UNIVERSIDADE DE LISBOA

FACULDADE DE MEDICINA VETERINÁRIA

QUALITY AND SAFETY ASSESSMENT OF DRIED SALTED COD IN A LOGISTIC OPERATOR: DEVELOPMENT OF A PRACTICAL VISUAL GUIDE TO ENHANCE PROCEDURES AT THE RECEPTION STEP

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Resumo

Avaliação da qualidade e segurança de bacalhau salgado seco num operador logístico: desenvolvimento de um guia visual prático para melhorar procedimentos à receção

Bacalhau salgado seco é um produto tradicional com uma longa história de consumo. Todos os anos em Portugal cerca de 70 mil toneladas são consumidas, correspondente a aproximadamente 7kg por pessoa. No entanto, pode apresentar várias não conformidades relacionadas com a sua segurança e qualidade. De modo a mitigar estes problemas, os operadores do setor alimentar devem adotar medidas de prevenção e controlo na sua produção, armazenamento e distribuição.

O objetivo deste trabalho foi o de avaliar não conformidades em bacalhau salgado seco e produtos afins detetadas à receção num operador logístico, e de desenhar um guia visual prático para melhorar procedimentos de controlo de qualidade na secção de receção de matéria-prima. Foram, então, avaliados os registos de atividades de controlo à receção, assim como os de medição da temperatura e de controlo analítico da humidade de 2017 a 2022. Adicionalmente, de modo a desenvolver o guia prático e visual, textos do *Codex Alimentarius Commission* foram analisados e foi realizado um registo fotográfico do bacalhau seco salgado e produtos afins de outubro de 2021 a fevereiro de 2022.

A maior proporção de não conformidades detetada está relacionada com defeitos de peso líquido (71,40%), mas também foram detetados *rouge* (0,25%) e empoado (0,37%). Considerando as medições de temperatura de bacalhau seco salgado e produtos afins efetuadas na fase de receção, 79,80% não estavam em conformidade, enquanto 69% apresentavam medições de humidade não conformes. O guia prático inclui um plano de amostragem, juntamente com imagens ilustrativas de produtos conformes e possíveis não-conformidades, e uma lista de referências também incluída.

Os resultados revelaram uma elevada taxa de não-conformidades relacionadas com a temperatura e humidade do bacalhau salgado seco e produtos afins no operador logístico. O guia prático e visual ajudará os procedimentos e atividades de controlo de qualidade e segurança e o processo de tomada de decisões relacionadas com o bacalhau seco salgado e produtos afins na fase de receção do operador logístico.

Palavras-chave: Bacalhau, produtos da pesca, não-conformidade, temperatura, humidade

Abstract

Quality and safety assessment of dried salted cod in a logistic operator: development of a practical visual guide to enhance procedures at the reception step

Dried salted cod is a traditional food product with a long history of consumption. Each year in Portugal, nearly 70 thousand tons are consumed, which accounts for approximately 7kg per person. Nevertheless, dried salted cod can present several quality and safety related non-conformities. To mitigate these issues, food business operators must adopt preventive measures and strict control procedures in the production, storage, and distribution of dried salted cod.

The aim of this work was to assess dried salted cod and related products non-conformities detected at the reception step of a logistic operator, and to design a practical visual guide to further enhance control procedures at the incoming raw materials section. Thus, quality and safety control records, as well as temperature monitoring records, and analytical control reports of dried salted cod from 2017 to 2022 were assessed. Additionally, to develop the incoming raw materials visual guide, *Codex Alimentarius* Commission texts were explored and a photographic record of dried salted cod and related products was performed from October 2021 to February 2022.

Most of the detected non-conformities were related to net weight defects (71.40%), but *rouge* (0.25%) and dun (0.37%) were also reported. Considering dried salted cod and related products temperature measurements performed at the reception step, 79.80% were non-compliant, while 69% presented non-conforming humidity measurements. The incoming raw materials visual guide included appropriate sampling plans for the reception step of dried salted cod and related products, together with illustrative pictures of conforming and non-conforming products and a references list of related publications for further delving were also included.

Taken together, results revealed a high rate of non-conformities related to temperature and humidity of incoming dried salted cod and related products at the logistic operator. The visual guide will further assist the quality and safety control procedures and activities, as well as the decision-making process related to dried salted cod and related products at the reception step of the logistic operator.

