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Title: Hazard Analysis and Critical Control Point (HACCP) in Seafood Processing: An Analysis of its Application and Use in Regulation in the Sultanate of Oman

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Abstract: When considering the supply of fish products to consumers, the adoption of food safety management systems throughout the 'net to plate' continuum is of a paramount importance. It is essential to safeguard consumers and to facilitate regional and international trade. This study has assessed the technical barriers and benefits associated with the implementation of management system incorporating HACCP and related pre-requisite programmes in the seafood processors in the Sultanate of Oman.

A survey, using qualitative surveys and interviews, was conducted out to verify the level of implementation of the seafood safety and quality requirements. A total of 22 (92% returned) HACCP processors, and 15 (83% returned) non-HACCP processors and 15 (75%) officials completed the questionnaires.

Differences between processors operating with or without a HACCP system in place have been identified. The survey of local officials provided an additional perspective on the issues involved. The implications of handling practices in the seafood supply chain, seafood trade and the cost implications of implementing HACCP-based food safety management systems were also assessed.

In comparison to the non-HACCP processors, the results indicated that HACCP firms were more diversified in their export markets and were able to target the more lucrative markets such as EU, Japan and America. However, the processors felt that the main barrier for exporting to these markets was the restriction imposed by the government on exporting certain species which reduced their ability to meet contracts with these countries. The study has also shown inadequate execution of prerequisite programmes due mainly to lack of training delivered to food handlers and a poor knowledge of food safety concepts. In particular there is an over-reliance on the use of CCPs to control hazards when prerequisite programmes would be more appropriate in many situations.

When considering whether to implement HACCP-based control systems, the seafood processors identified barriers linked to costs as their main concerns. However, whilst recognising this issue, the officials also

highlighted barriers linked to the lack of expertise, skills and commitment of the staff.

In general, the study highlighted significant gaps which undermine the effectiveness and success of implementing safety and quality requirements to meet national legislative obligations. These include: poor attitudes and understanding toward HACCP and its pre-requisite programmes, lenient enforcement by the authorities, the lack of training and consultancy organizations in the country, a lack of awareness. The overlapping structure of the regulatory authorities in the country and the distribution of national inspection resources have also been identified as an issue of concern.

Dear Editor,

I am enclosing herewith a manuscript entitled “ Hazard Analysis and Critical Control Point (HACCP) in Seafood Processing: An Analysis of its Application and Use in Regulation in the Sultanate of Oman” in your esteemed journal “Food Control” for possible evaluation and publication.

With the submission of this manuscript I would like to confirm that the above mentioned manuscript has not been published elsewhere, accepted for publication elsewhere or under editorial review for publication elsewhere.

Kindest Regards,

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(on behalf of all authors)

Reviewers' comments:

Reviewer #2: The work is now of easier reading, but it lacks of some other information.

Lines 6-8: please indicate the scientific name of the cited species

Difficult to mention all the scientific names for each of the mentioned species, as they are many types of tuna, kingfish and etc. And the used reference in this manuscript mentioned only the generic names.

Lines 7-8: is "abalone" a crustacean or a univalve mollusc?

The word crustacean has been deleted to reduce confusion.

Lines 160: please indicate the scientific name of the cited species

Scientific names have been added.

Please evaluate if eliminate some paragraphs or subsections in the section "Results and discussion"; the work is now of easier reading but in my opinion it is still too long (7213 words include figures and tables, as specified in "Guidelines for authors"?)

We believe to reduce it further would be detrimental to the value of the paper.

Reviewer #4: The subject is interesting and has a central importance in the development of HACCP methodology in Sultanate of Oman.

After corrections made to the manuscript, it meets conditions to be published.

Nevertheless, the manuscript, in my opinion, is improvable in some aspects, according to the following suggestions:

1) Line 74, the authors must indicate a reference that explains the "Likert scales".

The reference has been added as requested.

2) line 163, authors should remove the space at the beginning of the sentence.

3) line 188, authors should remove the space at the beginning of the sentence.

4) line 256, authors should remove the space at the beginning of the sentence.

5) line 259, authors should remove the space at the beginning of the sentence.

6) line 397, authors should remove the space at the beginning of the sentence.

Comments 2-6: there are no spaces at the beginning of the mentioned sentences in the original manuscript, and maybe these spaces appeared once the original manuscript has been transformed into PDF document.

7) Table 1, needs a review since in the line "Length of service in seafood industry (years)" it's not clear the presence of a symbol with a "?".

This symbol may have been introduced during generating a PDF document as in not present in the original manuscript.

8) Table 2 needs a review since the used asterisks "*" are not explained; "n%" lines need a space

between the number and the percentage, like "13 (59%)"; and the zero value displays incorrectly decimal places. In this last point, authors should use zero value without decimal places and introduce the zero percentage value, like "0 (0.0%)".

Corrected

9) Table 3 needs a review, authors should in line "Non- HACCP processors" remove the space before "HACCP" and add a parenthesis after (TBT).

Corrected

10) in Table 4, authors should remove the empty line before "sampling plan" line
Empty line may have been introduced during generating a PDF document as in not present in the original manuscript.

11) in Table 5, authors should add a decimal place in the percentage value in all results: "3 (20%)" and "6 (40%)".

Corrected

12) in Table 6A, authors should add "0 (0.0%)" in line "GHPs" and column "Dis-Agree frequency (%)".

Corrected

13) in Table 6B, authors should add a decimal place in the percentage value in all results: "3 (20%)".

Corrected

14) in the list of tables and figures, authors should change in Figures 7 to 10 the one "1" to first "1st" and five "5" to fifth "5th".

Corrected

Hazard Analysis and Critical Control Point (HACCP) in Seafood Processing: An Analysis of its Application and Use in Regulation in the Sultanate of Oman

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1 1 INTRODUCTION

2 In the Sultanate of Oman, seafood production is of paramount importance in providing employment,
3 food security, and foreign currency. The total production in 2014 amounted to 211 thousand tonnes
4 with 63% being exported to nearly 50 countries with an export value of 83 million O.R. (US\$215.6
5 million). The country is considered to be self-sufficient in terms of seafood production and much of
6 its production is consumed locally. The most commercialized seafood species in Oman include tuna,
7 kingfish, large jacks, sardine, emperors, grouper, seabream, cuttlefish, lobster, shrimp and abalone
8 (FSB, 2015). However, with large quantities being exported local shortages have occurred and the
9 government, led by the Ministry of Agriculture and Fisheries, has imposed restrictions. A decision in
10 2010 led to the banning of exports of certain fish species whilst others are now subject to specific
11 quotas for internal and export markets.

12 Adopting food safety management systems throughout the 'net to plate' continuum is of paramount
13 importance in safeguarding consumer's well-being and facilitating regional and international trade.
14 The Omani government has made progress in implementing HACCP systems and improving food
15 safety controls. The Fishery Quality Control Centre (FQCC), as part of the Ministry of Agriculture and
16 Fisheries (MAF), is the premier agency in Oman with the legal power to enforce and implement the
17 seafood safety and quality requirements stipulated in the national Fishery Quality Control Regulation
18 and its related guidelines and standards (Al-Busaidi & Jukes, 2015; Al-Busaidi, Jukes, & Bose, 2016).
19 We have previously analyzed the structure of the seafood supply chain (Al-Busaidi et al., 2016) and
20 noted that it is based on traditional practices and characterized by being a complex system linking
21 different stakeholders from fishermen to consumers. Distribution of seafood products can involve a
22 lengthy chain which, due to seafood perishability, accelerates the decline of its quality and safety.
23 Overall, the food safety control system in Oman has a multiagency structure with the current food
24 safety law and regulations shared across various governmental authorities with overlapping
25 responsibility and mandates (Al-Busaidi & Jukes, 2015).

26 In light of these factors, taking the Sultanate of Oman as the basis for the study, we have evaluated
27 the issues relating to HACCP implementation in the seafood industry and the role of the regulatory
28 authorities. In particular, the study collected data on the perceived benefits and barriers of
29 implementing HACCP. Since currently the use of HACCP is not a legal requirement, our analysis is
30 based on two groups of processors: those who have implemented HACCP (the 'HACCP processors')
31 and those who do not operate a HACCP based safety system (the 'non-HACCP processors'). Local
32 officials were also surveyed to provide an additional perspective on the issues involved. The
33 implications of handling practices in the seafood supply chain on the safety and quality of seafood,
34 seafood trade and the cost implications in implementing HACCP based food safety management
35 systems were also assessed.

36 2 MATERIALS AND METHODS

37 2.1 Business

38 An interview-based qualitative survey was conducted with seafood processors and officials from the
39 regulatory authorities in charge of implementing seafood safety and quality requirements in the
40 Sultanate of Oman in the period from August 2015 to February 2016. Study criteria were
41 established to include only the seafood processors with some elements of food safety and quality
42 systems in place, with processing operations (and not just storage), and with potential to export to
43 regional and international markets. In addition processors meeting the criteria were selected to
44 ensure representation from small, medium and large businesses. Excluded were those who did not
45 fulfil these criteria or were under construction and/or not operational during the study.

46 The processors were segregated into distinct groups based on their hygiene status: the HACCP
47 processors (seafood processors implementing the HACCP requirements) and non-HACCP processors
48 (seafood processors not implementing the HACCP requirements and have basic hygiene standards in
49 place). To gain further insights into the divergences between these two groups, the data was
50 analysed to provide cross-validation between the responses of the processors and the officials. A list
51 of 50 processing establishments was provided by the Ministry of Agriculture and Fisheries. The
52 processors that fulfilled the study criteria were contacted and 42 were selected for the survey. 8
53 processors under construction were excluded. The selected processors were visited and handed
54 questionnaires of which a total of 37 (88%) were completed and returned. A total of 22 (92%
55 returned) HACCP processors, and 15 (83% returned) non-HACCP processors completed the
56 questionnaires. For the officials, 20 were contacted and 15 (75%) completed questionnaires were
57 obtained. The contacted officials were from the Ministry of Agriculture and Fisheries and were
58 selected based on their official role and experience in the field of seafood safety control. Their roles
59 varied between seafood safety inspectors, section heads and directors of the different departments
60 that deal with seafood safety control.

61 The processors and officials were located in varied governorates across Oman. The majority of the
62 processes were based in the Al-Wusta governorate (30%), followed by Muscat (24%) and Al-Sharqiya
63 (24%) governorates. Most of the officials (73%) were based in the Muscat governorate where the
64 main headquarters for seafood control is located.

65 Prior to conducting the survey, ethical approval was obtained from the University of Reading and an
66 approval was given by the appropriate authority in Oman. The data collected was treated
67 confidentially and anonymously.

68 **2.2 Questionnaire design and development**

69 It had been decided to use an interview-based qualitative survey as the main method of data
70 collection supplemented by qualitative responses from interviews with key personnel from the three
71 groups. In addition, inspection reports covering the previous 12 months from the Fish Quality
72 Control Centre (FQCC) were examined to provide a means of verifying some of the data.

73 The questionnaires used a mixture of closed questions, open questions and attitudinal scales based
74 on five-point Likert scales (Likert, 1932) and designed to provide a valid and accurate measure of an
75 individual's responses. Although 3 separate questionnaires were prepared for the 3 groups, the
76 majority of the questions were common so as to allow comparison and to provide cross-validation of
77 the responses. After drafting, all 3 questionnaires were translated so as to provide both English and
78 Arabic language versions.

