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The future of caviar production on the light of social changes: a new dawn for caviar ?

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Abstract

Caviar consumption is increasing and main projections indicate that the presumable maximum production will be of 3000 t/year. From the productive point of view, the principal difference from the past caviar production is the definitive shift from wild to farmed caviar. Due to the recent advances in sturgeon aquaculture and the expansion of luxury consumers, there remains vast potential to reshape caviar consumption. Luxury market is extremely lucrative, it accounted for €217 - €253 billion in 2016 and this is about 1,5 times of world aquaculture production. However these perspectives are not only positive as this market segment is also affected by the diffusion of imitation (*i.e.* caviar substitutes, in this case). The proliferation of caviar substitutes can be interpreted as a kind of commercial Müllerian mimicry while the adoption of new marketing strategy defined "Masstige", that describes a downward luxury extensions directed toward middle class consumers, introduce new perspectives to this sector in its totality. What suggestions can be made by observing luxury consumers attitudes ? This review takes in consideration the relation between sturgeon farming and quality of caviar on the light of modern societal changes. . The main challenge for sturgeon aquaculture will be to spread a positive image of farmed caviar, thus introducing the aspects of excellence related to extensive aquaculture in controlled conditions by the adoption of shared rules on caviar quality. The most interesting aspects emerged are related to potential social expansion of caviar consumption, particularly in the middle class of consumers.

Keywords: caviar, caviar consumption, sturgeon farming, caviar production , luxury consumers, farmed caviar

1. Introduction

Caviar is the most expensive aquaculture product and the retail prices in sturgeon caviar can range from 1000 up to 5000 US$/kg. Caviar production is historically originated in Russia and by the early 20th century Russia was a major caviar trading country (Bronzi & Rosenthal 2014; Bronzi *et al.* 2011;Pourkazemi 2006; Pikitch *et al.* 2005; Williot *et al.* 2001). Nowadays, in order to contrast the decline of natural populations of sturgeon, caviar production is completely originated by aquaculture (Bronzi & Rosenthal 2014), this fact open extremely positive perspectives for sturgeon aquaculture. The annual caviar production is about 262 t and estimates for future range from 500 to 2000 t (Bronzi & Rosenthal 2014; Wei *et al.* 2011). Considering the extraordinary economic interest, traditional producer countries increased the production as the example of Kazakhstan that in 2010 launched a state caviar monopoly (Orange 2010).Currently, the Swiss and French are the biggest caviar consumers followed by Americans, British and Japanese.

In order to promote caviar market, it is important to consider the potential caviar consumers that belong to the category of luxury product consumers and useful suggestions can be taken observing these consumers attitudes. Caviar is a luxury product, but not more as exclusive as was in the past, it can be purchased by modern wealthy consumers and these consumers will be the future target for caviar producers.

Traditional and modern luxury consumers have specific features as high expending power and reasons for acquiring luxury products brand can act as a social marker, especially for middle-class wealthy consumers (Shukla *et al*. 2016; Godey *et al.* 2013). Emotional aspects of luxury products as the prestigious appeal and the rarity of products, made the difference

of successful products. These aspects will also affect the success of modern caviar producers.

From the productive point of view, the principal difference from the past caviar production is the definitive shift from wild to farmed caviar. Due to the recent advances in sturgeon aquaculture and the awareness of social changes with an expansion of luxury consumers, there remains vast potential to reshape caviar consumption. The point is: is this sector of aquaculture ready to answer to the modern market demand of caviar ? what are the aspects in sturgeon farming that can ameliorate the production of modern caviar ? what suggestions can be made by observing luxury consumers attitudes ? what can be the perspective of a food luxury sector that is inevitably affected by the emergence of imitations (*i.e.* caviar substitutes ?)

This article encompasses two main aspects of caviar production: supply (i.e. aquaculture) and demand (i.e. consumers). These aspects are rarely considered together in an aquaculture context, but caviar is not a mass production products and customer needs, attitudes and expectancies are of primary importance for the future development of caviar production. Progresses in aquaculture techniques are tangible and quantitative, while consumer attitudes are more related to human psychology and emotional, thus, more elusive and unfamiliar to aquaculture producers, but it is the time to include these aspects in order to have a profitable and realistic perspective of this sector.

This review takes in consideration in the first part the relation between sturgeon farming and quality of caviar, thus considering the current definition of caviar quality. Caviar substitutes are also shortly described in order to give a comprehensive perspective of the complete category. In the second part, the current and potential caviar consumers are considered. Considering the combination of these two main aspects, the present paper aims to consider caviar production and perspectives on the light of modern societal changes.

1 Caviar and aquaculture: the bright side of the moon

Caviar history follows the trend of typical luxury stereotype, in fact, in the beginning of 1900 it was sold for one penny per pound in the US, successively, passing through an intermediate phase, it reached the current extraordinary price. Its rarity and the need to preserve natural populations of sturgeon pushed to definitive shift to aquaculture (Bronzi & Rosenthal 2014). The effects of progress of sturgeon aquaculture combined with increased demand, have caused some main effects, that are typical of any kind of farming industry evolution: delocalization of production (sturgeon farms out of original geographic area), fragmentation of productive process (separation between production and processing) and diversification of products.