Keywords: Cod, fishery products, non-conformity, temperature, humidity

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List of abbreviations

AIB – *Associação dos Industriais de Bacalhau*, or, in English, Association of Codfish Industries

AQL – Acceptable Quality Level

A_w – Water Activity

BIOHAZ – EFSA Panel on Biological Hazards

CAC – Codex Alimentarius Commission

CCP – Critical Control Point

DSC – Dried Salted Cod

EC – European Commission

ELISA - Enzyme-linked immunosorbent assay

ERH – Equilibrium Relative Humidity

EU – European Union

FAO – Food and Agriculture Organization of the United Nations

FBO – Food Business Operator

FDA – U.S Food and Drug Administration

FSMS – Food Safety Management Systems

GHP – Good Hygiene Practices

HACCP – Hazard Analysis and Critical Control Points

IPQ – *Instituto Português da Qualidade*, or, in English, Portuguese Institute for Quality

NC – Non-conformity

PRP – Prerequisite programme

QC – Quality control

RH – Relative humidity

TRU – Traceable Resource Units

WHO – World Health Organization

Communications in congresses

Part of the activities developed during the internship were presented as electronic posters in the following congresses:

Oliveira MM, Cordeiro J, Manso L, Henriques AR (2021) Developing Product Specifications For Prepared Fish Products: An Essential Part Of The Food Safety Management Systems. ATAVET II. International III. National Veterinary Medicine Student Congress, 15th and 16th December 2021, Erzurum, Turkey, online (Annex 3).

Oliveira MM, Cordeiro J, Manso L, Silva A, Henriques AR (2022) Developing A Visual Guide To Enhance Quality Control Procedures At The Reception Of Dried Salted Cod In A Logistic Operator. Chapter 4-Conference on Food Science, Nutrition & Public Health (FNPH-2022), 24th and 25th February 2021, Lisbon, Portugal, online (Annex 4).

1. Introduction

1.1. Literature review

1.1.1. Dried salted cod

1.1.1.1. Brief historical note and consumption statistics

Dried salted cod (DSC) is a traditional Portuguese product, frequently associated with Christmas time, whose method of production was developed by the Basque around the year 1000 (Kurlansky 1997; Rodrigues et al. 2021). Its consumption dates back from the XIV century, where it was imported from Northern Europe (National Geographic 2021). In 1501, Portuguese fishermen started to fish in Newfoundland, a practice that expanded until the 1958, for which Portugal was considered the world's biggest dried salted cod manufacturer (Santos 2019; Garrido 2021). From the 1960's, as changes in maritime law ensued, the country's production declined (Santos 2019; National Geographic 2021).

Nowadays, Portugal is Norway's biggest importer of dried salted cod, importing 66% of its production in 2016 and the equivalent to 236 million dollars in salted cod (European Commission and Directorate-General for Maritime Affairs and Fisheries 2021; Observatory of Economic Complexity 2022). The biggest exporters of salted cod are Norway, Iceland and Sweden, accounting for 65% of total exports (Observatory of Economic Complexity 2022).

Gadus morhua is one of the most important marine species caught worldwide, representing 2% of total volume caught in 2018, with 1218 thousand tonnes caught. Classified as a vulnerable species, this species suffers with stock overfishing and recovery difficulties (Sobel 1996; Food and Agriculture Organization (FAO) 2020).

In 2016, consumption of DSC in Portugal accounted for 65 thousand tonnes, with most of the supply being local, with 64% correspondent to 45 thousand tonnes, and 36% imported from other countries as Norway (European Commission and Directorate-General for Maritime Affairs and Fisheries 2021). According to national statistics, Portugal's production of DSC reached 39 thousand tonnes in 2021, corresponding to 63% of total dried salted products production, a reduction since 2016 (European Commission and Directorate-General for Maritime Affairs and Fisheries 2021; Instituto Nacional de Estatística 2022). DSC represented 10.5% of total fish products imports, with frozen cod representing 6.3% and salted cod 5% (Instituto Nacional de Estatística 2022).