79 Each questionnaire was divided into seven sections. Sections 1 and 2 sought general information of
80 the responder and the processor. Section 3 was on the seafood trade and business issues and
81 Section 4 looked on the seafood supply chain. Section 5 mainly dealt with prerequisite programmes
82 – an essential component for HACCP implementation. For the HACCP-processors, Sections 6
83 assessed the level of implementation of HACCP principles and requested some financial information
84 on the costs associated with HACCP implementation. In the final Section, all groups were
85 encouraged to rate the effectiveness of the Omani food and seafood safety legislation and the work
86 of the control authorities.

87 After checking with an independent expert, an academic specialized in the HACCP system, the
88 questionnaires were piloted on four processors (2 for each of the HACCP and the non-HACCP
89 processors) and three officials from the FQCC and, based on these responses, modifications were
90 made.

91 **2.3 Statistical analysis**

92 A Statistical Package for Social Science (SPSS) version 21 was used to process and analyse the data.
93 Descriptive analysis and frequencies were computed for the variables of the study. Cross tabulations
94 and Fisher's exact Chi-square (χ^2) test was used to examine the relationships between and among
95 the different variables.

96

97 **3 RESULTS AND DISCUSSION:**

98 **3.1 Characteristic and demographic details of the Seafood Industries in Oman**

99 General characteristics of the respondents participating in the study are presented in Table 1. For
100 the HACCP processors, the majority (64%) of the respondents were quality controllers, for the non-
101 HACCP processors they were the owners (80%); for the officials the largest group was inspectors
102 (47%). These proportions correspond well with Qatan et al. (2015). Professional experience in the
103 seafood industry varied among the respondents of the three groups with 47% having above 20 years
104 for the non-HACCP group, 59% having less than 10 years for the HACCP group, and 60% within the
105 range of 11-19 years for the officials. The HACCP processors and the authority were more willing to
106 employ staff with degree-level training; the owners of the non-HACCP processors were less likely to
107 employ qualified personnel as they depend more on their own experience and that of experienced
108 staff. This interpretation agrees with that of Jin, Zhou, and Ye (2008) which indicated that managers
109 of HACCP processors are more educated and willing to implement HACCP principles in their
110 businesses. The higher the education levels of the managers of the processors the less the
111 requirement of support and consultancy from the government (Karaman et al, 2012).

112 Only 14% of the respondents within the HACCP processors were Omani; for the non-HACCP group it
113 was 53% and these were mostly the owners. All officials were Omani. Qatan et al. (2015) had a
114 similar profile and suggested several possible causes: shortage of local expertise in seafood safety
115 and quality, reluctance of Omanis to work in this field and/or cost minimization by the processors.

116 Information on the processors' business profiles is presented in Table 2. The survey included small,
117 medium and large establishments. Most process mainly fresh and frozen seafood products with
118 only one HACCP processor producing canned products and only one non-HACCP processor
119 undertaking drying and salting. Those in the HACCP group were likely to employ more workers and
120 these were mostly non-Omani. Although both groups of processors target the domestic and foreign
121 markets, most products from the non-HACCP group go to the domestic markets (93%) in comparison
122 to 73% for the HACCP group. The lucrative markets such as the European Union (EU), the USA and
123 Japan are mostly targeted by processors from the HACCP group since they fulfil these markets'
124 requirements. However, the share of the end products going to these markets has decreased due to
125 the ban in 2010 on exports of certain species that was imposed by the MAF in order to limit the
126 export of high valued seafood products and increase their availability for local consumers. Other
127 markets have been targeted by both groups with more diverse products but mostly focused on
128 marketing low value species to the Asian and African markets. Most of the raw seafood materials are
129 obtained locally: 77% for the HACCP group and 100% for the non-HACCP group. The HACCP
130 processors often use imported raw materials due to the seasonality of certain species in Omani
131 coastal waters.

132 The majority of the respondents from both categories declared their capacity to be below 5000
133 metric tonnes (MT) per year, with only 15% and 6.7% exceeding 10,000 MT per year for HACCP and
134 non-HACCP processors respectively. Processors in the HACCP group tended to have a larger turnover
135 with only 2 (12%) processors indicating an annual turnover of less than 1 million dollars compared to

136 7 (54%) in the non-HACCP group. However, there were some large non-HACCP processors (4; 31%)
137 that had an annual turnover above 10 million dollars. This was partly caused by some of these
138 processors being suppliers of raw seafood to the HACCP processors.

139 **3.2 Seafood trade and business issues**

140 The markets are shown in Figure 1, where the HACCP processors were more diversified and targeted
141 the more lucrative markets such as EU, Japan and America.

142 The questionnaire asked about the level of difficulty of accessing different markets in terms of
143 satisfying their quality and safety requirements – mean value of the responses are shown in in Figure
144 2 based on a five-point scale ranging from “very difficult” (5) to “very easy” (1). The non-HACCP
145 processors perceived the lucrative export markets as very challenging and difficult to break into. The
146 HACCP processors were less concerned about the difficulty since they satisfy the key HACCP
147 requirement and were experienced in dealing with these markets. The officials were more
148 discriminating and viewed the EU, Japanese and the American markets as the most difficult to
149 access, with the Asian, African and Arabian/GCC countries as the easiest.

150 Results (Table 3) indicate that the main barrier for exports to regional and international markets was
151 the restriction imposed by the MAF on export of certain species. With the imposition of these
152 controls most exporters lost their valuable contracts as they were unable to ensure continuity of
153 supply and switched to low valued seafood targeting less lucrative markets. Some have given up
154 their HACCP certification as compliance is largely market driven – a similar attitude has been
155 reported in a study of the Australian food industry (Ropkins & Beck, 2000).

156 Data on the barriers to enhanced operations is shown in Figure 3. The scale shows the mean values
157 of the barriers that are likely to prevent the enhancement of the seafood business operation rated
158 by the officials, HACCP and Non-HACCP processors based on a five-point Likert scale ranging from
159 “major barrier” (5) to “not a barrier” (1). Once again the MAF export ban, although relating to only
160 certain fish species harvested locally (for example Kingfish (*Scomberomorus commerson*), Longtail
161 tuna (*Thunnus tonggol*), Yellowfin tuna (*Thunnus albacares*) and certain species of Grouper such as
162 *Epinephelus diacanthus*) was also seen as the major barrier preventing the enhancement of
163 operations. Sudden changes in government policies without giving the business a time frame to
164 adjust their practices was seen as the second barrier – probably also linked to the export ban.
165 Although not ranked in the top group, staff turnover was also considered a barrier for many firms
166 but it was more significant to the non-HACCP processors in comparison to the HACCP processors.
167 The non-HACCP processors mostly employ workers with low level of education and expatriate,
168 seasonal or non-permanent workers since they are much cheaper to employ and there is a
169 reluctance to provide adequate training as its considered time consuming and a financial burden.
170 Mol et al (2014) reported a similar situation in the Turkish seafood processing sector.

171 **3.3 Food Safety Management Systems (HACCP and its pre-requisite programs)**

172 Seafood products are often exposed to lengthy handling and distribution processes before reaching
173 the consumers and, given its perishability, its safety can be adversely affected if controls are
174 inadequate (Al-Busaidi et al., 2016).

175 The quality and safety of raw material received from suppliers of local raw seafood products were
176 rated highly by the respondents in comparison to imports. Figures 4 and 5, show various stages and
177 factors in the supply chain that may impose negative effects on the quality and safety of seafood
178 products. The officials believed that the practices adopted by the fishermen, landing sites and
179 middlemen/truckers are the stages that contribute negatively to the quality and safety of seafood
180 products. With a mean score of 3.0, it is interesting to note that in Figure 4, the non-HACCP

181 processors gave 'negative' scores (higher than 3.0) for all the suggested factors whereas both the
182 officials and the HACCP processors were much more discriminating.

183 In terms of the different factors that lead to deterioration in the safety and quality of the seafood
184 products, inadequate control of time and temperature and poor ice availability were reported as the
185 major impact on the seafood products as shown in Figure 5.

186 **3.3.1 Prerequisite programmes**

187 The processors were asked about the level of implementation of prerequisite programmes within
188 the different stages of their processing. The officials were also asked for their assessment of the
189 same prerequisites so as to verify the responses of the processors. The responses are shown in
190 Figure 6.

191 The HACCP processors rated their implementation of prerequisites highly; the officials were mostly
192 in agreement with these responses – for example the maximum difference in mean scores was only
193 0.80 for 'personal hygiene'. The non-HACCP processors also rated their implementation quite high;
194 however, the officials disagreed with this rating giving much lower scores to all pre-requisite
195 elements. This is seen by the difference in scores varying between a minimum of 0.87 and a
196 maximum of 2.00. The data shows a lack of knowledge of prerequisite programmes in the non-
197 HACCP processors. This could be due to various factors: the lack of education, lenient enforcement
198 by the regulators or a lack of finance. Similar suggestions have been made by Jin et al. (2008)
199 following their research into food enterprises without HACCP in China.

200 Prerequisite programmes are considered the foundation of effective HACCP implementation. Even
201 within the EU it has been reported that it is common to misunderstand the different roles of
202 prerequisites and HACCP both by authorities and food businesses (Food and Veterinary Office,
203 2015). This situation can also be found in the Omani seafood industries where, due to the need to
204 meet the EU market requirements in the 1990's, the process was rushed and prerequisite
205 programmes were not given enough consideration. Our review of the official inspection reports
206 confirmed that a major problem with seafood processors was the absence or failure to follow
207 prerequisite requirements. Similar results have been reported by other researchers (Murat Bas et
208 al., 2007; Doménech et al., 2011; Tomasevic et al., 2013).

209 The questionnaire asked where in the operation critical control points (CCPs) were situated. The
210 most selected CCPs were raw material reception (33%) followed by cooling/chilling (17.3%),
211 processing (17.3%), raw material suppliers (13.5%) and storage (13.5%). The least selected was the
212 cooking step as most of the processors deal with fresh and frozen product - only the canning
213 processors, where retorting occurs, considered it as a CCP. This clearly indicates a degree of
214 confusion in the application of HACCP as correct temperature control ('cooling/chilling') is
215 fundamental to the processing of seafood and should really have been included by all processors as
216 a CCP. 23% of the HACCP processors indicated they had 6 or more operational steps where CCPs
217 have been identified. This suggests an excessive reliance on the use of CCPs when control using
218 their prerequisite programmes would be more appropriate in many situations.

219 During the last three decades, the HACCP system and its prerequisite programmes have been
220 progressively introduced into the seafood industries in Oman. The adoption of HACCP principles by
221 the seafood processors however, has not progressed easily (Al-Busaidi et al., 2016). Prior to 2009,
222 food safety management systems (FSMS), particularly the HACCP system, were enforced by the
223 seafood safety authorities on the processors that were exporting to the European markets. The
224 processors received a lot of support from these authorities to implement the system. However those
225 not willing to adopt the system had much less support and were only inspected periodically by other
226 food safety enforcement authorities. However, after the amendment of the Fishery Quality

227 Regulation (12/2009) in 2009, all seafood processors are expected to adopt a food safety system
228 with HACCP a preferred method. Nonetheless, pressure from seafood importing countries is the
229 major factor currently demanding HACCP application making HACCP a market driven system rather
230 than a locally driven safety and quality practise.