The recent advances in sturgeon aquaculture make this production much more exportable than in the past, in fact 41% of sturgeon farms are localized out of traditional area of caviar production and 31 out of 41 countries where the sturgeon farms are localized, are out of traditional consumers area (Bronzi & Rosenthal 2014). New countries have progressively entered in this production, with new sturgeon species as China and US and exotic geographical regions, as United Arab Emirates, Uruguay and Vietnam (Fig. 1). From the point of view of volumes, since 2006 the exports of Chinese farmed caviar have been constantly increasing (Wei *et al.* 2011). It is very well known that China is the first country for aquaculture in the world and represents 75 - 80 % of world production of sturgeon meat (YJC.IR 2013). Currently the estimated Chinese caviar production range between 128 and 144 t (Bronzi & Rosenthal 2014, Wei *et al*. 2011) (Fig. 1) in particular for medium priced product (Godfrey 2013).

1.1 Functional plasticity: the effects of sturgeon farming on caviar composition

In order to promote diversification of products, it is necessary to synthetically clarify the current concept of quality and parameters affecting quality. In the past it was not possible to precisely define the quality of caviar, as the fishermen caught several species of sturgeons from the wild with different age and stage of maturation. Grading caviar methods were developed at the beginning of caviar history in Iran and Russia, were essentially based on size uniformity. Currently, the reference point is considered the definition of Codex Alimentarius (CAC 2013) .

At present days, the complete shift to caviar production from aquaculture has introduced some disadvantages as the loss of unicity and rarity related with the wild caviar and these aspects are central in the definition of luxury foods (Hartmann *et al.* 2016), but there are also advantages as modern aquaculture techniques can introduce plasticity in these products, that means diversification. In aquaculture (and any modern zootechnic activity) a new category of novel products has been recently introduced, so-called "functional foods", targeted on specific consumer needs. Therefore, the adoption of these consolidate aquaculture techniques in sturgeon farming will presumably improve caviar quality during the long farming cycle (Zhang 2011).

On the light of recent progress in aquaculture, it is clear that caviar from aquaculture can reach high quality as a consequence of control of rearing conditions, particularly for the importance of farm water quality and sturgeon artificial feeds that can influence caviar sensory profile and fatty acid composition (Czesny *et al.* 2000; Cardinal *et al.* 2002; Gessner *et al*. 2002b; Gessner *et al.* 2008; Lu & Rasco 2013; Zhang 2011). Caviar characteristics can be synthetically clustered into two main categories: "*pre-mortem*" related with farming; "*post-mortem*" related with caviar processing and conservation.

1.1.2 "*Pre mortem*" caviar quality

Caviar off flavor are originated by lipophilic compounds that are stored in the fish eggs during vitellogenesis. Several researches have been carried out on seafood flavor and more than 300 volatiles have been identified in freshly harvested and processed fish (Schrader & Rimando 2003). Aldehydes, geosmine and isoborneol represent the largest group of substances isolated that can confer several kind of off flavors (Caprino *et al.* 2008). These compounds are known in aquaculture products and they are both originated from the presence of actinomycetes (*Streptomyces* and *Nocardia* spp.) and cyanobacteria (*Anabaena*, *Aphanizomenon*, *Lyngbya*, *Oscillatoria*, *Microcystis* e *Pseudanabaena*) naturally occurring in water bodies (Souza *et al.* 2012; Percival *et al.* 2008). For these reasons the farming conditions are carefully controlled in the sturgeon farms and several attempts have been made in order to contrast the formations of of-flavours, both chemical treatments (Schrader 2005) or biological (Schrader & Rimando 2003), but these researches demonstrated that the rearing water treatment is not practically suitable and the use of rearing water geosmine and isoborneol naturally-free is the optimal solution, at least in the final part of farming period.

1.1.3 Caviar: proximate and fatty acids composition

It is very well known that fish roe and particularly caviar contains high amounts of proteins (Al-Holy & Rasco 2006) and lipids. The average protein content of caviar is about 30% and fat ranges from 11 to 27 % (wet weight) (Billard *et al.* 2002; Gessner *et al.* 2006; Mol & Turan 2008; Wirth *et al.* 2002), among fatty acids oleic acid is the dominant and eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are particularly abundant (Caprino *et al.* 2008; Gussoni *et al.* 2006; Intarasirisawat *et al.* 2011; Wang *et al.* 2012). While proteins play a minor role in the definition of caviar quality, lipids, in particular fatty acids, noticeably influence caviar taste, being off flavors mainly originated by lipophilic compounds. During vitellogenesis, fatty acids are mobilized from the lipid reserves

153 localized in the adipose tissue and are included into the oocytes. Therefore, the fatty acid
154 composition of the oocytes it is influenced by the fish diet (Gessner *et al.* 2002a; Webb *et*
155 *al.* 2001; Wirth *et al.* 2000; Zhang *et al.* 2011). Similarly to sturgeon flesh, the majority of
156 researches found a relation between diet and caviar composition(Badiani *et al.* 1997; Zhang
157 *et al.* 2011).Caviar fatty acid composition varies among different sturgeons species, farmed
158 or wild, freshwater or marine origin (Czesny *et al.* 2000; Shin *et al.* 2010). Farmed caviar
159 from intensive aquaculture significantly differs from that of wild origin, while composition
160 of extensively farmed caviar does not largely differ from wild caviar (Gessner *et al.* 2002b;
161 Gessner *et al.* 2002a). Few recent researches indicated that in some cases sturgeon diet did
162 not affect the amount of egg yield and egg texture in white sturgeon (*A. transmontanus*)
163 (Zhang *et al.* 2011) or fatty acid composition in white sturgeon that was only minimally
164 influenced by dietary fatty acid composition (Caprino *et al.* 2008). These authors explained
165 this fact considering that the optimal threshold levels of fatty acids of caviar were reached
166 independently from dietary fatty acids. As regard as possible change in fatty acids
167 composition during conservation, Gussoni *et al.*(2007) investigated *A. transmontanus*
168 caviar thus showing that during caviar storage at 4 °C for a period of 4 months the fat
169 content and fatty acid composition remained unchanged.
170 Fatty acid profile can be a viable tool in discrimination of different sturgeon populations
171 with respect to caviar source (Czesny *et al.* 2000; Gessner *et al.* 2008). Capric acid has
172 been proposed as cheap and easy-to-assess fatty acid useful for discriminating caviar from
173 aquaculture (Wuertz *et al.* 2009). A patent application was submitted in US in 1998
174 (Birnstein *et al.* 1998). Considering the compositional plasticity of caviar, Gessner *et al.*
175 2008 proposed an international commercial agreement between feed producers and
176 sturgeon farmers that would ensure the utilization of specific feed compositions that include
177 peculiar fatty acids that will mark farmed sturgeon from wild ones.

