salted-ripened anchovies undergo a ripening process after salting that
377 takes at least 2-3 months ~~for E. enerasiocolus~~ (Anastasio et al., 2016). Therefore, the
378 processing time in this kind of products is much longer than the one required to effectively
379 kill the larvae.

380 Nematodes have been reported as highly resistant to the conditions created by traditional
381 marinating methods, being able to survive for periods of a few days up to several weeks,
382 depending on the concentration of salt, acetic acid and marinating times (AESAN 2007;
383 Anastasio et al., 2016; Karl et al., 1994). In the traditional marinating process, the fish is left
384 in a solution of vinegar and salt for less than 24 h. However, in a study the death of all larvae
385 in fillets exposed to vinegar did not occur until day 13 (Sánchez -Monsalvez et al., 2005).

386 Considering that all the larvae found were dead, the processing technologies (including the
387 preventive freezing treatment applied by FBOs according to the European legislation) for the
388 production of semi preserved anchovy products analysed in this study seem to be effective to
389 nullify the risk of contracting human gastrointestinal anisakiasis.

390 **3.3 Dead anisakid larvae in semi-preserved anchovies: a potentially hazardous defect**
391 **and hazard?**

392 ~~Dead visible larvae can be considered a defect according to the definition of the Codex~~
393 ~~Alimentarius: “A condition found in a product that fails to meet essential quality, composition~~
394 ~~and/or labelling provisions of the appropriate Codex product standards” (Codex~~
395 ~~Alimentarius, 2012).~~ *Anisakis* sp. larvae are whitish to transparent and are not easily detected
396 by the naked eye when they reside deeply embedded in fish muscles. On the contrary, they
397 are evident when they infect in high number the celomatic cavity of fish species. This is
398 particularly true in case of fresh fish containing live larvae ~~that which~~ can actively move and
399 become evident also on the external surface (Guardone et al., 2016b). However, dead visible

400 larvae can also be considered a defect according to the definition of the Codex Alimentarius:
401 “A condition found in a product that fails to meet essential quality, composition and/or
402 labelling provisions of the appropriate Codex product standards” (Codex Alimentarius,
403 2012). ~~also~~In fact, the presence of dead larvae ~~can~~represents a reason to disqualify the fish
404 product (Council Reg. EC No 2406/1996) and to consider it not fit for human consumption
405 ~~according to~~(Reg. (EC) No 178/2002).

406 The finding of parasitized products on the European market has elicited numerous RASFF
407 (Rapid Alert System for Food and Feed) notifications over the years. Between 2010 and
408 2016, 409 notifications for the presence of anisakid larvae in fishery products were issued.
409 Among these, the state of the product was indicated in 327 cases: besides fresh or chilled
410 products (n=254), 81 referred to non-fresh products (frozen, smoked, salted, marinated and in
411 oil) and thus probably involving dead larvae. In some of the heavily contaminated products
412 found in this study, visible parasites were evident at visual inspection even before opening
413 the packet or simply observing the fish edible tissue (Fig. 2). The observation of a similar
414 contamination by consumers might result in disgust and rejection of the product and may also
415 damage the brand reputation.

416 The ingestion of live *Anisakis* spp. worms may cause hazardous allergic reactions,
417 including anaphylaxis, generally in association with gastrointestinal forms (EFSA, 2010;
418 Daschner et al., 2012; Mattiucci et al., 2013). On the contrary, ~~T~~the potential of dead larvae
419 to induce allergies in sensitized subjects is still debated (Daschner et al., 2012). Oral
420 challenges performed in clearly allergic subjects with non-infective frozen or lyophilized
421 larvae (Alonso-Gòmez et al., 2004; Sastre et al., 2000) and parasitic antigens (Baeza et al.,
422 2004; Daschner et al., 2000) did not elicit any adverse effect. However, according to different
423 authors, allergic reactions may also occur after ingestion of processed fish or parasite proteins
424 alone (Audicana and Kennedy, 2008; Nieuwenhuizen et al. 2006) and it has been supposed

425 | that no-viable larvae or related antigens could be involved in chronic urticarial reactions
426 | (Mattiucci et al., 2017). Accordingly, the high prevalence (72.5%) of *Anisakis* larvae in
427 | frozen fillets of pink salmon was considered a public health issue due to the potential risk for
428 | allergic reactions in sensitized persons (Bilska-Zajac et al., 2016). The issue of allergic
429 | reactions is also related to different fish-eating habits, which probably account for different
430 | sensitization rates or the frequency of allergic symptoms in the different regions of the world
431 | (Mattiucci et al., 2017).