231 Asked about the time required from starting to implement the system, 68% of the HACCP processors
232 stated that it took them less than 6 months with 50% of the processors receiving guidance from
233 officials of the FQCC. Other studies have reported varying time: in the Mexican and Chinese meat
234 industries it was reported to be around 29 and 42 months respectively (Maldonado-Siman et al.,
235 2014); in both the Australian meat industries (Khatri & Collins, 2007) and in food businesses in China
236 (Bai et al., 2007) the time varied between 6-12 months; in the Serbian meat industry 50% of the
237 processors estimated the period to be 12 months or less with 11.7% indicating more time was
238 required (Tomasevic et al., 2013).

239 64% of the processors believed that they fully participated in the development of their HACCP plan,
240 and they all, to varying degrees, considered that they were participating in its day-to-day operation.
241 The majority of the officials considered that most of these processors performed the above tasks.
242 Most of the respondents considered that they fully implement all the seven principles of HACCP;
243 however, the officials were less positive only classing implementation at the 'most' to 'some' level of
244 implementation.

245 **3.3.2 Barriers of implementing and operating HACCP system**

246 The processors were shown a list of 14 'barriers to implementing HACCP' and were asked to identify
247 the top five barriers. Of the 15 non-HACCP processors, only 9 felt that they had sufficient knowledge
248 to answer making a total of 31 processor responses. Combining the two groups, those barriers which
249 were selected the most were:

- 250 1. Requirements to restructure the facility (65% included this item)
- 251 2. HACCP requirements added cost to the final product (61%)
- 252 3. Inadequate infrastructure and facilities (45%)
- 253 4. Consumer/market not requiring HACCP (45%)
- 254 5. Lack of financial resources (42%)
- 255 6. A need to retrain production staff (42%)

256
257 The order of the list corresponds to that of the HACCP processors taken on their own. For the non-
258 HACCP processors, the items are the same although the order was different – for example, the need
259 to retrain staff was ranked second equal (67%) with requirements to restructure the facilities whilst
260 the cost of HACCP was their first concern (at 78%). However, as the questionnaire asked for the
261 barriers to be ranked from "the first highest barrier" to the fifth highest barrier", a more detailed
262 analysis is possible and data from this is shown in Figure 7.

263 The officials were asked a very similar question on the top five barriers, but they considered the
264 issue generally from their experience rather than linked to a specific business. Their top six show a
265 rather different selection:

- 266 1. Requirements to restructure the facility (87% of officials included this barrier)
- 267 2. Lack of expertise and/or technical support (60%)
- 268 3. Lack of top management commitment/dedication (53%)
- 269 4. Lack of knowledge on how to implement HACCP (53%)
- 270 5. Lack of financial resources (53%)
- 271 6. Inadequate infrastructure and facilities (53%)

272

273 The more rigorous food safety controls required by HACCP suggest to the respondents that
274 significant alterations to their business's structure are required although this should be a factor in
275 their operation whether or not HACCP is employed. Although all groups put the requirement to
276 restructure as their top barrier, it is interesting to note that the officials had greater concerns about
277 the expertise, skills and commitment of the staff whereas the processors tended to select items
278 more related to the costs of HACCP.

279 The HACCP implementers were also requested to provide the negative impacts they faced once they
280 had decided to adopt HACCP. The ranking of negative factors was in agreement with those of Khatri
281 & Collins (2007) and Maldonado-Siman et al. (2014) in finding product testing as a major operating
282 cost. Nevertheless, in regard to the cost of investing in new equipment and staff training, Khatri &
283 Collins (2007) reported them as one of the major costs in the meat industries in Australia.

284 **3.3.3 Motivation and benefits arising from adopting HACCP system in the seafood** 285 **industry**

286 Successful implementation of any FSMS requires sufficient knowledge and commitment from
287 administrative and production staff. The officials and both types of seafood processors agreed on
288 the benefit of adopting FSMS system.

289 ***Motivation***

290 The participants were presented with a list of 14 potential motivational factors and were requested
291 to select and rank the top five factors when their businesses decided to implement HACCP. For the
292 HACCP processors, the motivational factors selected the most were as follows:

- 293 1. Improved product quality and safety (91% of HACCP processors included this item)
- 294 2. Meet quality and safety requirement of customers (55%)
- 295 3. Consumer protection (55%)
- 296 4. Meet with requirements of national, regional and international laws and regulations (45%)
- 297 5. Enhanced reputation of establishment (41%)

298 It is pleasing to note that the top three items focus on the consumer benefit of adopting HACCP. The
299 list from officials was very similar although their list had a different factor (Increased ability to retain
300 or access new export markets) in fifth place perhaps reflecting the recognition that the officials' role
301 is often linked to ensuring processors gain access to export markets.

302 The responses by all the groups varied within the ranking from "the first highest motivation" to the
303 "fifth highest motivation" for each motivational factor which is illustrated clearly in Figure 9.

304 ***Benefits***

305 The HACCP processors were also asked to provide the top benefits once they had implemented the
306 HACCP system as shown in Figure 10. The improvement of the quality and safety of the seafood
307 products was also selected as the top benefit of adopting the HACCP system. Similar results to our
308 study in terms of the HACCP system improving the products quality and safety have been reported
309 (Murat Bas et al., 2007; Jin et al., 2008; Karaman et al., 2012; Qatan, 2010; Qatan et al., 2015; Qijun
310 & Batt, 2016; Tomasevic et al., 2013). The meeting of laws and regulations, ranked second in our
311 survey, is similar to that of Tomasevic et al., (2013) although in their study of Chinese food
312 businesses Bai et al., (2007) found it the least motivational factor. The least motivational factor in
313 this survey was the potential to increase the motivation of production staff.

314 One of the new HACCP system implementers stated that the system protected the reputation of his
315 firm when he faced an overseas complaint on the safety of the received products which had been

316 mishandled during air transportation and he was protected from legal accountability by showing due
317 diligence. A similar situation was also reported by Khatri & Collins (2007).

318 One of the perceived HACCP benefits in the seafood business in Oman is export competitiveness and
319 being able to break into the highly competitive markets of the EU, USA and Japan. From several face-
320 to-face meetings with the processors, penetration to new markets or the capacity to attract new
321 customers has not been an issue as long as FSMS are adopted. Moreover, the willingness of the
322 Omani government in attempting to upgrade the existing control systems to ensure consumer
323 protection has made tremendous progress with regard to HACCP implementation (Al-Busaidi et al.,
324 2016).

325 **3.4 Economic impact of HACCP implementation**

326 Respondents in the HACCP group were requested to provide the different costs related to the
327 preparation, implementation and operation of their HACCP system. Each processing plant will have
328 had individual characteristics and this will greatly influence the costs involved.

329 A further complication was that most of the respondents were unsure of the exact costs involved (or
330 unwilling to provide them). The respondents reported the preparation cost inclusive of overall
331 structure and human resources to be the highest (mean of 401,000 \$US) due to structural changes in
332 particular for the older processors and the need to employ qualified staff to operate the HACCP
333 system.

334 The HACCP implementation cost (HACCP certification, audit cost and external consultancy service)
335 were very small in comparison (mean of 3380 \$US) although it can be noted that the FQCC provided
336 support for these services free of charge. HACCP certification is also provided by the FQCC rather
337 than by a commercial certification body with audits carried out by Ministry officials, thereby
338 reducing the processors' costs further. It has been reported that high operating and certification
339 costs of HACCP system were the major problems for Mexican's meat enterprises adopting HACCP
340 systems (Maldonado-Siman et al., 2014).

341 The highest reported expenditure was in the investment for new equipment and machines (322,000
342 \$US). Annual average operational costs were 63,030 \$US, with the largest component being waste
343 management followed by training programmes, maintenance of equipment and machines and
344 product testing (microbial, chemical, physical), with the least being record keeping. Khatri and
345 Collins (2007) found similar outcomes with staff training, audit costs and product testing to be the
346 largest cause of cost elevation in the processors. Time and money with lack of employee training
347 were seen as the greatest constraints of adopting HACCP in the food business in Turkey (Murat Bas
348 et al., 2007). Lack of understanding of HACCP system and a need of continuous training were other
349 constraints mentioned by Tomasevic et al. (2013). Investment in new equipment, product testing
350 and staff training were also deemed to be the main operational costs for the Mexican food
351 industries (Maldonado et al., 2005).

352 Although some average figures have been given above, in general the processors faced difficulties in
353 determining the actual cost of adopting and implementing their HACCP systems and caution is
354 needed in interpreting the data. However, in a previous study of the seafood industries in the
355 Sultanate of Oman, Qatan (2010) estimated the greatest cost was around 98,000 O.R per processor
356 for structural changes although he also stressed the difficulty in obtaining reliable cost data.

357 It can also be commented that the FQCC organizes an annual training course by hiring a consultant
358 to conduct professional training on FSMS targeting seafood processors and inspectors in order to
359 overcome and reduce the cost burden of training on these processors and enhance their skills and
360 knowledge. The processors showed eagerness to receive this type of training from the authorities as
361 indicated by Qatan (2010) and Zaibet (2000).

362 3.5 The effectiveness of food safety legislation and control authorities

363 Respondents evaluated different aspects of the regulatory control of seafood quality and safety.
364 Most respondents were subject to the Fishery Quality Control Regulations (MD No. 12/2009) with
365 the majority of the HACCP processors rating it as excellent in implementation. However, the non-
366 HACCP processors had more varied views with opinions differing from 'excellent' to 'fair'. In most
367 cases the Aquaculture and Related Quality Control Regulations (MD No. 177/2012) were not
368 implemented as most of these processors did not process aquaculture product at the time of
369 conducting this survey.

370 The implementation of the general Food Safety Law (84/2008) that was issued to protect consumer
371 well-being was rated very good by the HACCP processors but poorly by the non-HACCP processors
372 and, more worryingly, most of these processors were not fully aware of its existence. Nevertheless,
373 when the officials were requested to give an opinion on the implementation of the legislation within
374 the steps of the seafood chain (fishermen, landing sites, truckers, transportation prior to processing,
375 processors, fish farms, distribution of processed products and markets), their response indicated
376 that the part of the chain from 'processors' to 'distribution of processed products' was the strongest
377 portion implementing all the legislation related to food and seafood quality and safety with the start
378 of the chain from 'fishermen' to 'transportation' much weaker. This result agrees with the
379 suggestion given by Qatan et al. (2015) that there is a need for a more holistic approach to promote
380 the quality and safety of seafood throughout the entire chain from "net to plate". The quality and
381 safety of seafood products cannot be maintained if the initial input is uncertain (Qatan et al., 2015).