178

179 **1.1.4 Contaminants**

180 Sturgeons reach maturity at 5 – 30 years of age (Billard & Lecointre 2001), consequently
181 caviar is prone to bioaccumulation of toxic substances eventually contained in feeds.
182 Considering the exiguous consumption of caviar, the risks for human health is really low
183 and the diffusion of caviar from aquaculture will probably reduce these risks. Even if the
184 situation of contaminant in caviar is highly variable, in different researches (Gessner *et al.*
185 2002b; Kruger & Pudenz 2002; Wang *et al.* 2008), the amount of contaminants in caviar
186 seems to be primarily influenced by geographical area of production and secondarily, for
187 wild caviar, by trophic level occupied by sturgeon species. Beluga caviar is most exposed
188 to accumulation of chlorinated hydrocarbons (Gessner *et al.* 2002b). The highest
189 concentration of toxic compounds in caviar was found by Billard *et al* 2002 that reported
190 concentration of polychlorinated biphenyl (PCBs) ranging from 10 to 100 times higher than
191 the limit for sturgeon flesh, particularly in Beluga from Romania. Kruger & Pudenz (2002)
192 stated that the quantity of organochlorines, as DDT, in caviar coming for Black and
193 Caspian Sea was largely influenced by trophic level occupied by species. Caviar coming
194 from Azerbaijan, Bulgaria, Iran, and Russia was found with high organochlorine and
195 polychlorinated biphenyls (PCBs) contents (Wang *et al.* 2008), while caviar
196 commercialized in Pakistan resulted in a very low concentration of various toxic elements
197 and heavy metals (Rehana 2008).

198

199 **1.2"*Post mortem*" caviar quality**

200 The techniques utilized for caviar processing have a significant impact on product quality
201 (Gessner *et al.* 2002a; *Rasco et al.* 2006), off flavors originated during conservation, total
202 volatile nitrogen, histamine and other biogenic ammines are related with microbial

contamination caused principally by *Pseudomonas* and coliforms (Jelodar & Safari 2006). Microbial contamination can take place in processed fish products and caviar (Bagge-Ravn *et al.* 2003), in particular caviar can be contaminated with various species of opportunistic bacteria, as *Aeromonas* sp., *Proteus* sp. and *Vibrio* sp. (Bledsoe *et al.* 2003) or coliforms and *Escherichia coli* (Altug & Bayrak 2003). The principal factors favoring the caviar bacterial contamination are pH level, the storage temperature and presence of free amino acids. Bacterial contamination during the processing increases the content of total volatile nitrogen, peroxide value, free fatty acid, ammonia and biogenic amines as methylamine and trimethylamin (Krízek *et al.* 2011; Lapa-Guimaraes *et al.* 2011; Safari & Yosefian 2006). Although processing techniques for canned caviar are generally safe from this problem (Altug & Bayrak 2003), one of the most efficient method tested for control the contamination and spoilage of caviar is considered the Hazard Analytical Critical Control Point (HACCP) system (Jelodar & Safari 2006).

1.2.1 Additives and conservation methods

Caviar refrigeration at 4 °C is the main conservation method for caviar (Gussoni *et al.* 2006) while sodium chloride (NaCl) is the only preservative universally accepted by consumers. Caviar is added with salt for preservation, that normally ranges between 3% and 5%. The best quality caviar is only slightly salted and is called “Malossol”. Packaging in anaerobic condition is also used for the control of contamination and spoilage of caviar (Salmani *et al.* 2009). In other fish roe the addition of preservatives (as sodium benzoate or citric acid) or colorant is permitted (Kirschbaum *et al.* 2006; Lapa-Guimaraes *et al.* 2011), in Europe, the only permitted caviar preservatives are boric acid and sodium borate at maximum concentration of 4g/kg, Commission Regulation (EU) 1129/2011. Borax use is prohibited in the U.S (Shin *et al.* 2010). Currently only few preservatives can be used,