DSC and other cod products represent the top 3 fisheries and aquaculture commodities in Portugal, being sold mainly by large retailers, that account for 90% of market share (European Commission and Directorate-General for Maritime Affairs and Fisheries 2021). DSC sales increased by 5.9% in 2021, compared to 2020 (Instituto Nacional de Estatística 2022), with Portuguese citizens consuming approximately 7kg per year of DSC *per capita* (Jornal de Notícias 2021). Apparent consumption, defined as production plus imports minus exports of

DSC and other salted fish products decreased from 2012-2015 to 2016-2020 (United Nations Statistics Division 1997; Instituto Nacional de Estatística 2021)

1.1.1.2. Raw materials

1.1.1.2.1. Fish

1.1.1.2.1.1. Cod

According to *Decreto-Lei* no. 25/2005 of 28th of January establishing the commercialization conditions for salted, green, semi-dried or dried cod, and related salted, green, semi-dried or dried species, legitimate DSC is produced with *Gadus morhua* (Atlantic cod), *Gadus macrocephalus* (Pacific cod), or *Gadus ogac* (Greenland cod), all members of the *Gadidae* family.

Gadus spp. species have a lower jaw shorter than the upper and no palatine teeth, together with a well-developed chin barbel. With three dorsal fins and two anal fins, all separate from each other, their pelvic fins have a slightly elongated filament. They have a pale lateral line, continuous for at least mid-length of the third dorsal fin (Dunn et al. 1990; Oliveira et al. 2012). These species are lean fishes, as they store fat in their liver and have a lipid flesh content of 0.1 to 1% (Gordon 2003; Calder 2021).

*Gadus macrocephalus (*Pacific cod*)* (Figure 1) is found in the North Pacific, from the Yellow Sea to the Bering Strait, and south to about the Los Angeles area (Dunn et al. 1990; Mecklenburg et al. 2016). Characterized by a broad head, its interorbital space comprises 18 to 25% of head length, and the anterior part of its swim bladder has 2 relatively short, horn-like extensions. Visually, it is dorsally brown to grey with spots or vermiculations, ventrally paler (Dunn et al. 1990; Mecklenburg et al. 2016).

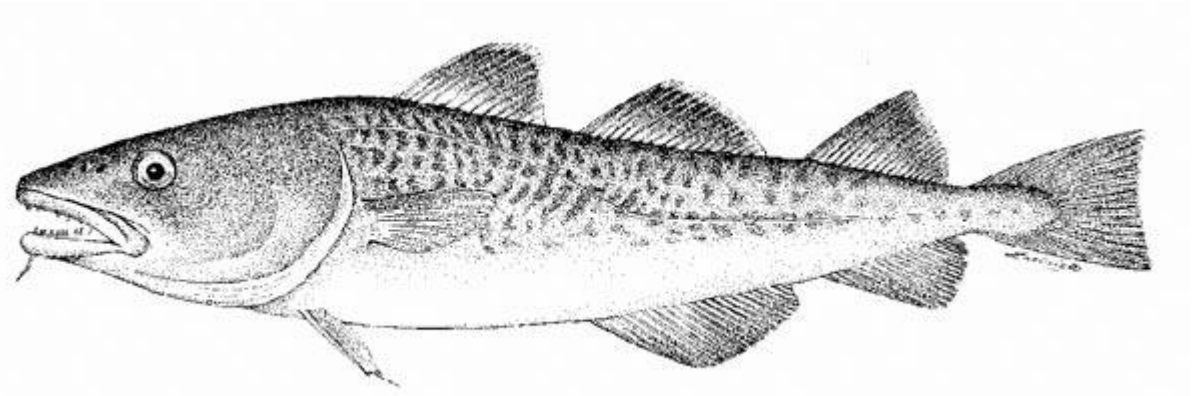


Figure 1 - *Gadus macrocephalus* (FAO 2022a).

Gadus ogac (Figure 2) is found from Alaska to Greenland, named Greenland cod. Usually lives close to the coast, from 0 to 200 m depth, and is rarely found offshore, in deeper water. *Gadus ogac* is sometimes considered a synonym of *Gadus macrocephalus* (Mecklenburg et al. 2016; Taboada et al. 2017), but it is still a species on its own based on genetic and embryological data (Dyldin and Orlov 2017). With similar morphology to *Gadus macrocephalus*, this species differs on its coloration, with indistinct spots dorsally and on sides, and a generally dark shading that turns paler ventrally (Mecklenburg et al. 2016; Taboada et al. 2017).