432 | Therefore, even though it is not possible, on the basis of the current knowledge, to
433 | consider dead larvae as a proven hazard, appropriate measures should be implemented to
434 | avoid commercialization of obviously contaminated products. This would require FBOs
435 | involved in processing of salted, in oil or marinated anchovies, at industrial or artisanal level,
436 | to include appropriate risk management measures in their self-checking programs. In
437 | practice, FBOs should implement a system, based on the sampling method associated with a
438 | visual inspection as usually applied in Italy (D'Amico et al. 2014), or others of similar
439 | efficiency, to inspect batches of fresh anchovies. This would allow to select the most
440 | appropriate kind of processing (salting, preparation in oil or marinating) on the basis of the
441 | level of contamination detected. In fact, in this study, the level of contamination depended on
442 | the products' typology, being high in salted-ripened, medium in fillets in oil and very low for
443 | industrially marinated anchovies. The observed differences are linked to the preliminary
444 | preparation of the fish, in particular to the complete or incomplete removal of the viscera.
445 | Batches with a higher level of contamination should be destined to the production of
446 | marinated products. This would be economically advantageous for industries to reduce the
447 | costs arising from the discard of heavily contaminated batches of fresh anchovies and from
448 | the withdrawal of unfit product from the market. The continuously growing awareness of
449 | consumers and food authorities as to the occurrence of parasites in seafood, emphasises the

450 importance of providing the fish processing industries with procedures able to reduce hazards
451 and defects.

452 In fact, an incorrect risk communication can influence consumers' trust and even lead to a
453 significant reduction of fish consumption.

454 A study conducted in Italy showed that the highest prevalence was detected along the
455 Adriatic and Tyrrhenian coasts where marinated anchovies are a frequently consumed
456 traditional food, often prepared at home. In seaside areas of Southern Italy, where anchovies
457 are generally eaten fried rather than marinated, *Anisakis* hypersensitivity was much less
458 commonly found (AAITO-IFIACI, 2011). The same association between *Anisakis*
459 hypersensitivity and marinated seafood was observed in studies in Spain (Garcia et al., 1997;
460 Valinas et al., 2001).

461 Therefore, even though it is not possible, on the basis of the current knowledge to consider
462 the dead larvae as a proven hazard, a precautionary approach should be adopted. In practice,
463 this would mean to adopt appropriate measures to reduce the risk of ingestion of dead larvae.
464 ... In fact, when the available supporting information and data are not sufficiently complete
465 to enable a comprehensive risk assessment, official authorities may take measures based on
466 the precautionary principle, while seeking more complete scientific and other data (Reg. EC
467 178/2002).

468 Incorrect risk communication can influence consumers' trust and even lead to a significant
469 reduction of fish consumption. Therefore, the finding of contaminated products by FBOs
470 within their self control programs requires corrective actions to avoid that products heavily
471 contaminated with dead larvae reach the market. The HACCP approach, usually aimed at
472 ensuring food safety and preventing risks, can also be applied to cover food quality aspects, if
473 instead of identifying the hazards of the process, potential defects are considered. The
474 continuously growing awareness of consumers and food authorities as to the possible

~~presence of parasite or parasite-related quality defects in seafood emphasises the importance of providing the fish processing industries with feasible procedures able to monitor hazard and defect.~~

Conclusion

The present work ~~highlighted how~~ showed that semi preserved anchovy products heavily contaminated with *Anisakis* spp. larvae ~~can~~ reach the market and that the processing technology can influence the occurrence of parasites in semi-preserved products. Therefore, the batches intended for the production of these products (whole or filleted) should be accurately selected by industries, at the initial phases of the fish supply chain, according to the industrial fate of the raw material. Beyond the negligible risk for anisakidosis, due to the inactivation of larvae by freezing and processing technologies, the occurrence of dead parasites may cause immediate rejection in consumers. In addition, the risk related to allergic reactions in sensitized individuals is still an open issue. Providing the fish processing industries with procedures able to reduce hazards and defects is particularly important in the light of the continuously growing awareness of consumers and food authorities as to the occurrence of parasites in seafood. and that the processing technology can influence the occurrence of parasites in semi-preserved products. Therefore, the batches intended for the production of these products (whole or filleted) should be accurately selected by industries, at the initial phases of the fish supply chain, according to the industrial fate of the raw material. Providing the fish processing industries with procedures able to reduce hazards and defects is particularly important in the light of the continuously growing awareness of consumers and food authorities as to the occurrence of parasites in seafood. In particular, the level of contamination depended on the products' typology, being high in salted-ripened, medium in fillets in oil and very low for industrially marinated anchovies. The observed differences are strictly linked to the processing procedure and to the preliminary preparation of the fish, in