228 while physical treatments are not suitable for caviar conservation (Tab.1). Natural
229 antioxidants can be eventually used during processing or directly in the fish feed, in order
230 to decrease dietary artificial antioxidants commonly used, as happens in other sectors of
231 aquaculture (O'Sullivan *et al.* 2005).
232
233 **1.3 Analytical methods: war between man and machine**
234 Promotion of quality needs quantification, but in several luxury foods as wine or cheese,
235 human taste still plays a central role in the definition of quality. The scientific literature
236 basically shows analytical methods from one side and panel test on the other.
237 Historically, the assessment of quality of caviar was principally based on sensory
238 evaluation by specialized panelists and their job represented a great cost for enterprises,
239 consequently several analytical methods have been developed in these last years (Ludvig *et*
240 *al.* 2002; Moradi 2003; Rodushkin *et al.* 2007). Caviar quality is evaluated by four main
241 methodologies: sensorial, chemical, physical and microbial tests. Eggs size, color and
242 intensity of darkness and bronze color are crucial from the point of view of consumer. Pale
243 caviar and bigger size eggs are worldwide considered better quality, secondary parameters
244 are texture and flavor (Guinard & Mazzucchelli 1996; Wilkinson *et al.* 2000; Szczesniak
245 2002; Sorensen *et al.* 2003). Flavor profile can be defined by panel test, chemical
246 evaluation with chromatography and mass spectrometry or by gas – chromatography and
247 olphactometry (Golovnya 1976; Triqui & Zouine 1999; Jonsdottir *et al*. 2004; Caprino *et*
248 *al.* 2008). Considering the effect of sturgeon feeding, panel test analysis has been also
249 applied on caviar for the evaluation the effects of dietary flavonoids on sturgeon (Wang *et*
250 *al*. 2012). Between the methodologies used, the olfactometric approach seems to be more
251 suitable (Caprino *et al.* 2008). Texture analysis can be carried out with sensorial or
252 instrumental analysis, but texture is heavily influenced by packaging methods. Instrumental

253 detection of texture has been also studied in several fish product and it is considered more
254 suitable (Hyldig & Nielsen 2001). Previous study demonstrated the efficacy of instrumental
255 detection of texture even comparing result obtained with sensorial analysis (Borderias *et al.*
256 1983; Hyldig & Nielsen 2001).
257 Compared with others food products, the caviar sensory analysis still needs a shared
258 lexicon with specific and univocal descriptors and standardized methods. Some attempts
259 have been carried out by Cardinal *et al* (2002) that defined a list of descriptors for caviar
260 sensory analysis in order to discriminate between farmed and wild caviar and Rasco *et al.*
261 (2006) that listed 16 attributes useful to discriminate between 22 commercial caviars.
262 Successively, a lexicon for standardized sensory evaluation based on 16 sensory attributes
263 for evaluation was proposed (Baker *et al.* 2014). Sensory analysis was initially used in
264 caviar production for detection of difference between farmed and wild caviar (Cardinal *et*
265 *al.* 2002), successively other parameters were investigated as sturgeon feeding, farming
266 techniques, geographical origin, conservation and processing (Schrader & Rimando 2003;
267 Lu & Rasco 2013).
268
269 **1.4 Caviar substitutes in an evolutionary perspective: the raise of modern market**
270 **parasitism or mimicry?**
271 There is a proliferation of alternative products of caviar that deliberately or unconsciously
272 refers to appeal of true caviar (Bronzi & Rosenthal 2014). From an evolutionary point of
273 view, the relationship between caviar and its substitutes can be interpreted following two
274 main ecological paradigms: parasitism or mimicry, that in turn reflect two sides of this
275 phenomenon: vertical relation between original and substitutes or horizontal relation
276 between substitutes and original (Fig. 4).

If the relation caviar - caviar substitutes can be considered a parasitic relation, the most similar case of parasitism can be considered the cuckoo example that lays eggs in other bird nest (host species), that in the case of caviar is the consumer. Exactly as happens for bird eggs, in this case fish eggs (caviar substitutes) are produced in the marketplace (bird nest) in order to confuse host bird (or consumer). This can be the case of substitutes that try to passively refer to caviar (some products that have only assonant names, for instance Deluga caviar).

Otherwise, if the similitude between caviar and caviar substitutes is emphasized, it is clear that the presence of exclusive products immediately stimulates the surrounding elements to imitate the original one. Observing with more attention the production of caviar and caviar substitutes, it is likely that the diffusion of caviar substitutes has benefitted also caviar, therefore this phenomenon can be compared with Müllerian mimicry, that is a form of mimicry where all the species take benefit from mutual resemblance (Benson 1972). A lexical Müllerian convergence sequence is immediately visible already in the abuse of "caviar" definition (Fig. 5), that induces a confusion in the consumers exactly in the same way as a predator bird can confuse bees with an innocuous insect, but at the same time stimulates general consumption of caviar and its substitutes.

Considering these analogies, the point is: what is the advantage to consider caviar and caviar substitutes market in an evolutionary approach, does it makes really sense?

Shortly considering the occurrence of these phenomena in the natural ecosystems, (*i.e.* cuckoo parasitism and Müllerian convergence), two simple considerations can be made and transposed to the caviar production market: those caviar substitutes that try to passively imitate caviar, similarly to cuckoo are condemned for their evolutionary lifespan to incessantly follow their host, following the Red queen hypothesis, as the consumers will be progressively able to discern original caviar from this substitute. In practical terms, this

indicate that few companies can imitate passively original caviar in the future and from aquaculture point of view these two categories of company will both survive, but these substitutes of caviar will not proliferate. In fact, few species of cuckoos are currently diffused that are extremely specialized on few species of host birds.

Otherwise, if we take in consideration the horizontal imitation process that by the proposed analogy can be considered the origin of a Müllerian convergence sequence, the number of mimics is markedly more elevated, thus indicating that those companies that produce caviar substitutes with distinctive features are likely to be more numerous in the future. This Müllerian sequence looks more convenient for substitute caviar producing companies and for true caviar itself. Therefore, this paradigm fits better to the description of current situation of caviar and it has been already observed in the packaging of other food products (Sherratt 2008).

