LWT - Food Science and Technology 84 (2017) 298–305

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Technological and nutritional advantages of mechanical separation process applied to three European aquacultured species

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ARTICLE INFO

Article history:
Received 24 January 2017
Received in revised form
24 May 2017
Accepted 26 May 2017
Available online 31 May 2017

Keywords:
Mechanical separated meat
Process yield
Mineral
Fatty acids
Color

ABSTRACT

Recently, mechanical separation (MS) process has been applied on fish sector, however, its impact on fish quality is scarcely investigated. Aim of the present study was to compare the impact of mechanical separation with manual mincing applied on European sea bass, gilthead sea bream, and rainbow trout by evaluating physico-chemical properties and nutritional quality. MS process yield was found higher than the manual one when applied to sea bass, and sea bream (42, and 45 g/100 g, respectively against 39, and 40 g/100 g). Rainbow trout had the highest processing yield even if the high presence of residual on the drum (5 g/100 g) lead a lower MS yield than the manual processing. MS seemed to slightly increase water content in sea bream and trout (71.12, and 70.65 g/100 g, respectively against 68.05, and 68.11 g/100 g of fillets) and decrease minerals, especially in trout, which showed loss of Ca, Mg, Na, and P. Hopefully, lipid fraction of the three species remained unaltered, indeed no significant differences were found in the fatty acid composition of the products, and consequently for the calculated atherogenicity and thrombogenicity indexes. In sum, manufacturing of products by exploiting fish without altering the nutritional value of whole fish is a goal reached adopting mechanically separation process.

1. Introduction

Fish represent a source of high-quality protein, essential fatty acids, and a range of macro- and micronutrients that have shown beneficial effects on human health. Fatty acids of ω3-series, especially eicosapentaenoic acid (C20:5ω3, EPA) and docosahexaenoic acid (C22:6ω3, DHA), have been proved to be involved in anti-inflammatory responses, anti-carcinogenic, and anti-thrombogenic effects (Maskrey, Megson, Rossi, & Whitfield, 2013). Furthermore, fish muscle includes a large variety of mineral (Alasalvar, Taylor, Zubcov, Shahidi, & Alexis, 2002; Asghari, Zeynali, & Sahari, 2013), from K to Se. The main functions of essential minerals include skeletal structure, maintenance of colloidal system, and regulation of acid–base equilibrium. Minerals also compose hormones, enzymes, and enzyme activators (Belitz, Grosch, & Schieberle, 2001). Despite the high nutritive value of fish, the time for their preparation and the price can discourage some consumers from purchasing, leading to a preference for ready to cook or ready to eat products (Palmeira et al., 2016).

The edible proportion of fish represents approximately 45% of total fish weight (depending on fish species); thus, 55% is composed by head, fins, guts, bones, frame, and meat adhered to bones and skin which are considered as fish waste from processing (Arvanitoyannis & Tserkezou, 2014). Numerous technological strategies have been adopted in the recent years in order to trade on wastes, such as the production of functional ingredients from bones and skin, semi-ready or ready to cook/eat products obtained by meat adhered to bones and skin. The latter is commonly named mechanically separated meat (MSM) and it derives from the removal of the remaining meat from bones applying low ($<10^4$ kPa) or high pressure ($>10^4$ kPa). Fish burgers (Marengoni et al., 2009), surimi (Fogaça, Otani, Portella, dos Santos Filho, & Sant'Ana, 2015), and flour (Oliveira, Lourenço, Sousa, Joele, & Amaral Ribeiro, 2015) have been developed using MSM from Nile tilapia (*Oreochromis niloticus*), and Brazilian catfish (*Brachyplatystoma vaillantii*) wastes (Freitas, Resende, Furtado, Tashima, & Bechara, 2012; Kirschnik, Trindade, Gomide, Moro, & Viegas, 2013; Marengoni et al., 2009; Fogaça et al., 2015; Oliveira et al., 2015). On the other hand, not only residual from commercial fish processing, but also damaged and noncommercial sized fish are considered discards even if they might be shifted to human consumption.

Seafood represents an important component of the food supply

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http://dx.doi.org/10.1016/j.lwt.2017.05.068
0023-6438/

for the Italian population. However, the loss of high quality food image, the saturation of internal market, and the strong foreign competition have been responsible for the seafood industry stagnation, from which new marketing approaches, such as products diversification, might help to be turned out (http://www.fao.org/fishery/countrysector/naso_italy/en). Therefore, current innovations could be directed towards the manufacturing of new products, also by exploiting fish wastes, without altering the nutritional value of whole fish.

For this reason, this study aimed to compare the impact of mechanical separation process and manual minced technology applied on three aquacultured species of interest for European aquaculture. Physico-chemical properties and nutritional quality of European sea bass, gilthead sea bream, and rainbow trout derived products were evaluated immediately after the fish treatments.