382 The official regulation for seafood safety and the official control activities were assessed for their
383 effectiveness and the respondents were requested to evaluate them based on a five-point Likert
384 scale ranging from "Excellent" to 'Poor'. The responses were then split into three clusters; 'agree' for
385 those responding with 'excellent' or 'very good', 'uncertain' for responses 'satisfactory' and
386 'disagree' for responses 'fair' and 'poor' as shown in Table 4. The Fishery Quality Control Regulation
387 (12/2009) is perceived by the Ministry as the key legal document. Respondents were asked to assess
388 the strength of this regulation (see Table 4). All the three groups were in agreement in terms of the
389 regulation ensuring the seafood quality and safety requirements. The officials and HACCP processors
390 rates were in agreement with the regulation meeting the needs of different sized processing
391 establishments although the non-HACCP processors were divided between being in agreement and
392 disagreement. In discussion with them it was viewed as being too complicated and not easy to be
393 implemented in their smaller operations. Asked to consider whether the regulation provides
394 consistent application of the seafood safety requirements across different establishments in Oman,
395 the officials and HACCP processors generally agreed but the non-HACCP processors were again split
396 for similar reasons as before.

397 The effectiveness of the official control activities in enhancing seafood quality and safety was also
398 rated by the groups and the results, split into 3 clusters (Table 4). One element of the official control
399 operation is a sampling plan operated by the FQCC to collect samples from the processors which are
400 submitted for physical, microbiological and chemical analysis with the emphasis on ensuring that the
401 HACCP processors are complying with the requirements. These were seen as effective control
402 procedures by the officials and HACCP processors but the non-HACCP processors were less
403 consistent with their responses being between in agreement and uncertain and discussion indicated
404 that they considered it a cost burden on small scale processors. Less than half of the officials (46%)
405 supported the effectiveness of the 'Recall and Revision' protocol in handling rejected products from
406 markets. However subsequent discussion suggested some uncertainty on this point with some
407 officials being unaware of this aspect of the legislation. Overall they felt that the current status of
408 this system is not effective in protecting the safety and quality of seafood products and needs to be
409 improved. In this case both groups of processors considered this protocol effective. The current level
410 of penalties that apply to those caught breaking the rules within the Fishery Quality Control

411 Regulation (12/2009), was well supported by both processors but not supported by the officials
412 (with only 20% in agreement) who regarded them as too lenient and not sufficient to encourage
413 compliance with the regulation. The Fisher's exact Chi-square test indicated a significant difference
414 ($p < 0.05$) in the views of the three groups in the study for two items: the consistent application of
415 the seafood safety requirements across different establishments and the level of violation and
416 penalties imposed by the regulators.

417 When asked to indicate the frequency of official inspection, 59% of the HACCP processors indicated
418 that they were inspected monthly which correlated well with the view of the officials (with 71%
419 giving this response). However, only 21% of the non-HACCP processors gave this response with a
420 larger proportion (29%) selecting 'random inspection'. Subsequent discussion indicated that the
421 processors situated close to Muscat (where the FQCC is based) are inspected frequently but the
422 inspection is much less frequent for the more distant processors (for example, in Al-Wusta and Al-
423 Sharqiya governorates). On the other hand, the non-HACCP processors were subject to less
424 inspection and subsequent discussion actually indicated that they would be in favour of more
425 inspection visits as they see them as educational and providing an opportunity to improve their staff
426 compliance. Overall, excessive official inspection was not considered a barrier effecting the
427 enhancement of the business operation by either the HACCP or non-HACCP processors (Figure 3).

428 As well as conducting inspections, the government can provide support to improve the safety and
429 quality at processors. The respondents evaluated the government contribution based on a five point
430 Likert scale ranging from 'Excellent' to 'Poor' which we have further clustered into three groups:
431 'agree' for those indicating 'excellent' or 'very good', 'uncertain' for 'satisfactory', and 'disagree' for
432 'fair' and 'poor' as shown in Table 5. Divergent responses were obtained for this question. However,
433 all groups were in agreement with regard to 'officials response on enquires about quality and safety
434 issues faced by the industry'. On the point relating to 'funding', it can be noted that the majority of
435 the processors considered this to be limited although the officials tended to be more supportive of
436 the level. Based on the views given by the study groups on the support provided by the
437 government, the Fisher's exact Chi-square test indicated a significant difference ($p < 0.05$) for four
438 items: funding, training, consultancy and the response by officials to HACCP enquiries.

439 **3.5.1 Authority's inspection reports**

440 A number of reports of inspections carried out by the FQCC inspectors were analysed to verify the
441 data obtained from this survey. In general non-compliances identified in these reports were in the
442 maintenance of facilities and equipment, cleanliness, staff hygiene, maintaining and recording time
443 and temperature, record keeping, coding of the seafood products (traceability), recording of sensory
444 evaluation and temperature during fish receiving and calibration of the equipment. Most of these
445 comments were due to the improper implementation of prerequisites prior to adopting the HACCP
446 system. The finding of the study of Bas et al. (2006) in Turkey is similar to our findings. In particular
447 that study had highlighted inadequate time and temperature control, handwashing practices and
448 low level of general hygiene.

449 Despite being repeated in subsequent reports, the inspection comments were frequently ignored by
450 the processors delaying improvements. This could be due to a lack of communication between the
451 officials and the processors, and insufficient training on seafood quality and safety aspects for the
452 processors. Ensuring effective communication links between the regulatory authority and the
453 seafood processors will enhance the efficacy and effectiveness of the inspection process (Qatan,
454 2010) but should be supported by enhanced professional training of both inspectors and processing
455 staff.

456 Food processors are responsible and accountable for the safety of the food they produce as stated in
457 Article 3 of the Food Safety Law (RD No.8/2008) and Article 10 of the Food Safety Regulation (MD

458 No.2/2010). They are also required by Article 7 of the Fishery Quality Control Regulation to register
459 to obtain a quality and safety control certificate (Ministerial Decision, 2009). By being registered,
460 processors sometimes consider that this is sufficient to indicate compliance with their legal
461 responsibilities and they rely on officials to tell them if this is not the case. Nonetheless, the
462 processors should themselves be taking a proactive approach towards compliance.

463 The questionnaire asked officials to grade the effectiveness of the inspection report in covering the
464 pre-requisite programmes (such as GMPs and GHPs) and the HACCP principles (and related CCP
465 procedures) on a five point Likert scale from 'Excellent' to 'Poor'. The responses were also split into
466 three clusters: 'agree' for those responding 'excellent' or 'very good', 'uncertain' for the response
467 'satisfactory' and 'disagree' for responses 'fair' and 'poor' as shown in Table 6-A. Although their
468 responses were mostly supportive, it was observed that the inspection reports were mostly focusing
469 on the different segments of the processing layout. With the exception of temperature recording,
470 less attention was given to the identified CCPs for each processor. Again the limitations were
471 analysed on a five point Likert scale and split into three clusters labelled 'agree' (responses
472 'significant' or 'major', 'uncertain' ('moderate' barrier) and 'disagree' ('limited' or 'not a barrier') as
473 shown in Table 6-B. The officials considered lack of training, lack of laboratory support and
474 appropriate facilities and lack of continuity and commitment of the staff from the processors as
475 important barriers. Scattering of the responsible authorities within the ministry and lack of
476 awareness of HACCP and its pre-requisite programs (GHPs& GMPs) by the seafood establishments
477 were regarded as moderate barriers limiting their ability to enforce and meet the national legislation
478 requirements.

479 **4 CONCLUSION**

480 This study has assessed the technical barriers and benefits associated with the implementation of
481 FSMS such as HACCP and related prerequisite programmes in the seafood processors in the
482 Sultanate of Oman. In particular, differences between processors operating with or without a
483 HACCP system in place have been identified. The implications of handling practices in the seafood
484 supply chain on the safety and quality of seafood, seafood trade and the cost implications in
485 implementing HACCP based food safety management systems were also assessed.

486 The responses have shown significant gaps in various aspects which undermine the effectiveness
487 and success of implementing safety and quality requirements to meet national legislative
488 obligations. The presence of a small-scale or artisanal sector represents a challenge in attempting to
489 adopt modern food safety schemes and create a modern processing sector. Modernization of
490 fishing vessels and their ability to fish at a greater range should overcome some of the current
491 problems faced by the industry. Improved continuity of supply could reduce the impact of, or the
492 need for, the MAF export ban that has damaged the export revenues of seafood processors.

493 Adoption of HACCP by the seafood processors has mostly been driven by external requirements
494 imposed by export markets - it has not been a decision of the processors themselves to enhance
495 their systems. Nonetheless, the requirement can be considered to be market-driven although the
496 pressure has come from the more lucrative markets – especially that of the EU. Although the legal
497 requirements locally require certain elements of FSMS, HACCP enforcement is not compulsory thus
498 making the decision on implementation for many processors a commercial judgement rather than a
499 fundamental quality and safety issue.

500 The majority of the surveyed seafood processors were small and medium enterprises (SMEs) which
501 is the most numerous food industry sectors in the country. Large and medium food enterprises are
502 less reluctant to adopt HACCP, whereas the small-sized food enterprises have less incentive and are
503 therefore less willing to adopt it.

504 The survey has shown that HACCP implementation is made complex by a lack of well-defined
505 prerequisites programmes and a lack of understanding of general HACCP principles. This leads to a
506 complete dependency on HACCP to control all the hazards that arise at the different processing
507 steps through many Critical Control Points (CCPs) increasing the financial burden of implementing
508 the system. The requirement to restructure the facility was considered by all the participants of the
509 study as the top barrier to the adoption of HACCP and the greatest cost. Investing in equipment was
510 also highlighted as a major cost. However when asked to identify the negative impacts of adopting
511 HACCP systems, the HACCP processors listed the costs of product testing as being the biggest with
512 the cost of equipment coming second. However the top benefits perceived for HACCP were
513 improving product quality and safety and enhanced market competitiveness allowing access to the
514 most dynamic and highly competitive markets locally, regionally or internationally.

515 Further efforts are needed by the authorities to improve the entire infrastructure including fishing
516 vessels, landing sites, markets and distribution facilities. Adopting a proactive approach throughout
517 the entire chain from “net to plate” is fundamental to supplying seafood products which are safe
518 and of the correct quality - this cannot be achieved without appropriate controls.

519 The nature of the risks associated with unsafe seafood products must be well communicated to the
520 different stakeholders. In particular, each stakeholder should be accountable for any failure that
521 could threaten the well-being of the end users. There is a need for sustainable training for both the
522 authorities and employees of the processors to enhance their knowledge of HACCP and
523 prerequisites. This would boost the confidence of inspectors allowing them to be more rigorous in
524 enforcing national legislation. Educating consumers is also an important element as they are the
525 end users and the driving force and, once educated and with appropriate knowledge, they can
526 impose pressures on the food enterprises to change their attitudes and behaviour towards adopting
527 appropriate FSMS in their businesses.

528 Overall the study has identified the major concerns where attention is needed. These include:

- 529 • poor attitudes and understanding toward HACCP and prerequisite programmes
- 530 • lenient enforcement
- 531 • the lack of training and consultancy organizations in the country
- 532 • a lack of awareness
- 533 • lack of food safety expertise
- 534 • the overlapping and disorganized structure of the regulatory authorities in the country
- 535 • a poor match in the inspection resources in the country and the location of the processors.

536 These lead to the slow development of a proper food safety culture and inadequate adoption of
537 HACCP principles. Appropriate policies and strategies for effective food control to overcome
538 fragmented legislation, multiple jurisdictions, and limitations in surveillance, monitoring and
539 enforcement will enable the authorities to protect public health by enhancing seafood safety and
540 quality and facilitate internal and external trade (FAO/WHO, 2003).