1.5 Caviar substitutes: the downshifting of caviar

If the caviar substitutes are considered in the context of luxury market dynamic, some interesting considerations can be made. From this point of view, caviar substitutes can be considered as an effect of adoption of marketing strategy of imitation. The presence of imitations in luxury market is very well known, that has stimulated competition and has forced the traditional companies to develop new strategies to increase customers loyalty and fidelity (Anselmsson *et al.* 2014).

Caviar substitutes and imitations are represented by an highly heterogeneous category of products which were estimated about 50000 t/year in 2011 (Bronzi & Rosenthal 2014; FAO 2012) (Fig.2 and 3). This impressive production can be interpreted in a negative sense in terms of competition with true caviar or in positive sense in terms of market demand of low price caviar for new consumers. This demand may be an opportunity for aquaculture.

Market demand for products made from the roe of salmon, herring, cod, Alaskan pollock, lumpfish, rainbow trout, capelin and other species is increasing (Airado-Rodriguez *et al.* 2010; Johannesson 2006; Machado *et al.* 2016). Bronzi & Rosenthal (2014) excellently described these products and their potentialities, thus showing that caviar definition by itself represent an appeal and the abuse of this term can induce confusion in modern consumers by one hand and loss of competitiveness for caviar producers by another hand. Within caviar substitutes, traditional products, as lumpfish (*Cyclopterus lumpus*) caviar, encounter a constant market demand (Johannesson 2006), they gained a specific market segment that apparently will not represent a competition with true caviar, while modern substitutes can interfere with caviar production. A modern entry in this category is "caviar from ovulated eggs", i.e. obtained without animal sacrifice, that sounds more ethically sustainable and improves the acceptance of consumers concerned on sturgeon over exploitation. The main disadvantage is that the ovulated eggs lose some organoleptic characteristics, mainly the typical consistence of traditional caviar. First attempts to get caviar from ovulated eggs were carried out in France, where in 1997 a EU COST project titled "Production of caviar from roe and ovulated oocytes from some farmed sturgeon species" was funded, successively in Romania and Moldova (Billard *et al.* 2002) and more recently a method have been patented in Germany (Köhler-Günther 2007) based on caviar production from ovulated stripped sturgeon eggs. Roe can be eventually harvested again from these fish during later spawning cycles (AWI 2011). A case of seven harvests from same fish over a period of 15 years has been reported (Bledsoe *et al.* 2003).

In southern Spain the first organic sturgeon farm in the world has been founded in 2009 (Wrathall 2009), while the first organic caviar farm in North America has been launched in February 2013 (Global Trust 2013). However organic caviar is not obtained by

standardized procedure and this definition is still self-referential and based on local farm definition.

1.6 Labels

In order to protect and promote future caviar trade, the correct caviar labeling is a primary question of international relevance, unfortunately, at the moment there is not yet a clear agreement on this question. International organizations as FAO, Convention on International Trade of Endangered Species (CITES) and International Union for Conservation of Nature (IUCN) primarily emphasized the importance of species indication in caviar labels (Carocci *et al.* 2004; Wuertz *et al.* 2009). FAO and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) documents stated that roe from any fish not belonging to the Acipenseriformes species are considered "substitutes of caviar" (Carocci *et al.* 2004; CITES 2002).

Despite these suggestions, caviar labels change in different countries and fraudulent mislabeling is a serious problem, with low value caviar substituted for highly prized caviar (Birnstein *et al.* 1998; Pikitch *et al.* 2005; Wuertz *et al.* 2007). Currently only in the U.S. sturgeon caviar can be labeled as "caviar", roe from other fish species must be identified with a specific term that should include the common name of the fish. China, that is emerging country in caviar production, is strongly oriented toward the adoption of CITES requirements for labeling, in order to open up to international markets (Wei *et al.* 2011). Labeling must be supported by analytical methods necessary to detect certified quality. Several methods as DNA-based techniques, scanning calorimetry (DSC), N and C stable isotopes, and reverse transcription PCR have been applied for identification of caviar authenticity species and source (wild vs farmed) (Arvanitoyannis *et al*. 2005; Debus *et al*. 2002; Rehbein *et al.* 2008). The indication of geographical origin and modern labeling are

already adopted in other fish roe. In Sweden a quality scheme called Protected Designation of Origin (PDO), based on EU rules, has been recently proposed for a vendance (*Coregonus albula*) roe (Bonow & Rytkönen 2013), in Mauritania an artisanal fish product obtained from mullet roe, the "Imraguen Women's Mullet Botargo", has obtained an international label, sponsored by an Italian Association that protect local products, "Slow Food",
(http://www.slowfood.com/donate/pagine/eng/donate/dettaglio_progetti.lasso?-idp=038).
same foundation sponsored mullet roe product in Italy, "Bottarga"
http://www.slowfoodfoundation.com/italian-presidia/details/3306/orbetello-botargo.

2. Caviar and consumers: the dark side of the moon ?

Historically, caviar was a food product exclusively consumed by aristocracy. In fact in the United Kingdom there is a special link between royal family and caviar from Middle Age. Today the market is changed, much more consumers can afford caviar as other luxury products. There is an extended scientific literature that investigated the luxury product consumers market (Anselmsson *et al.* 2014; Chandon *et al.* 2016; Hartmann *et al.* 2016) and the consideration that caviar belong to this category (i.e. luxury products) may add interesting aspects to the discussion on caviar itself.