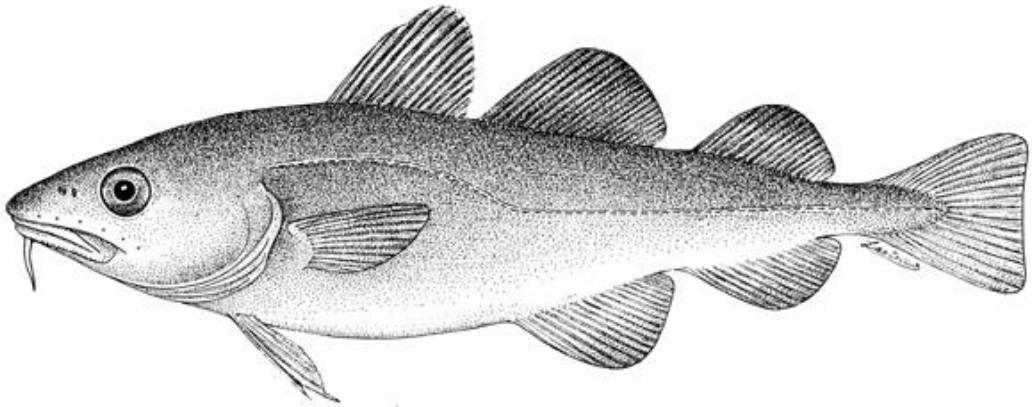


Figure 2 - *Gadus ogac* (FAO 2022c).

Gadus morhua (Atlantic cod) (Figure 3) is found in Northeastern and Northwestern Atlantic Ocean, along the North American coast, coasts of Greenland, Iceland, and of Europe from the Bay of Biscay to the Barents Sea, including around Bear Island. It has a narrow head, with an interorbital space of 15 to 22% of its head length. With variable colour, it is brownish to greenish or grey dorsally, and pale ventrally (Dunn et al. 1990; Mecklenburg et al. 2016).

According to AIB's (2010) *Caderno de Especificações e Obrigações do Produto Bacalhau de Cura Tradicional Portuguesa,* fresh cod must comply with the chemical criteria present in table 1 and should be checked for viable parasites (FAO and World Health Organization (WHO) 2020a).

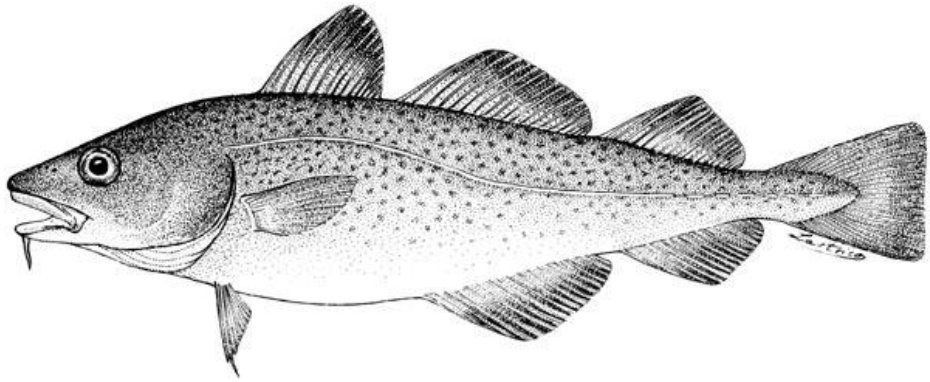


Figure 3 - *Gadus morhua* (FAO 2022b).

Table 1 – Fresh cod chemical criteria (adapted from AIB 2010).

Parameter	Value
Protein	16 -18g/100g
Total Volatile Basic Nitrogen (TVB-N)	<25mg/100g
Nitrogen Content of Free Amino Acids (FFA)	<85mg/100g
Trimethylamine nitrogen (TMA-N)	<2.5mg/100g
Humidity	80-85%

1.1.1.2.1.2. Related species

Phycis blennoides (Greater forkbeard), *Melanogrammus aeglefinus* (Haddock), *Eleginus navaga* (Navaga), *Boreogadus saida* (Polar cod), *Pollachius virens* (Saithe), *Molva molva* (Ling), *Pollachius pollachius* (Pollack), *Theragra chalcogramma* (Alaska pollock), and *Brosme brosme* (Cusk) are all the related species considered for the development of dried salted products in *Decreto-Lei* no. 25/2005 of 28th of January establishing the commercialization conditions for salted, green, semi-dried or dried cod, and related salted, green, semi-dried or dried species. All these species share a common taxonomy, as they are part of the *Gadiformes* order, with most of them being part of the *Gadidae* family. *Brosme brosme* and *Molva molva* belong to the *Lotidae* family, while *Phycis blennoides* is part of the *Phycidae* family.