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Table 2

Characteristics of the Processors	HACCP Processors (n=22)					Non-HACCP Processors (n=15)					
	≤ 10 years		(11-19)	≥ 20		≤ 10 years		(11-19)	≥ 20		
Years of Establishment	11		4	7		3		6	6		
n*	11		4	7		3		6	6		
Employees	Omani				Non-Omani	Omani				Non-Omani	
n (%)	214 (25%)				647 (75%)	62 (18%)				284 (82%)	
Date of HACCP implementation	1998-2003		2004-2009		2010-2015						
n*	7		3		10						
Annual Capacity in Quantities (tonnes/year)	<5000		5000-10,000		>10,000		<5000		5000-10,000		>10,000
n (%)	12 (60%)		5 (25%)		3 (15%)		10 (66.7%)		4 (26.7%)		1 (6.7%)
Annual Turn Over (Million Dollars)	<1	(1-5)		(6-10)	>10		<1	(1-5)		(6-10)	>10
n (%)	2 (11.8%)	9 (52.9%)		3 (17.6%)	3 (17.6%)		7 (53.8%)	2 (15.4%)		0.0	4 (30.8%)
Origin of the Raw Materials	100% Domestic		Mixture of Domestic & Imported		100% Imported		100% Domestic		Mixture of Domestic & Imported		100% Imported
	77.3%		22.7%		0.0%		100%		0.0%		0.0%
Quantities to Domestic Market (tonnes/year)	<1000		1000-3000		>3000		<1000		1000-3000		>3000
	47.4%		42.1%		10.5%		53.8%		38.5%		7.7%
Quantities to Export Market (tonnes/year)	<1000		1000-3000		>3000		<1000		1000-3000		>3000
	35%		25%		40%		36.4%		36.4%		27.3%
Processing Techniques in Use	Chilling	Freezing	Canning	Drying	Salting	Chilling	Freezing	Canning	Drying	Salting	
n (%)	13(59%)	22(100%)	1 (4.5%)	0 (0.0%)	1 (4.5%)	10 (66.7%)	11 (73.3%)	0 (0.0%)	1 (6.7%)	1 (6.7%)	

*n= Respondents frequency

Table 3

Barriers to Export Frequency (%)	Trade restrictions (SPS) & (TBT)	Lack of consumer demand in specific market	Uncertainty in obtaining a regular supply of raw materials	Exchange rate fluctuations	Administrative delay locally	Administrative delay in the destination country	Export bans of certain fish species by the MAF	Import duty (tax) in foreign market	Others
Officials	4 (10.3%)	6 (15.4%)	8 (20.5%)	2 (5.1%)	6 (15.4%)	3 (7.7%)	8 (20.5%)	1 (2.6%)	1 (2.6%)
HACCP Processors	5 (8.2%)	4 (6.6%)	15 (24.6%)	5 (8.2%)	3 (4.9%)	1 (1.6%)	18 (29.5%)	8 (13.1%)	2 (3.3%)
Non HACCP Processors	4 (8.7%)	3 (6.5%)	7 (15.2%)	4 (8.7%)	11 (23.9%)	1 (2.2%)	12 (26.1%)	1 (2.2%)	3 (6.5%)

Table 4

	TARGETED GROUPS*	AGREE Frequency (%)	UNCERTAIN Frequency (%)	DIS-AGREE Frequency (%)	χ^2 test p-value**
The assessment of the strength of the Fishery Quality Control Regulation (12/2009) requirements in achieving the following:					
Ensuring seafood quality and safety	A	13 (86.7%)	1 (6.7%)	1 (6.7%)	0.425
	B	19 (86.4%)	3 (13.6%)	0 (00.0%)	
	C	10 (71.4 %)	2 (14.3%)	2 (14.3%)	
Meeting the needs of different sized processing establishments	A	11 (73.3%)	3 (20.0%)	1 (6.7%)	0.171
	B	14 (63.6%)	6 (27.3%)	2 (9.1%)	
	C	5 (35.7%)	4 (28.6%)	5 (35.7 %)	
Providing consistent application of the seafood safety requirements across different establishments in Oman	A	9 (60.0%)	6 (40%)	0 (00.0%)	0.030
	B	15 (68.2%)	4 (18.2%)	3 (13.6%)	
	C	6 (42.9%)	2 (14.3%)	6 (42.9%)	
The effectiveness of the official control activities in enhancing seafood quality and safety:					
Inspection process	A	10 (66.7%)	4 (26.7%)	1 (6.7%)	0.807
	B	16 (72.7%)	5 (22.7%)	1 (4.5%)	
	C	8 (53.3%)	5 (33.3%)	2 (13.3%)	
Auditing process (QC Holder)	A	12 (80.0%)	2 (13.3%)	1 (6.7%)	1.000
	B	17 (77.3%)	3 (13.6%)	2 (9.1%)	
Sampling plan	A	9 (60.0%)	5 (33.3%)	1 (6.7%)	0.883
	B	13 (59.1%)	8 (36.4%)	1 (4.5%)	
	C	7 (46.7%)	6 (40.0%)	2 (13.3%)	
Sample analysis	A	9 (60.0%)	6 (40.0%)	0 (0.0%)	0.815
	B	12 (54.5%)	8 (36.4%)	2 (9.1%)	
	C	7 (46.7%)	6 (40.0%)	2 (13.3%)	
Pre-requisite programs such as GHPs& GMPs	A	12 (80.0%)	2 (13.3%)	1 (6.7%)	0.936
	B	15 (68.2%)	5 (22.7%)	2 (9.1%)	
	C	10 (66.7%)	3 (20.0%)	2 (13.3%)	
HACCP/ISO22000	A	10 (66.7%)	5 (33.3%)	0 (0.0%)	0.105
	B	19 (86.4%)	2 (9.1%)	1 (4.5%)	
	C	9 (60.0%)	3 (20.0%)	3 (20.0%)	
'Recall and Revision' protocol in handling rejected products from markets	A	7 (46.7%)	4 (26.7%)	4 (26.7%)	0.449
	B	13 (59.1%)	8 (36.4%)	1 (4.5%)	
	C	9 (60.0%)	4 (26.7%)	2 (13.3%)	
Level of violation and penalties that apply to those caught breaking the rules within the Fishery Quality Control Regulation (12/2009)	A	3 (20.0%)	7 (46.7%)	5 (33.3%)	0.013
	B	16 (72.7%)	4 (18.2%)	2 (9.1%)	
	C	8 (53.3%)	2 (13.3%)	5 (33.3%)	

* A= Officials (n=15); B= HACCP-Processors (n=22); C=Non-HACCP Processors (n=15)

** p <0.05

Table 5

QUESTIONNAIRE STATEMENTS	TARGETED GROUPS*	AGREE Frequency (%)	UNCERTAIN Frequency (%)	DIS-AGREE Frequency (%)	X_2 test p -value**
Funding	A	6 (40.0%)	5 (33.3%)	4 (26.7%)	0.022
	B	3 (13.6%)	3 (13.6%)	16 (72.7%)	
	C	1 (6.7%)	2 (13.3%)	12 (80.0%)	
Training	A	5 (33.3%)	5 (33.3%)	5 (33.3%)	0.027
	B	10 (45.5%)	5 (22.7%)	7 (31.8%)	
	C	1 (6.7%)	2 (13.3%)	12 (80.0%)	
Consultancy	A	10 (66.7%)	3 (20.0%)	2 (13.3%)	0.019
	B	13 (59.1%)	5 (22.7%)	4 (18.2%)	
	C	2 (13.3%)	5 (33.3%)	8 (53.3%)	
Technical advice	A	11 (73.3%)	2 (13.3%)	2 (13.3%)	0.068
	B	14 (63.4%)	5 (22.7%)	3 (13.6%)	
	C	4 (26.7%)	4 (26.7%)	7 (46.7%)	
Communication with establishment	A	10 (66.7%)	4 (26.7%)	1 (6.7%)	0.160
	B	15 (68.2%)	3 (13.6%)	4 (18.2%)	
	C	5 (33.3%)	5 (33.3%)	5 (33.3%)	
Response of officials to enquires about quality and safety issues faced by the industry	A	11 (73.3%)	3 (20.0%)	1 (6.7%)	0.667
	B	13 (59.1%)	5 (22.7%)	4 (18.2%)	
	C	7 (46.7%)	5 (33.3%)	3 (20.0%)	
Response of the officials to enquires about the HACCP system	A	13 (86.7%)	1 (6.7%)	1 (6.7%)	0.008
	B	17 (77.3%)	3 (13.6%)	2 (9.1%)	
	C	6 (40.0%)	1 (6.7%)	8 (53.3%)	

* A= Officials (n=15); B= HACCP-Processors (n=22); C=Non-HACCP Processors (n=15)

** $p < 0.05$

Table 6

A. The effectiveness of the inspection report in covering the following:	Agree Frequency (%)	Uncertain Frequency (%)	Dis-Agree Frequency (%)
• Good Manufacturing Practices (GMPs)	10 (66.7%)	4 (26.7%)	1 (6.7%)
• Good Hygiene Practices (GHPs)	9 (60.0%)	6 (40.0%)	0 (0.0%)
• HACCP	9 (60.0%)	4 (26.7%)	2 (13.3%)

B. The factors limiting the ability of the inspectors to enforce the regulations related to seafood quality and safety control during performing the inspections duties	Not/Limited Barrier Frequency (%)	Moderate Barrier Frequency (%)	Significant/Major Barrier Frequency (%)
• Lack of time	10 (66.7%)	2 (13.3%)	3 (20.0%)
• Lack of training	6 (40.0%)	2 (13.3%)	7 (46.7%)
• Lack of laboratory support/facilities	4 (26.7%)	5 (33.3%)	6 (40.0%)
• Lack of transport	9 (60.0%)	5 (33.3%)	1 (6.7%)
• Scattering of the responsible authorities within the ministry	6 (40.0%)	7 (46.7%)	2 (13.3%)
• Low priority within the government to effectively enforcing legislation	8 (53.3%)	5 (33.3%)	2 (13.3%)
• Lack of continuity and commitments of the staff from the establishments	3 (20.0%)	4 (26.7%)	8 (53.3%)
• Lack of continuity of the staff from the ministry	10 (66.7%)	4 (26.7%)	1 (6.7%)
• Lack of awareness of HACCP and its pre-requisite programs (GHPs& GMPs) by the seafood establishments	4 (26.7%)	8 (53.3%)	3 (20.0%)