First of all, it should be remembered that luxury market is extremely lucrative. The global luxury market includes several modern brands and products, it has constantly grown from €77 billion in 1995 to €217 - €253 billion in 2016 and it is traditionally not affected by economic crisis (Parguel *et al*. 2016; Hartmann *et al.* 2016). This amount is about 1,5 times of last estimate of entire world aquaculture production that is of €147,6 billion (FAO 2016). Nowadays, the customer demand of luxury products is increasing due to a combination of

400 demographic and cultural shifts, in combination with an increase of incomes that increased
401 the general availability to spend more money on premium products.
402 Looking a little bit inside this market segment, it results clear that there is a lot of internal
403 competition and it is a really challenging market as new products original or imitations,
404 constantly are introduced in this sector. New perspectives for caviar market are not
405 exclusively positive and although this market segment is promising, it is also intrinsically
406 unstable. Technical advantages in luxury products quickly become ordinary as new
407 competitors standardize innovations. Nearly 80% of all cars contain standard features that
408 were considered luxury features only a few years ago (Silverstein & Fiske 2003).Luxury
409 food market is also of cyclic nature "In short, our eating habits today largely are the result
410 of, and reflect, the luxury food of the past" (Hartmann *et al.* 2016). For 25 centuries, luxury
411 has been the privilege of few persons, starting with modern society, luxury spread to other
412 social groups. Luxury goods entered in a new era, providing a kind of democratic right to
413 happiness and the inaccessible become accessible to almost everyone, and the average
414 European citizens buys two luxury items every year (Chandon *et al.* 2016; Godey *et al.*
415 2013). Luxury consumers represent a small portion of our society, but they are the core
416 target of caviar production. If we take in consideration the most successful brand of luxury
417 products, some new suggestion can be adopted for the promotion of caviar consumption in
418 the future. Caviar is a symbol and new consumers are probably more attracted by its
419 prestige and rarity than by its flavor. In fact Gault *et al*. (2008) demonstrated that caviar
420 consumers show an irrational attraction for more rare caviar has happens in several luxury
421 product originated by rare animals.
422 New luxury consumers are emerging and Silverstein & Fiske (2003) in an Harvard
423 Business Review article entitled "Luxury for Masses", defined "Masstige" term indicating
424 "luxury but attainable" products. These products occupy a position between mass and class.

Masstige describes downward luxury extensions and this marketing strategy has been used by several industries producing premium level products, with success. It is considered as an innovative strategy to position a prestige company without changing the appeal (Truong *et al*. 2009). Masstige has grown in that segment of consumers that switch some of their purchases from normal products to something more exclusive (Silverstein & Fiske 2003). Caviar can be perfectly included in the category of old-luxury brand extension products.

Successful producers of food luxury products may be useful examples for modern caviar entrepreneurs. Considering wine for instance, it is clear that France spent centuries to make one of the most prestigious wine industry in the world and U.S. in few decades adopted the French model. Today American wine producers contend in quality with the best French wines. One of the most successful premium wine producers in California said "I realized there was a hole in the market I could drive a truck through, really good wines that the average person could afford." (Silverstein & Fiske 2003).

Caviar producers can take great advantage looking to this marketing strategies. Many new-luxury brands move down-market to make their products more accessible and competitive (Kapferer & Lauren 2016; Silverstein & Fiske 2003), this could the case of future caviar production. A kind of mentality shift is requested to modern caviar producers that will include caviar production in the modern society, it is clear that it is not more only a question of aquaculture, but also a question of positioning caviar in the modern society. Even if it appears a promising perspective, it is not exempt of risks, principally the brand dilution. This can happens when purchases from middle class consumers becomes frequent. The more affordable a product is, less prestigious is its perception (Parguel *et al.* 2016).

While middle class consumers may be gained adopting downshifting market strategies, higher class consumers may be gained thus transferring best aquaculture practices (principally related to rearing water conditions and artificial feeds) into a sturgeon

aquaculture, in order to contrast the erroneous belief that reared caviar has lost the characteristics of rarity and authenticity of wild caviar. Authenticity is an important aspect of traditional luxury foods (Arvanitoyannis *et al* 2005; Hartmann *et al* 2016) and it represents the relation between a food product and its distance from industrial product and mass production. Considering that the concept of luxury products is strongly related with local traditions, it is likely that high class consumers will mainly increase in the area of traditional caviar consumption, specifically in Russia.

Conclusion and perspectives

The perspectives of caviar consumption are based on two main pillars: one is the caviar supply, i.e. sturgeon aquaculture, another is the caviar demand. The future of caviar will essentially regard geographical and social expansion of consumption, the most interesting aspects emerged from this paper are related to potential social expansion of caviar consumption. Similarly to other luxury products, it is clear that caviar is not more an exclusive product as in the past and sturgeon aquaculture will play the major role in the future diffusion of caviar.

Scientific literature clearly shows that caviar quality is affected by sturgeon farming practices in several ways, by sturgeon artificial feeds, by conditions of rearing not only inside the farm but also in the processing phases and farmed caviar can be better respect wild one, as the controlled farming conditions can guarantee consumers health, organoleptic characteristics and conservation of endangered wild populations of sturgeons.

