Food Chemistry 173 (2015) 355–362

Contents lists available at ScienceDirect

Food Chemistry

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

Seasonal changes in technological and nutritional quality of *Mytilus galloprovincialis* from suspended culture in the Gulf of Trieste (North Adriatic Sea)

Tiziana Bongiorno, Lucilla Iacumin, Franco Tubaro, Eva Marcuzzo, Alessandro Sensidoni, Francesca Tulli *

Department of Food Science, University of Udine, via Sondrio, 2, 33100 Udine, Italy

ARTICLE INFO

Article history:
Received 15 May 2014
Received in revised form 12 September 2014
Accepted 6 October 2014
Available online 14 October 2014

Keywords:
Mussel
Proximate composition
Amino acid
Fatty acid
Commercial traits
Heavy metals
North Adriatic Sea

ABSTRACT

Nutritional quality parameters, microbiological and technological quality indicators (condition index, meat yield and water-holding capacity) of blue mussel, *Mytilus galloprovincialis*, reared in the North Adriatic Sea were characterised at monthly intervals over a 1 year period. Contents of protein (7.5–11.6 g/100 g), lipid (1.0–2.2 g/100 g) and ash (2.2–3.3 g/100 g) varied significantly accordingly to condition index (6–15%). n-3 PUFAs were the predominant fatty acids (38.7–45.9% of fatty acids) and docosahexaenoic and eicosapentaenoic acids were the most abundant (167 and 93.3 mg/100 g, respectively). Glycine, glutamic and aspartic acids accounted for 40% of total amino acids. All samples exhibited limited concentrations of Cr, Mn, Ni, Cu and Zn, as well as Na. *M. galloprovincialis* from the North Adriatic Sea showed the highest technological and nutritional quality, considering also the inter-annual variability, in late spring, which corresponds to the period immediately before gamete release.

1. Introduction

Mussels, as filter feeders, are important to marine ecology, but they also have an exceptional nutritional value, making them ideal nutrients in human diet. Consumption of bivalve molluscs helps to provide high biological value proteins, essential vitamins, and minerals as well as polyunsaturated fatty acids with known health beneficial effects (Simopoulos, 2003). Moreover, mussels are appreciated by consumers for sensory attributes and their competitive price compared to other bivalves (Orban, Di Lena, Casini, Marzetti, & Caproni, 2002).

Shellfish farming is the main item of Italian aquaculture production (Ismea, 2008) and, within the EU, Italy is one of the main edible bivalve producer countries after Spain and France (Irepa, 2009). In 2008, 165,000 tons of shellfish were produced: 115,000 tons of Mediterranean blue mussels (*Mytilus galloprovincialis*) and 50,000 tons of clams (*Tapes* spp.) (FAO, FishstatPlus, 2012). Mussel cultivation is widespread and is found in 12 out of 15 Italian regions that have access to the sea (Prioli, 2001). In Italy, mussels are usually marketed as a raw product and packaged still alive in plastic pouches but, currently, according to the market demand, there is an increasing interest in commercialisation of processed products. Due to the changes in consumer habits, Mediterranean mussel farmers show increasing interest in technologies aimed to increase the shelf life of live mussels, such as modified atmosphere (MAP) or vacuum packaging. To obtain high quality final products, the high quality of raw material, and the correct production technologies and storage conditions are essential. Studies have shown that several factors, such as quality and temperature of water, nutrient availability and reproductive cycle, may affect the overall quality of mussels in terms of microbiological, nutritional, technological and sensory characteristics (Okumuş & Stirling, 1998; Orban et al., 2002; Parisi, Giorgi, Messini, & Poli, 2005; Vernocchi, Maffei, Panciotti, Suzzi, & Giardini, 2007). Thus they may have an impact on the technological and nutritional qualities of the product.

The aim of this study was to analyse the seasonal variations of biometric and physico-chemical characteristics related to quality of *M. galloprovincialis* cultivated in the Gulf of Trieste (North Adriatic Sea) and define the ideal time when the mussels, in relation to their physiological condition, are most suitable for processing. The study, for the first time, takes into account a large number of variables for a period of 1 year.

* Corresponding author. Tel.: +39 0432558195; fax: +39 0432558130.
E-mail address: francesca.tulli@uniud.it (F. Tulli).

http://dx.doi.org/10.1016/j.foodchem.2014.10.029
0308-8146/

2. Materials and methods

2.1. Animals and environmental conditions

Mussels of commercial size, cultured in a long-line system in the Gulf of Trieste (North Adriatic Sea), were collected monthly from December, 2009, to November, 2010, and used as raw material. Samples were immediately transported to the laboratory of the Department of Food Science of the University of Udine under refrigeration (3 ± 1 °C) to be brushed, washed and processed on the same day. Seawater temperature, salinity and dissolved oxygen were measured, at farm, using a YSI-Pro probe at a depth of 4 m.

2.2. Biometric parameters, shell hardness, condition index and meat yield

At each sampling point, shell length, width and height of 50 randomly selected mussels were measured, using a 0.05 mm precision stainless steel calliper (Storm 6 in. digital calliper, Mod. 3C301). Thickness was detected at the shell margin (TM) and at the maximum curvature of the valves (TC), using a micrometre (Maurer 1/100 mm Vogel, Germany).

The shell hardness of each specimen was evaluated with an INSTRON 4301 (Instron Ltd., High Wycombe, UK) device equipped with a 40 mm diameter cylindrical probe and a 1 kN load cell. A compression test was applied to the maximum height of both, right and left, mussel shells: starting from an initial gap of 13 mm, the probe moved down to 5 mm with a test speed of 50 mm/s. The instrumental settings and operations were accomplished using the software, Automated Materials Testing System (version 5, Series IX, Instron Ltd., High Wycombe, UK). Fracturability (*N*) was measured as the force applied to obtain a significant break in the curve.