Figure 1

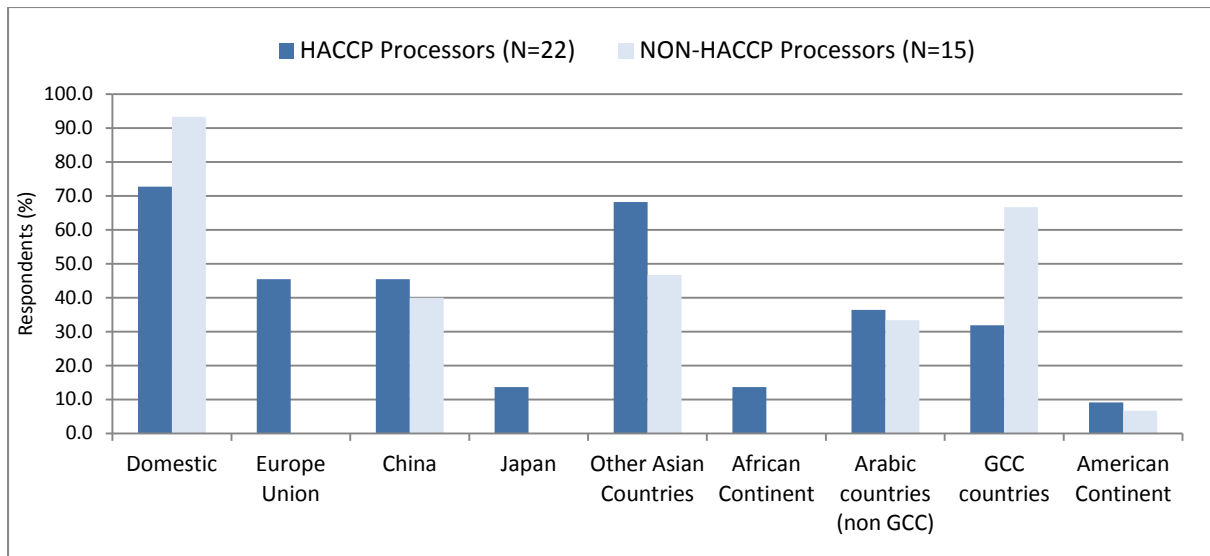


Figure 2

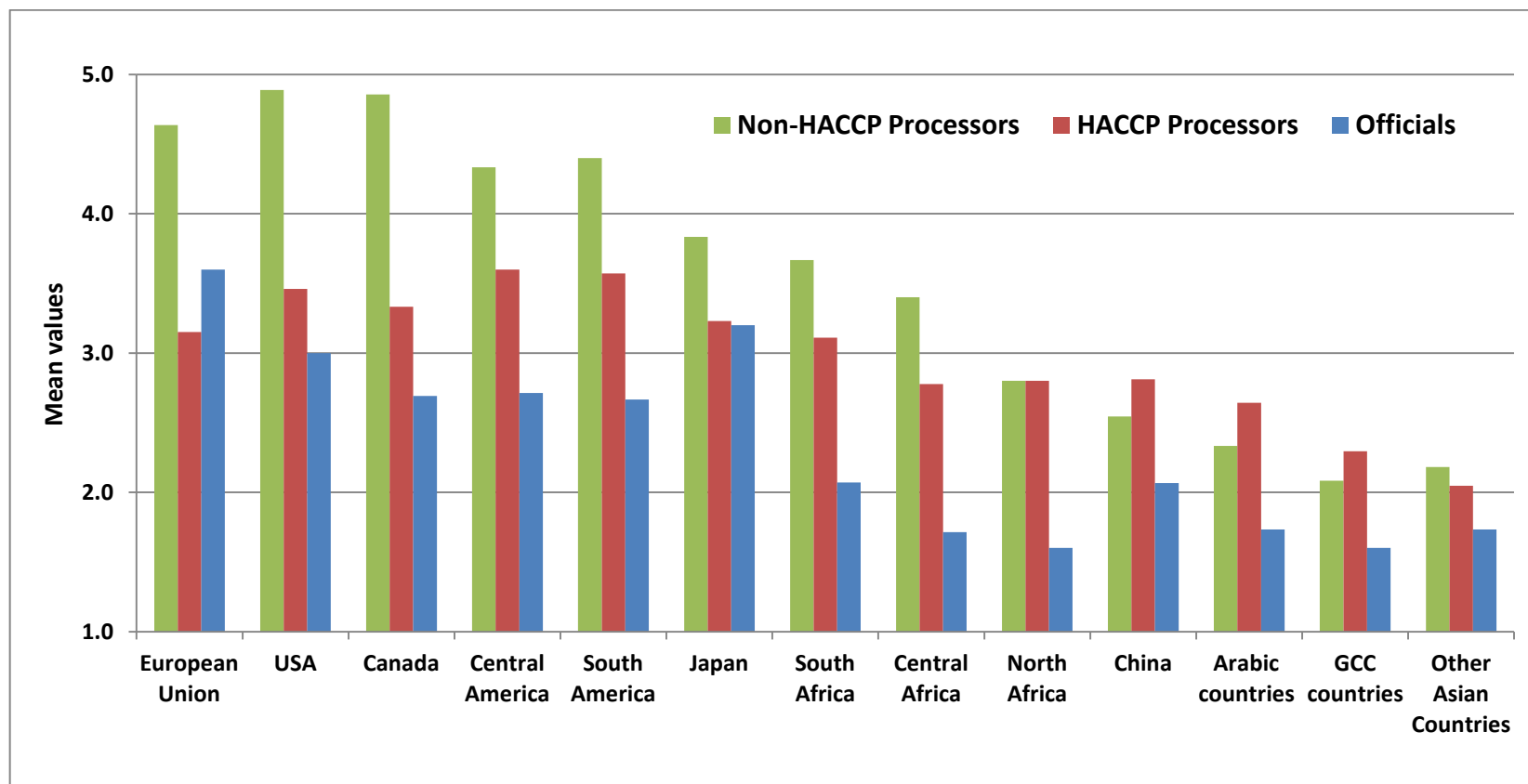


Figure 3

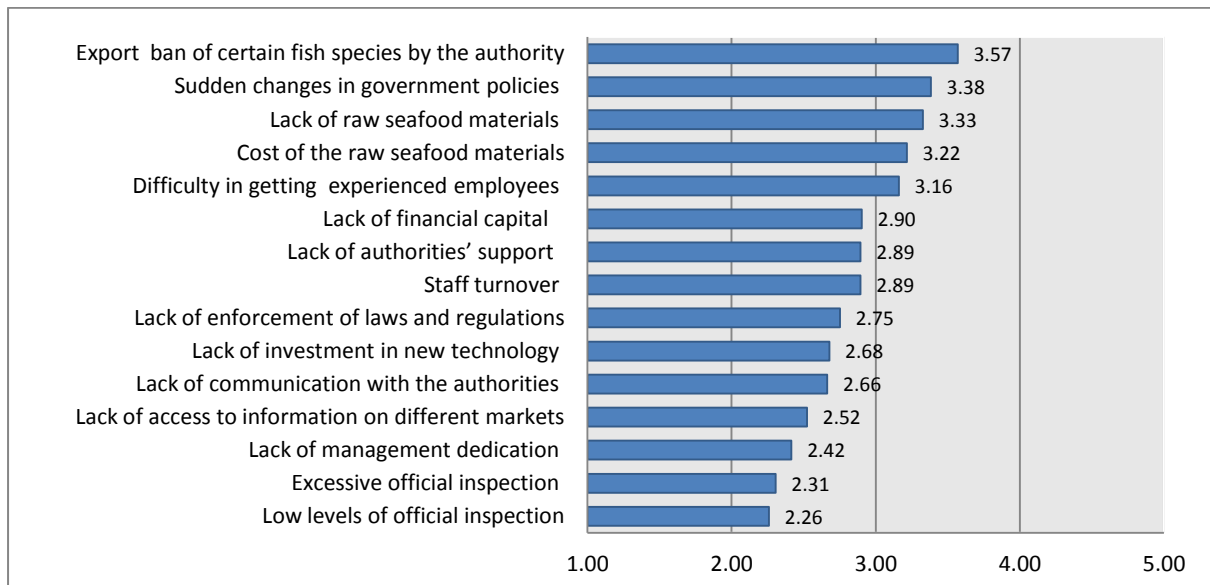


Figure 4