Moreover, a shared international definition of caviar and clear caviar labeling is an urgent need in order to promote effective quality in the future. Considering the questions posed in the beginning of the article, it can be stated that the sturgeon aquaculture is ready to answer

475 to modern consumers demand, thus keeping in mind the rapid changes of modern society
476 and the concept of luxury products.
477 In the 80s the world caviar production reached 3000 t/year and main projections indicate
478 that it is the presumable maximum production for the future, however these estimates don't
479 take into account the social changes of our society. Looking at luxury market trend, it is
480 likely that caviar consumption will go over these previsions, considering the expansion of
481 middle class consumers and diversification of caviar productions, promoted in turn by
482 modern aquaculture techniques and food processing techniques. Making a comparison with
483 other food luxury products, as French wines, their market evolution showed that from
484 original area, new geographical areas have gained success as California or South Africa or
485 Australia. This expansion (similarly to other successful products) has been characterized by
486 a combination of geographical vocation, sharing of technical advances and increased local
487 market demand. A well-established aquaculture industry (as the case of China and
488 Vietnam) combined with favorable geographical conditions, favors the creation of new
489 sturgeon farms out of the traditional regions. China is the country where the highest
490 number of caviar consumers and producers are expected. Moreover, new opportunities will
491 emerge looking the successful market strategies in particular for the middle class of
492 consumers. Many luxury brands have engaged in "masstige" positioning strategies , if
493 applied to caviar productions, these strategies can promote a tremendous success for future
494 of caviar.
495 The challenge for sturgeon aquaculture will be to spread a positive image of caviar from
496 aquaculture that has substituted wild caviar, thus introducing the aspects of excellence
497 related to extensive aquaculture in controlled conditions by the adoption of shared rules on
498 caviar quality. Scientific literature showed that sturgeon extensive farming doesn't
499 negatively affect quality of caviar and can even ameliorate the safety of caviar, thus

reducing the risks of contamination with toxic compounds naturally spread in polluted regions. Moreover, looking at the experience of other sectors of aquaculture, it is clear that modern consumers are concerned about sustainability of products and these aspects will improve the future acceptance and diffusion of caviar, considering that this product is traditionally linked with negative image of over exploiting wild stocks of sturgeon. The attention for environmental impact of fish farms and fish welfare confers an extra value to those products that respect natural exploitation of resource and sustainability of production.

The impressive amount and proliferation of caviar substitutes represents the potentiality to gain large segment of low class consumers or an opportunity to increase their consumption, as happened in several aquaculture products that have become common food products following success of aquaculture. Considering that this proliferation can be considered a social Müllerian convergence sequence, other research efforts can be addressed to understand what is the maximum number of caviar imitators (i.e. substitutes) that can be expected in the market, or in more formal terms, where is the limit of this sequence. In this context, it is likely that Game Theory (Meyerson 1991) could be a really useful approach to investigate the relation between consumers, caviar companies and substitute caviar companies, as this relation can be probably explained by a non-cooperative game with relevant implications for future sturgeon farming.

Finally, being an exclusive and evocative luxury product, the future expansion will be influenced by emotional forces that are rather evanescent and intangible. These aspects are only indirectly related to aquaculture and are largely influenced by media, for this reason, appropriate marketing plans will be necessarily aimed at communicating these new products to the consumers. Research is needed on the overlapping area between caviar production and consumer needs, consumer choices analysis and purchase attitudes for caviar. Future aquaculture should not finish on the store threshold, as the rest of the path,

from the store to the consumer home, has a particular relevance in these sectors where human psychology plays a crucial role. The knowledge of social attitudes and behavior of caviar consumers may probably drive successful caviar producing companies as strongly as the diffusion of modern aquaculture techniques.

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Figure captions

Fig.1 Main caviar producer and importer countries in 2011 (Bronzi and Rosenthal, 2014 ; FAO 2012, modified. Geographical elaboration obtained with R, version 3.3.2, Copyright © 2016 – The R Foundation for Statistical Computing, library(rworldmap))

Fig.2 Main caviar substitutes producer countries in 2011 (FAO 2011)

Fig.3 Production of caviar substitutes in main producers countries, between 2001 and 2011 (FAO 2011, modified)

Figure 4. The relation between caviar and caviar substitutes is a parasitism or a Müllerian mimicry ?

Fig. 5 Canine caviar: an example of social Müllerian mimicry

Table 1. Caviar preservatives

Additive	**species**	**Reference**
Borax	*A.persicus*	Salmani *et al.* 2009;
Methylparaben	*A. persicus*	Reza & Zabihollah2010
5% NaCl plus 0,3% boric acid plus 0,4 borax	*A.persicus*	Salmani *et al.* 2009
5%NaCl plus 0.15% methyl paraben	*A.persicus*	Salmani *et al.* 2009
Flavonoids extracts from the fungus *Phellinus igniarius*	n.r.	Wang *et al.* 2012
Radio frequency and microwave heating	*A. transmontanus*	Al-Holy *et al.* 2005
High pressure Pasteurization	*A. baeri*	Fiorettoet *al.* 2005 Bledsoe *et al.* 2003; Shin *et al.* 2010)
Pasteurization in airtight or vacuum packaged containers (50 – 70 °C)	*A. transmontanus*	Al-Holy *et al.* 2005
NaClbetween 3.2% to 11.8%	*H. huso, A. gueldenstaedti, A. stellatus, A. baeri, Polyodonspathula*	Shin *et al.* 2010 Gessner *et al.*2002
Borates (4g/kg)	French caviar	Rizzi 2007