1.1.1.2.2. Salt

Salt is “a crystalline product consisting predominantly of sodium chloride. It is obtained from the sea, from underground rock salt deposits or from natural brine” (Codex Alimentarius Commission 2006, p.1)

Salt is mainly a crystal form sodium chloride (NaCl), but can also contain different elements, according to its origin. Marine and solar salt can contain substances such as calcium and magnesium ions, as well as sulphates, bromides, and other impurities (Codex Alimentarius Commission 2006; Turan and Erkoyuncu 2012; FAO and WHO 2020).

The use of salt in the food industry has been documented for centuries, with the aim to preserve and extend the shelf-life of foodstuffs (Oliveira et al. 2012; Pedro and Nunes 2019; Singh et al. 2022). Furthermore, it also influences product’s final texture and structure, colour and flavour, giving it a salty taste (Pedro and Nunes 2019). It is used as a preservation method, controlling microbial growth by lowering product’s a_w and reducing enzymatic spoilage (Ravishankar and Juneja 2014; Inguglia et al. 2017; U.S. Food and Drug Administration (FDA) 2021).

When used for the salting of fish, it must be white, odourless, cleaned, and free of foreign objects and contaminants. With a minimum level of 95% NaCl, additives and other

elements can be added, such as magnesium and calcium (Associação dos Industriais de Bacalhau (AIB) 2010; FAO and WHO 2020a). Marine salt is normally used, but care must be taken, as it can be harbour of halophilic microorganisms that can lead to spoilage (Oliveira et al. 2012; FAO and WHO 2020; Sekar and Kim 2020).

Salt granulometry affects its efficacy, with very fine salt forming clusters, while coarse salt can lead to product damage (Turan and Erkoyuncu 2012; FAO and WHO 2020). A mixed granulometry with 1/3 fine salt and 2/3 coarse salt is recommended by Rodrigues (2006, cited by Oliveira et al. 2012), contrasting with AIB's (2010) recommendation of usage of 90% of salt with granules of less than 8mm.

1.1.1.3. Manufacturing process and desired characteristics

According to *Decreto-Lei* no. 25/2005 of 28th of January, these products are classified according to their commercial quality and commercial type (Table 2). First category fish have no defects, while 2nd category fishes are broken, amputated or have the following defects:

a) defective splitting with the removal of the whole backbone of the fish or without removal of the front two-thirds of the fish;
b) tears of $\geq \frac{1}{2}$ of the fish thickness in the anterior two-thirds of the fish;
c) non-deep tears affecting more than 15% of the fish in a continuously delimited area or more than one-third of the total surface of the fish;
d) blood or liver clots and blood or liver spots affecting more than 5% of the surface of the fish;
e) exposed clavicular bones with torn muscle;
f) excess salt adhering to the dried fish and/or mucus on the dorsal surface due to improperly washed fish before drying.

Table 2 - Commercial classification of DSC and related species according to Decreto-Lei no. 25/2005.

DSC and related species commercial classification	1st Category	2nd Category
>3kg	*Especial*	*Sortido* >3kg
2kg – 3kg	*Graúdo*	*Sortido* 2kg – 3kg
1 kg- 2kg	*Crescido*	*Sortido* 1 kg- 2kg
0.5kg – 1kg	*Corrente*	*Sortido* 0.5kg – 1kg
≤0.5kg	*Miúdo*	*Sortido* ≤0.5kg