500 ~~particular to the complete or incomplete removal of the viscera. Beyond the negligible risk~~
501 ~~for anisakidosis, due to the inactivation of larvae by freezing and processing technologies, the~~
502 ~~presence~~occurrence ~~of dead parasites may cause immediate rejection in consumers. In~~
503 ~~addition, the risk related to allergic reactions in sensitized individuals is still an open issue.~~

504 ~~This study demonstrated~~showed that the processing technology can influence the presence
505 of parasites in the final semi-preserved products. Therefore, the batches intended for the
506 production of these products (whole or filleted) should be accurately selected by industries, at
507 the initial phases of the fish supply chain, according to the industrial fate of the raw material.

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514 Captions

515 **Figure 1** Presentation of the most part of the products analysed in the present study: whole
516 salted anchovy (left), salted fillet preserved in oil (centre), marinated fillet (right).

517 **Figure 2** From left to right: (a) salted anchovies heavily contaminated, one of the larvae
518 was already visible from outside the glass jar before opening; (b) detail of another heavily
519 contaminated salted product, the larva was visible from the external of the package; (c) larva
520 in the muscle (edible part) of a salted anchovy; (d-e) parasites collected from the one of the
521 most contaminated products: (d) natural light, (e) UV light.

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Table 1 Summary of the results concerning ~~positivity~~contamination, number of collected larvae, range ~~of larvae per product,~~and mean number of larvae per product ~~and density~~ for each analysed category and overall

Product category (n)	Positivity (to Products with at least one larvae: n (% of the total of contaminated products for each category)	Total n Number of collected larvae (% of the total of collected larvae products)	Range	Mean number of larvae per product	Density (larvae/gram)
Salted (33)	33 (100.0%)	1139 (88.8%)	1-105	34.5 (± 29.3 SD)	0.13
In oil (49)	24 (49.0%)	143 (11.1%)	0-28	2.9 (± 5.8 SD)	0.03
Marinated (25)	1 (4.0%)	1 (0.1%)	0-1	0.0 (± 0.2 SD)	0.00
Total (107)	58 (54.2%)	1283	0-105	12.0 (± 22.5 SD)	0.05

SD: Standard Deviation

Table 2 Summary of the results obtained analysing the 107 products, sub-divided per product category and per brand. NA: Not Available

Commercial name of the product	Product codes	Geographical origin	Product presentation	Mean net weight/product (g)	N analysed products	Total n L3 <i>Anisakis</i> spp.	Density (larvae/gram)	Range	N positive contaminated products ^a	N products exceeding MA threshold ^b	Molecular identification (n analyzed)
Salted anchovies Brand 1	RTE25, RTE33, RTE72, RTE73, RTE74	Atlantic Ocean NE FAO 27.VIII.C, Cantabrian Sea	whole	153.8	5	105	0.1	5-51	5	4	<i>A. pegreffii</i> (1) <i>A. simplex</i> (11)
Salted anchovies Brand 2	RTE12, RTE36, RTE42, RTE63, RTE69, RTE70	South Gulf of Biscay, Cantabrian Sea	whole	195.8	6	165	0.1	1-42	6	5	<i>A. pegreffii</i> (11) <i>A. simplex</i> (2)
Salted anchovies Brand 3	RTE 46, RTE48, RTE49, RTE87, RTE88, RTE89	Mediterranean Sea FAO 37.2.1	whole	100.0	6	55	0.1	3-15	6	5	<i>A. pegreffii</i> (12) <i>A. simplex</i> (2)
Salted anchovies Brand 4	RTE53, RTE75, RTE76, RTE93, RTE94	FAO 37	whole	221.4	5	146	0.1	20-48	5	5	<i>A. pegreffii</i> (13) <i>A. simplex</i> (1)
Salted anchovies Brand 5	RTE5, RTE6, RTE7, RTE24, RTE144, RTE145	FAO 37.2.1	whole	427.9	6	439	0.2	39-105	6	6	<i>A. pegreffii</i> (16) <i>A. simplex</i> (2)
Salted anchovies Brand 6	RTE32, RTE110, RTE121, RTE126, RTE149	FAO 37.2	whole	571.8	5	229	0.1	2-87	5	4	<i>A. pegreffii</i> (12) <i>A. simplex</i> (1)
Total salted anchovies (%)					33	1139		1-105	33 (100.0)	29 (87.9)	<i>A. pegreffii</i> (65) <i>A. simplex</i> (19)
Anchovies in oil Brand 7	RTE23, RTE40, RTE65, RTE67, RTE71	FAO 37	whole (red)	73.2	5	40	0.1	3-13	5	5	<i>A. pegreffii</i> (5) <i>A. simplex</i> (4)
Anchovies in oil Brand 2	RTE37, RTE58, RTE64, RTE66, RTE95	Not reported	whole (red)	109.5	5	80	0.1	8-28	5	5	<i>A. pegreffii</i> (13)
Anchovies in oil Brand 1	RTE54, RTE59, RTE61, RTE68, RTE92	Not reported	whole (whitish)	88.4	5	0	0.0	0	0	0	
Anchovies in oil Brand 8	RTE127, RTE128, RTE129	Not reported	whole ^c (whitish)	285.0	3	1	0.0	0-1	1	NA ^c	
Anchovies in oil Brand 9	RTE103, RTE104, RTE105, RTE106	Mediterranean Sea FAO 37	fillets	88.0	4	1	0.0	0-1	1	NA	<i>A. simplex</i> (1)
Anchovies in oil Brand 5	RTE8, RTE142, RTE143	FAO 37	fillets	140.0	3	2	0.0	0-1	2	NA	<i>A. pegreffii</i> (1)
Anchovies in oil Brand 10	RTE34, RTE108, RTE109	FAO 37	fillets	60.0	3	2	0.0	0-1	2	NA	<i>A. simplex</i> (1)
Anchovies in oil Brand 7	RTE116, RTE117, RTE118	FAO 37	fillets	50.7	3	0	0.0	0	0	NA	
Anchovies in oil Brand 11	RTE136, RTE137, RTE138	Not reported	fillets	82.3	3	0	0.0	0	0	NA	