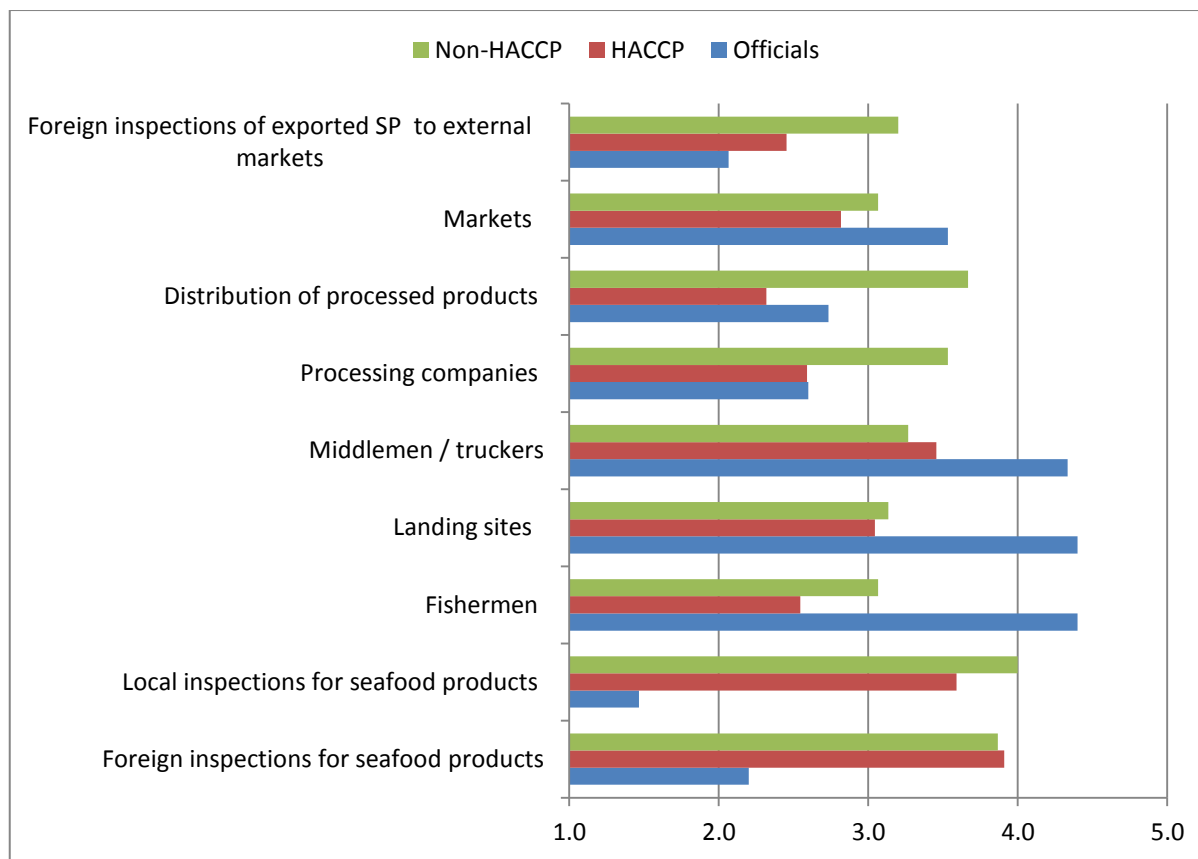


Figure 5

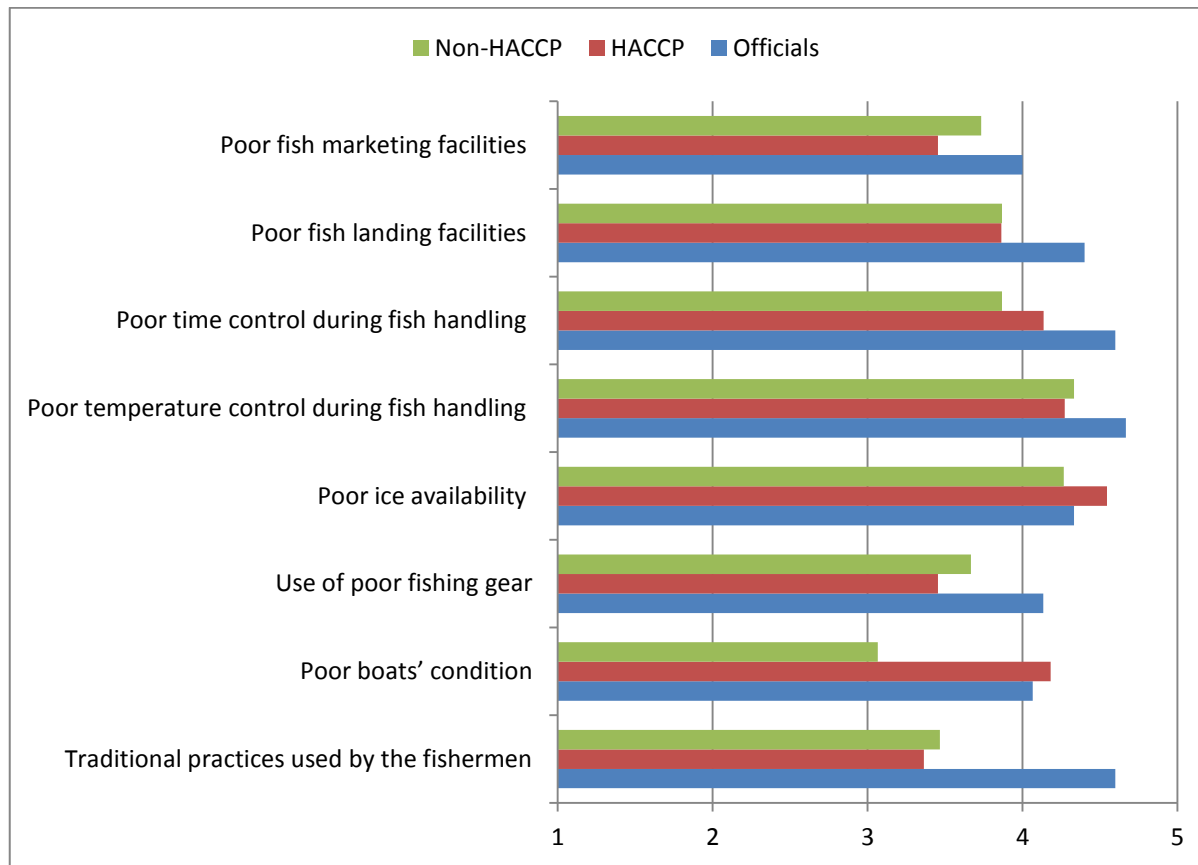


Figure 6

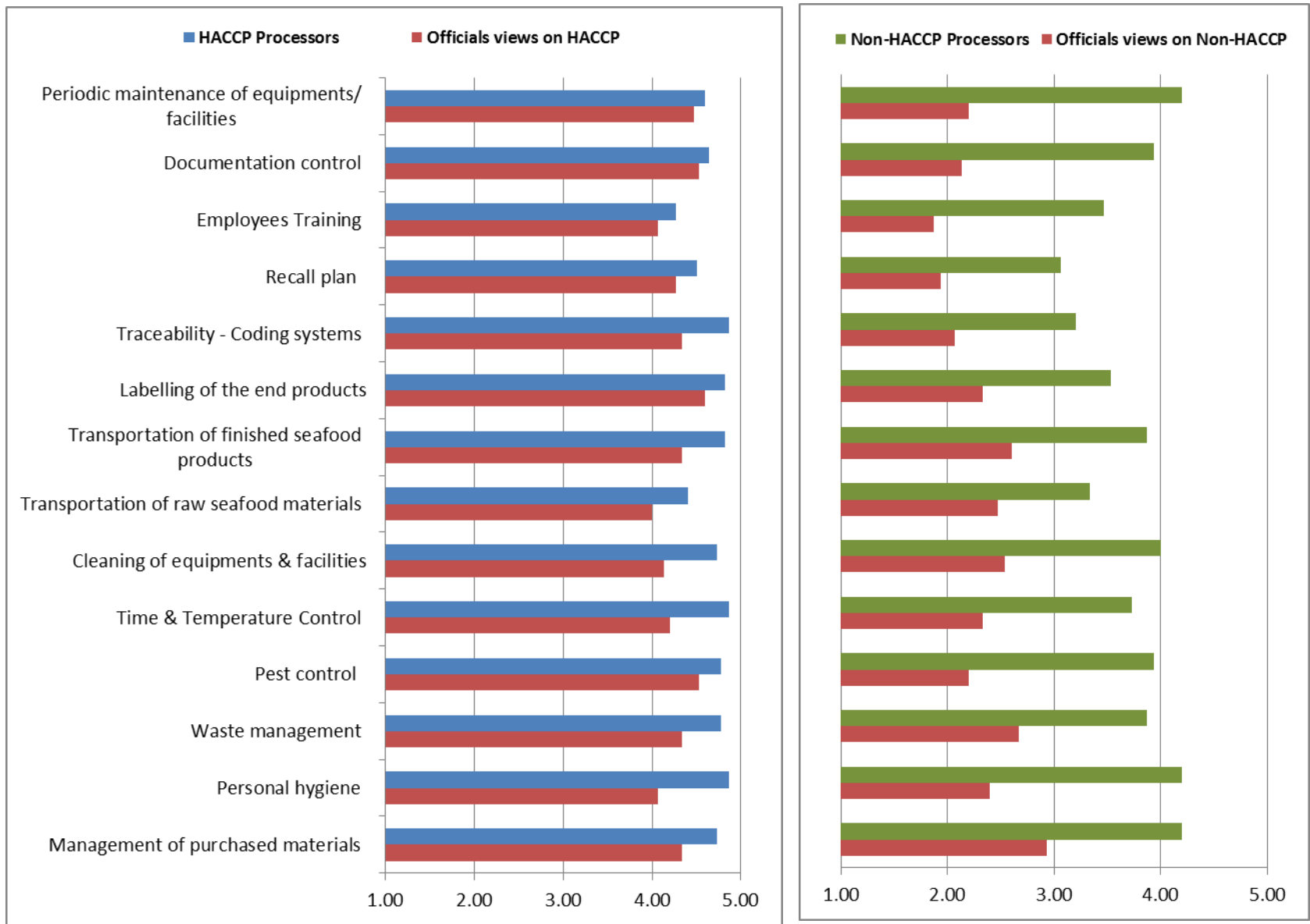
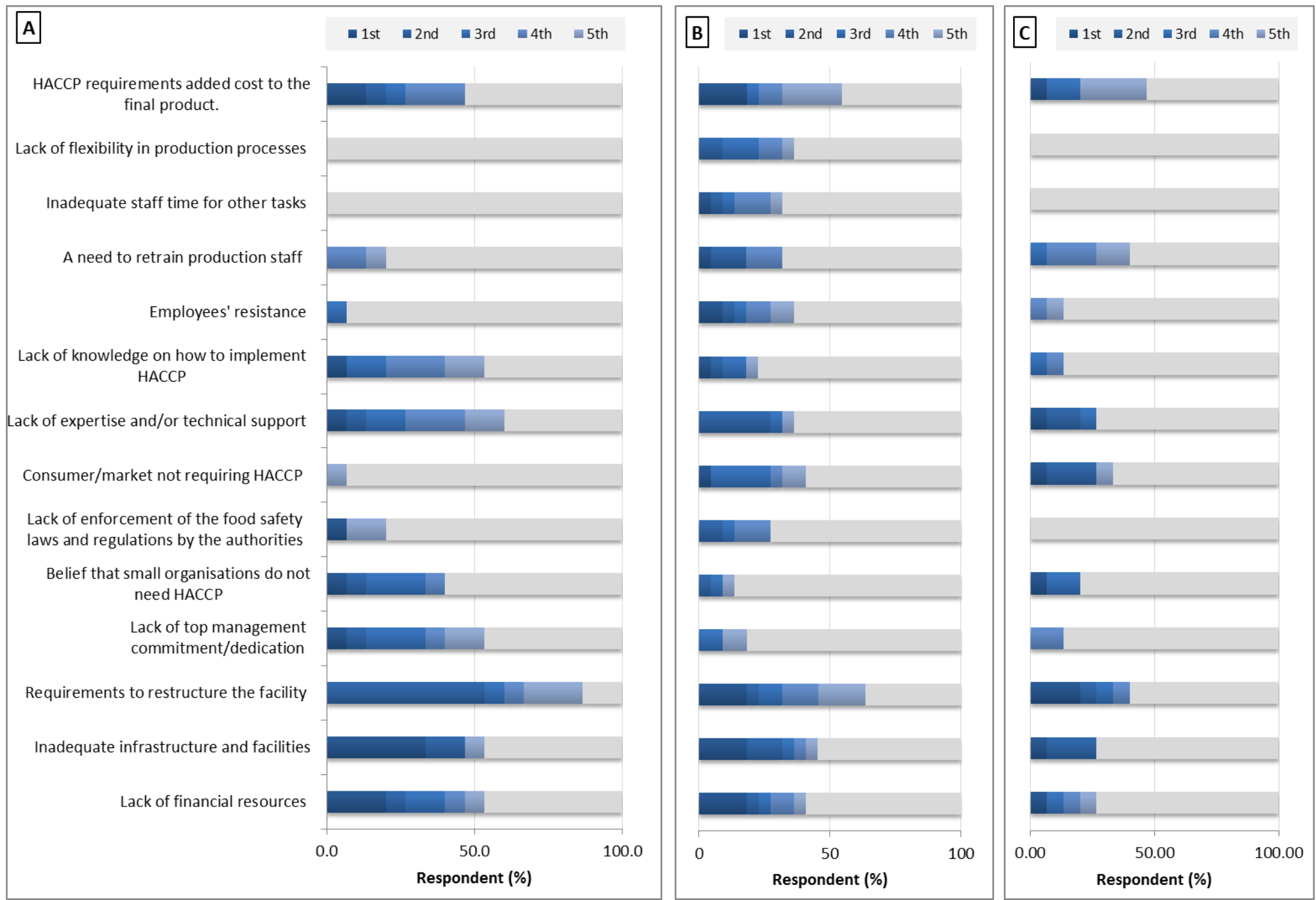