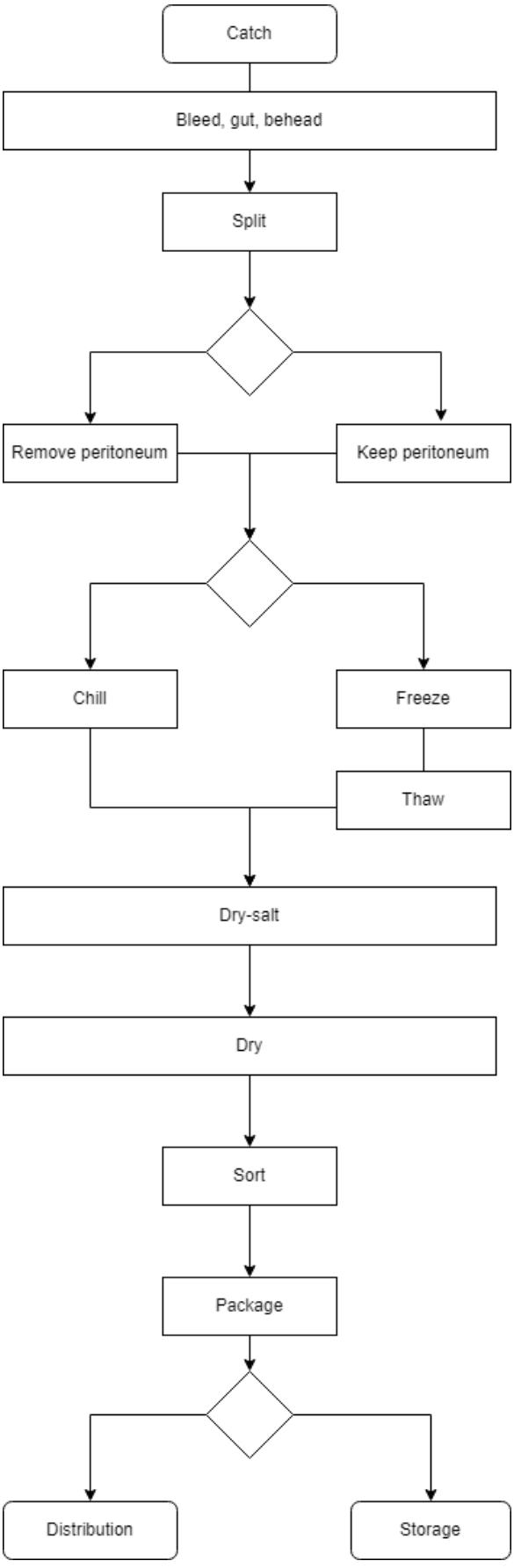


Figure 4 - Dried salted cod processing flowchart (adapted from AIB 2010, Oliveira et al. 2012, Codex Alimentarius Commission 2018, FAO and WHO 2020).

Despite recent developments and focus on aquaculture production, the majority of cod is wild caught along the coasts of Greenland, Iceland, Labrador and Norway, where catch is seasonal from January to May (Sønvisen and Standal 2019; Sørensen et al. 2020; Puvanendran et al. 2022). An array of fishing gear can be used, from cod traps and handlines, to gillnets and trawls (Esaiassen et al. 2004; Mecklenburg et al. 2016; Nguyen and Morris 2022; Sogn-Grundvåg et al. 2022). Fishing gear influences fish's quality, with longliners delivering 90% of 1st category fish, while trawlers deliver only 80% and gillnets lead to fish with frequent defects (Sogn-Grundvåg et al. 2022; Sogn-Grundvåg et al. 2020; European Commission and Directorate-General for Maritime Affairs and Fisheries 2021).

Figure 4 illustrates DSC processing flow chart. After being caught, cod is readily bled, gutted, and is then chilled or frozen. When it arrives to the processing unit, it is then beheaded, split, and thoroughly washed (Oliveira et al. 2012). Splitting cod, sometimes called butterfly split (Teixeira and Mendes 2020), consists of cutting fish along its median line and opening it to remove the anterior $\frac{2}{3}$ of the vertebral column (AIB 2010; Oliveira et al. 2012; Codex Alimentarius Commission 2018; FAO and WHO 2020). It is at this stage that peritoneum can be removed, according to the desired characteristics, as black winged DSC has its peritoneum intact, contrary to white winged DSC (FAO and WHO 2020). Salting of fish can be done in diverse ways, such as wet salting, brining, dry salting, brine injection or a combination of the various techniques, with changes in product appearance, weight yields and protein denaturation (Oliveira et al. 2012; Codex Alimentarius Commission 2018; Pedro and Nunes 2019). Brine injection, despite increasing weight yields when combined with brining, can lead to higher drip losses, due to possible muscle destruction, and higher losses of nitrogenous compounds (Brás and Costa 2010; Thorarinsdottir et al. 2010). Brining and brine injection can be considered pre-salting procedures, that, when followed by a traditional dry-salting process, show an improvement of appearance, but a milder cured flavour (Jónsdóttir et al. 2011). Considering the traditional Portuguese process, outlined by AIB (2010), cod is dry salted, covering its ventral area uniformly with about 0.33 kg of salt/kg of fish. It is stacked in layers, allowing for drainage of the resulting brine. When finalized, the stack is pressed for at least 30 days, in a refrigerated chamber, with temperature and humidity control (10ºC and 80 to 85% relative humidity (RH)) (AIB 2010; Oliveira, Nunes, et al. 2016). The resulting product is called green salted cod, *i.e.*, product that has been bled, gutted, headed, scaled or filleted and which, having undergone physical-chemical maturing by salt, has a salt content of not less than 16% expressed as sodium chloride; and a humidity of more than 51% but not more than 58% (*Decreto-Lei* no. 25/2005 of 28th of January, p.2, open translation).