Anchovies in oil Brand 12	RTE133, RTE134, RTE135	FAO 27	fillets	64.7	3	10	0.0	2-5	3	NA	<i>A. pegreffii</i> (2) <i>A. simplex</i> (4)
Anchovies in oil Brand 13	RTE130, RTE131, RTE132	FAO 37.2.1	fillets	51.2	3	4	0.0	0-1	2	NA	<i>A. pegreffii</i> (3)
Anchovies in oil Brand 14	RTE119, RTE124, RTE125	FAO 37.2	fillets	112.4	3	2	0.0	0-1	2	NA	<i>A. pegreffii</i> (1) <i>A. simplex</i> (1)
Anchovies in oil Brand 15	RTE139, RTE140, RTE141	Not reported	fillets	59.3	3	0	0.0	0	0	NA	
Anchovies in oil Brand 6	RTE120, RTE122, RTE123	FAO 37.2.1	fillets	22.3	3	1	0.0	0-1	1	NA	<i>A. pegreffii</i> (1)
Total anchovies in oil (%)					49	143		0-28	24 (49.0)		<i>A. pegreffii</i> (26) <i>A. simplex</i> (11)
Marinated anchovies Brand 9	RTE39, RTE102, RTE107, RTE150, RTE151	Mediterranean Sea FAO 37	fillets	70.1	5	0	0.0	0	0	NA	
Marinated anchovies Brand 12	RTE52, RTE60, RTE62, RTE98, RTE99	Adriatic Sea	fillets	124.4	5	0	0.0	0	0	NA	
Marinated anchovies Brand 2	RTE55, RTE56, RTE57, RTE96, RTE97	Not reported	fillets	108.0	5	0	0.0	0	0	NA	
Marinated anchovies Brand 16	RTE113, RTE114, RET115, RTE152, RTE153	Adriatic Sea	fillets	135.6	5	1	0.0	0-1	1	NA	<i>A. pegreffii</i> (1)
Marinated anchovies Brand 17	RTE9, RTE10, RTE146, RTE147, RTE148	Not reported	fillets	121.9	5	0	0.0	0	0	NA	
Total marinated anchovies (%)					25	1		0-1	1 (4.0)		<i>A. pegreffii</i> (1)
Total (%)					107	1283		0-105	58 (54.2)		<i>A. pegreffii</i> (92) <i>A. simplex</i> (30)

^apresence of at least 1 larva; MA: mean abundance; L3: third stage larvae; ^bMA threshold $LpG-1$ proposed in Guardone et al., 2016b2017; ^cdespite the fact that the product was originally prepared with whole anchovies it was not possible to count the number of specimens due to the loss of anatomical integrity of the specimens induced by processing.

Figure

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Figure
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