2. Materials and methods

2.1. Preparation of fish samples and storage conditions

Thirty-three European sea bass (*Dicentrarchus labrax*) and 33 gilthead sea bream (*Sparus aurata*) were purchased from a fish farm located in Orbetello (Grosseto, Italy) whereas 33 pigmented rainbow trout (*Oncorhynchus mykiss*) were purchased from a farm located in the north west of Tuscany (Lucca, Italy). All the fish were killed by percussion. Immediately after death, fish were transferred in polystyrene boxes, covered by ice, and moved to the industry where 18 fish for each species were minced by the soft belt-drum separator (BAADER Mod. 601; Baader, Lübeck, Germany) after being washed, eviscerated and decapitated, and washed again in order to eventually remove blood and gut residuals. In details, fish were manually inserted into the MSM machine, previously sanitized, where a conveyer belt pressed the carcass on the surface of a perforated drum (hole diameter: 5 mm). Bones, skin and thicker layers of connective tissue remained outside from the drum and were ejected through a discharge chute, while meat (MSM) passed through the holes and conveyed in a plastic box. A one-step separation was conducted without any washing or centrifugation additional phases. The remained whole fish and the MSM were immediately brought, in refrigerated condition, to the Agri-Food and Environmental Science Department laboratories (University of Florence, Firenze, Italy) where all the whole fish were filleted. Fifteen fillets (right) for each species were analyzed as such (control, C samples) while fifteen fillets (left) for each species were grounded by using a manual mincer (Mod. Tritacarne New Style; Westmark Gmbh, Elspe, Germany) and the minced meat was shaped in 15 flat round cakes, similar to burger (FB samples) made with 100% of fish (referred as fish burger in this paper) that were manually formed with a plastic stamp. Fifteen MSM-fish burger were directly obtained by forming MSM with the same plastic stamp (MSM samples). Three replicates of C, FB, and MSM were analyzed for pH, color, proximate composition, fatty acid profile, and mineral composition.

2.2. Processing yield

The whole, headed and gutted weights of each fish, as well as the minced meat weight were recorded. Similarly, the fillet yield of manually filleted fish was calculated considering the whole fish, headed and gutted weights and the weight of the two fillets from each fish. Yield was calculated as g/100 g of deboned meat weight relative to whole fish weight (Booman, Márquez, Parin, & Zugarramurdi, 2010).

2.3. Physical analyses

pH and color were measured on C, FB, and MSM samples. The pH value was monitored in three different points of the epaxial region of the whole fillets and of the burger's (FB and MSM) diameter by using a pH-meter (Columbus, OH, USA).

Lightness (L^*), redness index (a^*) and yellowness index (b^*) were measured according to the CIELab color space system (CIE, 1976) by a Spectro-color® colorimeter (Keison International Ltd, Chelmsford, Essex, UK) and data were recorded by the software Spectral qc 3.6.

2.4. Proximate composition

Moisture, crude protein (N×6.25), crude fat, and ash contents were determined by using 950.46, 976.05, 991.36, and 920.153 A.O.A.C (2012) methods, respectively. For total lipid analysis, approximately 2 g of sample were ground and extracted using chloroform and methanol according to Folch, Lees, & Sloane Stanley (1957) method. Total lipids were measured gravimetrically.

2.5. Fatty acid profile

Fatty acids (FAs) were determined in the lipid extract after transesterification to methyl esters (FAME) using the method proposed by Morrison & Smith, 1964. The FA composition was determined by gas chromatography (GC) using a Varian GC 430 gas chromatograph (Varian Inc., CA, USA) equipped with a flame ionization detector (FID) and a Supelco Omegawax™ 320 capillary column (30 m × 0.32 mm i.d., 0.25 μm film and polyethylene glycol bonded phase; Supelco, PA, USA) set as previously described in Secci et al. (2016). Fatty acids were quantified through calibration curves using tricosanoic acid (C23:0) (Supelco, PA, USA) as internal standard. This analysis was carried out on C and MSM samples, but not on FB samples, because they were obtained from minced (left) fillets of the same fish from which the C samples were obtained and consequently they were considered with the same characteristics of C samples in term of FA composition. Atherogenicity index (AI), according to the formula [C12:0 + (4 × C14:0) + C16:0]/(ΣPUFAω3 + ΣPUFAω6 + ΣMUFA), and thrombogenicity index (TI), according to the formula [C14:0 + C16:0 + C18:0]/[0.5 × ΣMUFA) + (0.5 × ΣPUFAω6) + (3 × ΣPUFAω3) + (ΣPUFAω3/ΣPUFAω6)] were calculated as suggested by Ulbricht and Southgate (1991); hypocholesterolaemic/hypercholesterolaemic FA ratio (h/H), as (C18:1ω9 + C18:2ω6 + C20:4ω6 + C18:3ω3 + C20:5ω3 + C22:5ω3 + C22:6ω3)/(C14:0 + C16:0) was also calculated (Santos-Silva, Bessa, & Santos-Silva, 2002).

2.6. Mineral composition

Three samples for each treatment were lyophilized (Vacuum Pump Welch Directorr; Welch Vacuum Technology Inc., Skokie, IL, USA) and utilized for determination of mineral composition. The contents in calcium (Ca), phosphorous (P), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu), chromium (Cr), sodium (Na), potassium (K), selenium (Se), arsenic (As), cadmium (Cd), and lead (Pb) were determined. One-hundred mg of lyophilized samples was dissolved in 10 mL of concentrated nitric acid (67% Suprapur®; Merck, Darmstadt, Germany) in Teflon tubes. The tubes were mineralized in a microwave (Mod. Mars; CEM Corporation, NC, USA) by applying the mineralization stages at 1600 Watt: 200 °C (ramp time 20 min, hold time 15 min). After cooling, the volume was made up to 25 mL with bi-distilled water. Minerals were measured by inductively coupled plasma - optical emission spectrometry (ICP-OES) (Mod. IRIS Intrepid II ICP Spectrometer; Thermo Electron Corporation, MA, USA). Trace minerals were quantified on the basis of peak areas