Figure 7



* A= Officials; B= HACCP-Processors; C=Non-HACCP Processors

Figure 8

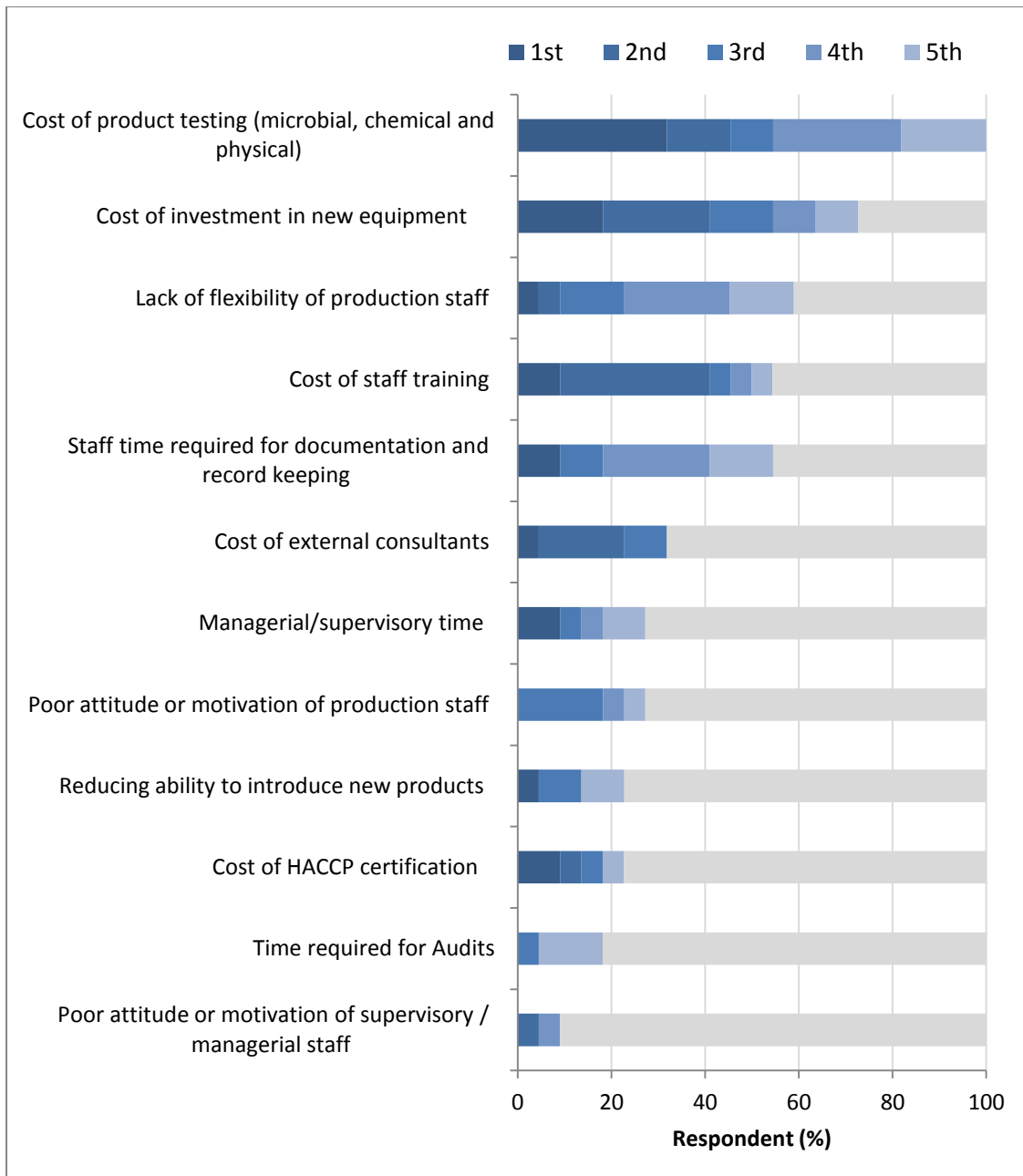
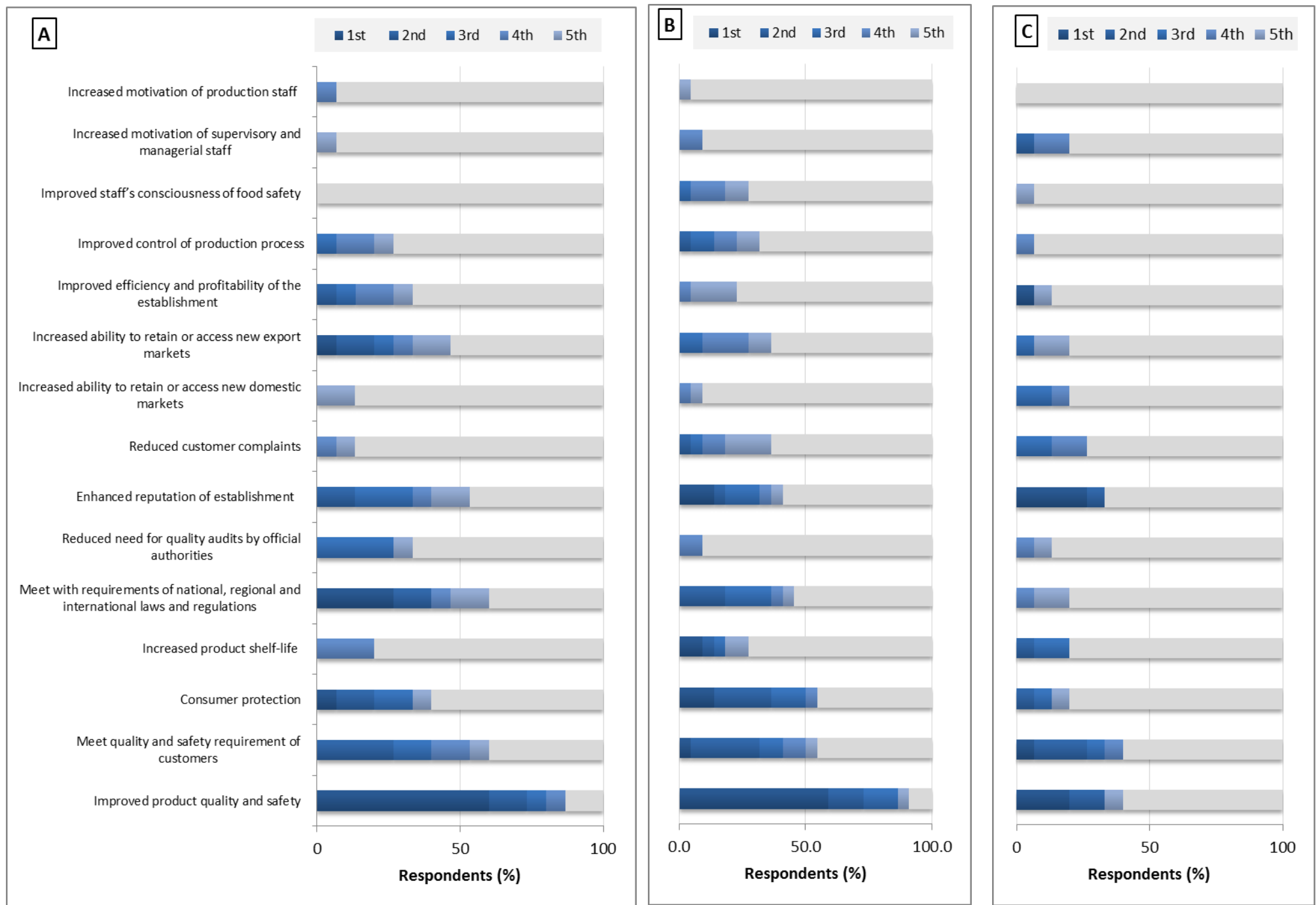
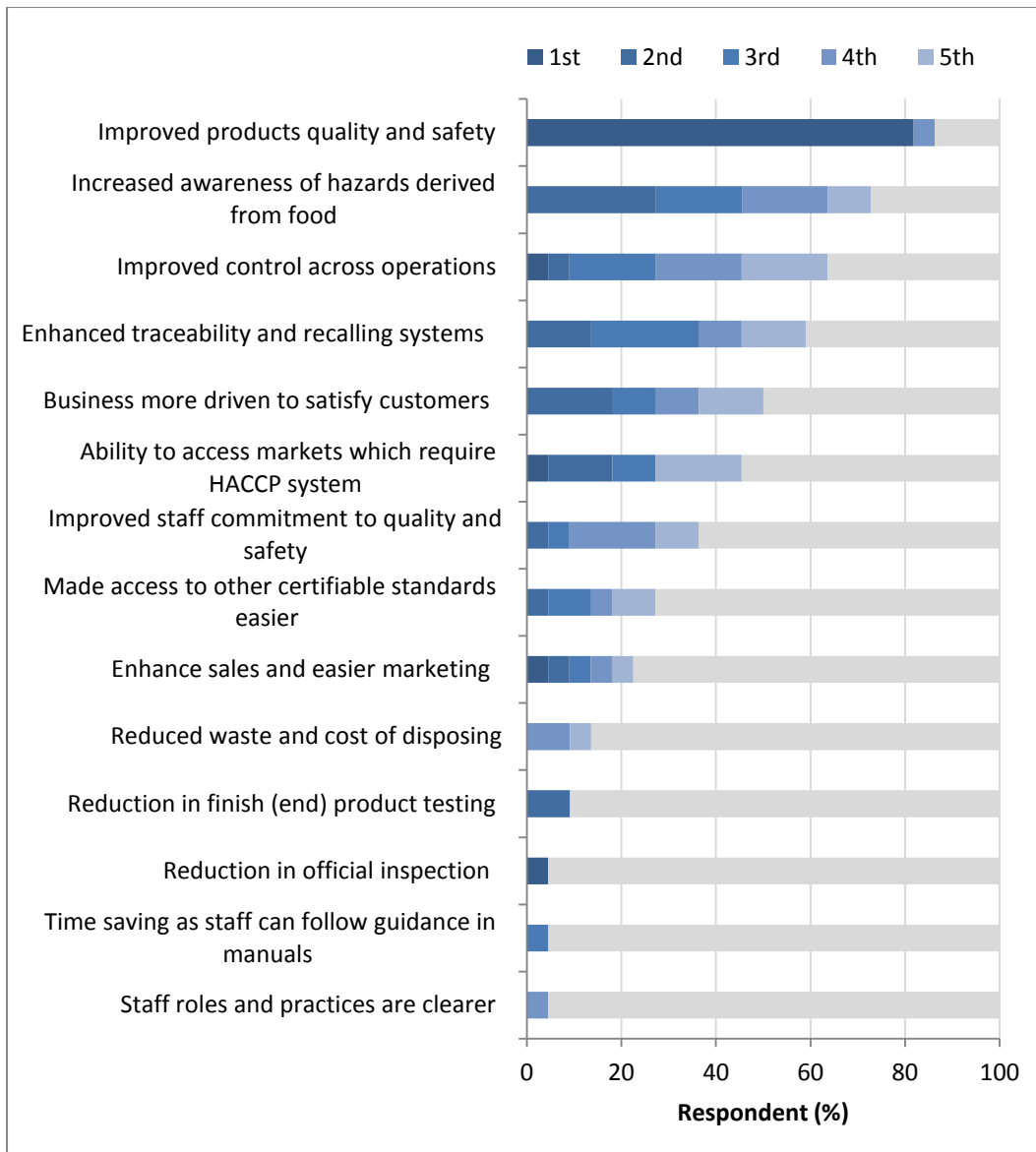


Figure 9



* A= Officials; B= HACCP-Processors; C=Non-HACCP Processors

Figure 10



Highlights:

- The research assessed HACCP implementation in the Omani seafood sector
- Significant gaps in aspects of seafood safety and quality are highlighted
- The use of HACCP in Omani seafood processors is limited and the reasons assessed
- The poor use of prerequisites programmes makes HACCP implementation more complex
- Inspection resources and the location of the processors are poorly matched