After the determination of individual total weight, meat was spun off and meat and shell weights were registered before and after oven-drying (105 °C). Condition index (CI) was calculated according to Orban et al. (2002) as follows:

$$CI = [\text{meat dry weight (g)}/\text{shell dry weight (g)}] \times 100$$

Meat yield (MY) was calculated according to Okumuş and Stirling (1998) as follows:

$$MY = [\text{wet meat weight (g)}/\text{total weight (g)}] \times 100$$

Cooked meat yield was also calculated according to Vernocchi et al. (2007) and Parisi et al. (2008), after 7 min of boiling and 5 min of cooling, as follows:

$$MY_{cook} = [\text{meat weight after cooking (g)}/\text{total weight (g)}] \times 100$$

2.3. Water-holding capacity

To determine water-holding capacity (WHC) of the edible part, six pools (15 g each) of whole soft tissues (about 5 randomly chosen mussels per month) obtained after byssus cutting by means of a scalpel and gentle removal of the soft part, were centrifuged (210*g* for 15 min) at 5 °C according to Olsson, Ofstad, Lodemel, and Olsen (2003). WHC was determined as liquid loss and expressed as percentage of weight of liquid released (Osfad, Kidman, Myklebust, & Hermansson, 1993) as follows:

$$WHC\ (\%) = [\text{weight of liquid released (g)}/\text{total weight (g)}] \times 100.$$

2.4. Chemical analysis

2.4.1. Protein, ash and mineral content

At each sampling point, three pools of animal soft parts were freeze-dried and moisture (DM) (method 950.46), protein as Kjeldahl N * 6.25, after acid digestion (method 928.08) and ash, after burning in a muffle furnace (method 920.153) contents were determined according to AOAC (1997). Mineral content was determined after sample digestion with suprapur nitric acid (65%) and suprapur hydrogen peroxide (90%) in a high performance microwave digestion unit (MLS 1200 MEGA), increasing power from 200 to 700 W in 20 min and adjusting to a final volume (100 ml) with mQ deionised water. Macroelements (Na, K, P, Ca) were analysed, using spectroquant kits (Merk Millipore spa, Vimodrone, MI) by spectrophotometry (CARY 50BIO, Varian Inc., CA, USA) and quantified by the software, Cary Win UV. Microelements (Cr, Mn, Ni, Mg, Fe, Cu, Zn, Se) were quantified by inductively coupled plasma-mass spectrometry (ICP-MS, Spectromass 2000 Type MSDIA10B, Spectro Analytical Instruments, GmbH, Germany) equipped with a standard torch and high matrix content (HMC) Ni sampler. Pure argon was used for all determinations and the operating conditions are given below:

Plasma conditions		*Ion optic ensemble*	
Frequency	27.12 MHz	Extraction lens (LO)	(−460) to (−500) V
Rf power	1200–1350 W	Optic lens (LA)	−60 V
Auxiliary gas flow	1.2 l/min	Photon stop lens (LB)	0 V
Coolant gas flow	18 l/min	Optic lens C (LC)	−80 V
Sampler	Nichel (HMC) 1.0 mm Ø orifice	Quadrupole entr. Lens (LD)	(−60) to (−70) V
Skimmer	Nichel (HMC) 0.8 mm Ø orifice	Field axis (FA)	0–9.0 V
		Deflexion in/out	−500 V/ −200 V
Vacuum parameters		*Mass Spectrometer settings*	
Interface	2.04 mbar	Secondary electron multiplier 1900 V	
Quadrupole	8.9–10.6 mbar	Peak resolution	0.75 a.m.u.
Turbo voltage	10 V	Pause calibration factor	3.0

2.4.2. Amino acids analysis

The total amino acid (AA) content of 2 pooled mussel samples (100 mg edible part) per month, was determined after hydrolysis (6 M HCl, 110 °C, 24 h), using an HPLC Analysis System LC 200 Perkin Elmer pump fitted with an ISS-100 auto sampler (20 µl loop) and a fluorimetric detector (Perkin Elmer, Norwalk, Connecticut, USA), λ excitation 250 nm and λ emission 395 nm column. Separation was achieved with an AccQTag Amino Acid Analysis (3.9 × 150 mm) reverse phase column (Waters Corporation Milford, MA, USA) and a Waters pre-column filter. Turbochrom software, with two NCI 900 PE Nelson Perkin Elmer interfaces, was used for data collection and integration. The column was thermo-regulated at 37 °C and the flow rate was 0.8 ml/min according to Liu, Chang, Yan, Yu, and Liu (1995). Mobile phase A consisted of acetate-phosphate aqueous buffer, while mobile phase B was acetonitrile (100%) and C was UHQ water. After addition of borate buffer, filtered (0.45 µm pore size filter) hydrolysated samples were derivatised at 55 °C for 10 min with 20 µl of AccQFluor reagent (6-aminoquinolyl-*N*-hydroxysuccinimidyl carbamate) and injected into the HPLC (Bosch, Alegria, & Farrè, 2006). L-amino-n-butyric acid (AAbA, 2.5 mM in 0.1 M HCl) was added to the samples as internal standard for quantification. Under these conditions, cysteine, methionine and tryptophan could not be detected.

2.4.3. Lipid content and fatty acids analysis

The lipid content of three pooled mussel samples (120 g edible part) per month was determined after extraction in chloroform/methanol (2:1, v/v) containing 0.01% butylated hydroxytoluene (BHT), according to Folch, Lees, and Sloane Stanley (1957).