n.r. not reported

Fig.1

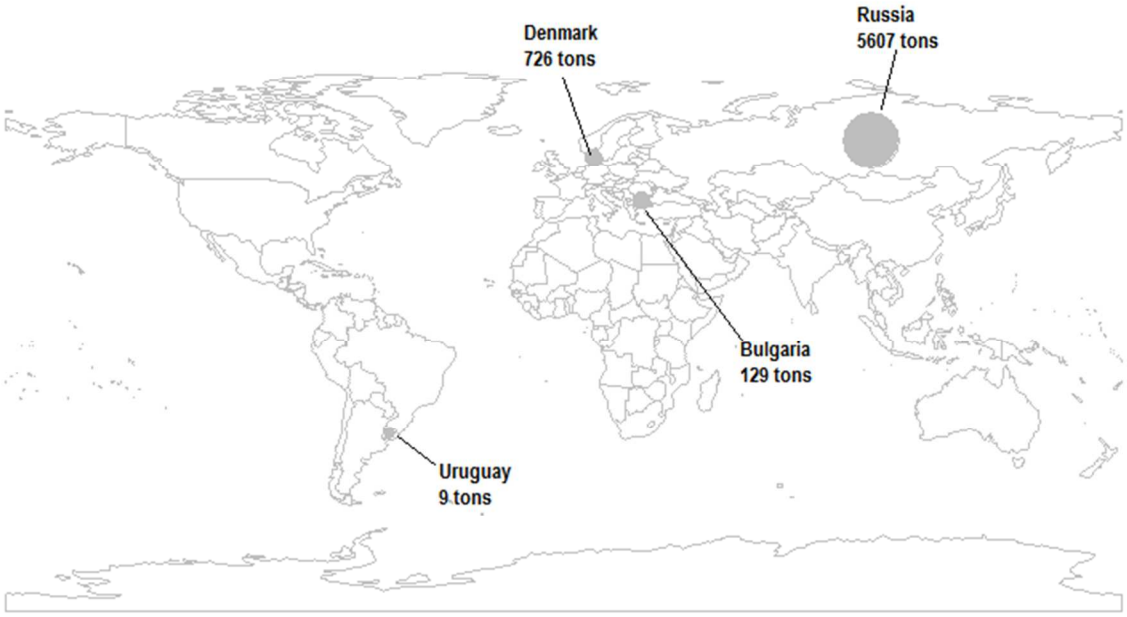

Fig.2

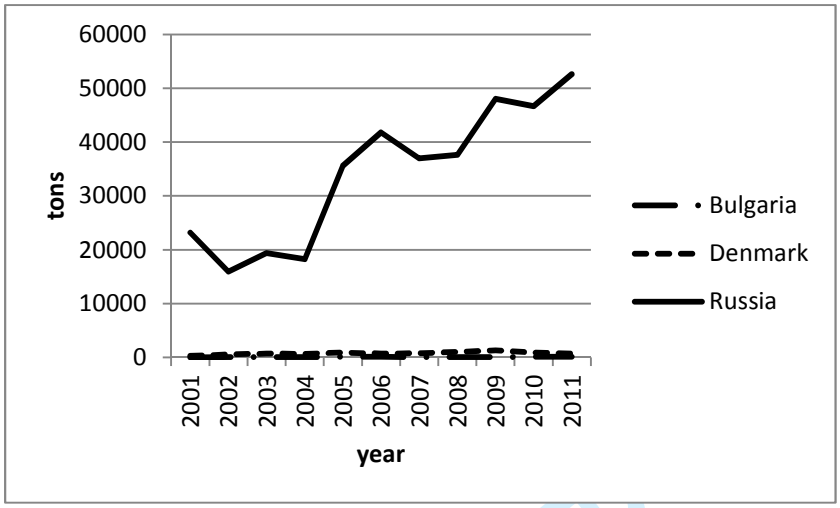

Fig.3

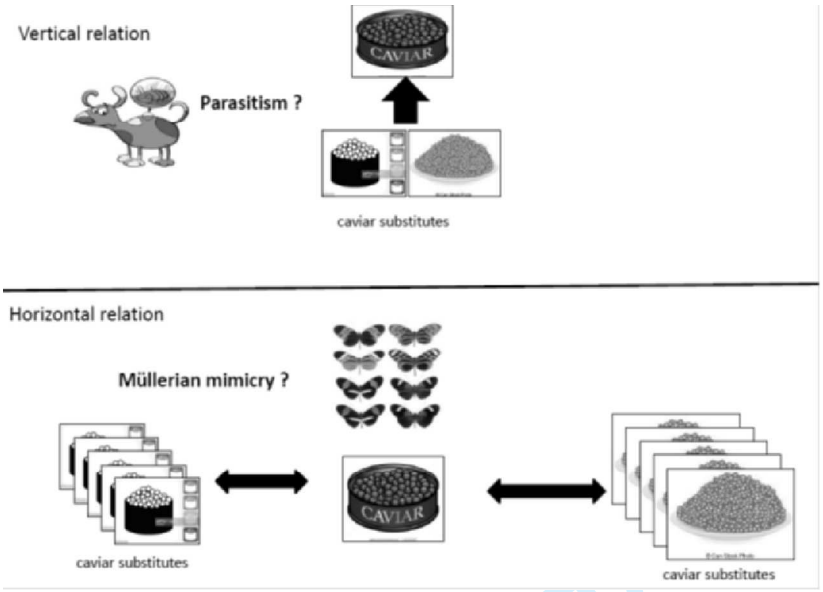

Figure 4.

Fig. 5