Green salted cod is transferred to another pallet, layer by layer, amongst which a layer of salt is added, and pressed. A period of at least 30 days follows during which salted cod is

stacked, at a temperature of 4ºC and relative humidity of 80 to 85%; maturing continues and volatile compounds form, contributing to the products' characteristic smell and flavour (AIB 2010; Oliveira, Nunes, et al. 2016; FAO and WHO 2020). Depending on the desired degree of curing and shape, size, composition, and thickness of the fish, maturing takes 2 to 8 weeks (AIB 2010; FAO and WHO 2020). After salt curing, fish is washed with safe water and brushed to remove residual salt and mucus. It is then stacked, resting for 2 days to allow drainage of water.

Cod is then dried. Drying can be done naturally, with sun and wind exposure, or artificially in a drying tunnel. This process happens over 2 to 4 days, with resting periods, in temperatures between 18 and 21ºC and RH of 45 to 80%, with Oliveira et al. (2012) specifying 70% RH.

After drying, DSC is sorted according to size and quality (Table 2), with defective fish being rejected. It is then packaged in food grade cardboard and stored in a refrigeration chamber at 2 to 4ºC and 55 to 60% RH, where it further cures for more than 90 days (AIB 2010; FAO and WHO 2020). Final product has a humidity content of <47% and salt content of >16%, and must be stored at a controlled temperature of less than 7ºC and controlled relative air humidity close to 70% (*Decreto-Lei* no. 25/2005 of 28th of January, Costa 2010, cited by Oliveira et al. 2016).

DSC and related species are included in the definition laid out in Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 of processed fishery products: "processed products resulting from the processing of fishery products or from the further processing of such processed products" (Reg 852/2004, of 29th of April, p.18). DSC and related species can be sold as whole fish, half fish, chops, or other presentations, at temperatures no higher than 7ºC (*Decreto-Lei* no. 25/2005 of 28th of January).

1.1.1.4. Non-conformities and hazards

Hazards are defined in Regulation (EC) Nº 178/2002 of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety as "a biological, chemical or physical agent in, or condition of, food or feed with the potential to cause an adverse health effect" (Reg 178/2002, of 28th of January, p.4), and non-conformities are failures to comply with product requirements (ISO 2018).

As any other foodstuff, DSC and related species products carry several possible hazards and non-conformities, as outlined in Codex Alimentarius Commission's *Standard For Salted Fish And Dried Salted Fish Of The Gadidae Family Of Fishes* and *Decreto-Lei* no. 25/2005 of 28th of January:

a) Hazards
    a. Foreign bodies

Presence of foreign matter, not derived from the fish, that does not pose a threat to public health and is recognisable to the naked eye (Codex Alimentarius Commission 2018). Any evidence of foreign bodies leads to product rejection (*Decreto-Lei* no. 25/2005 of 28th of January).

b. Parasites detectable with naked eye

Gadus morhua's parasitic fauna is comprised of more than 100 species, with the most frequently detected parasites including zoonotic species such as *Anisakis simplex*, *Contracaecum osculatum*, and *Pseudoterranova decipiens*. (Aspholm 1995; Hemmingsen and MacKenzie 2001; Khan et al. 2011; Klapper et al. 2018; Severin et al. 2020). Commonly referred as anisakids, these organisms, even when not viable, may cause allergic reactions and other public health concerns, being of upmost importance to food safety (EFSA Panel on Biological Hazards (BIOHAZ) 2010; Bruschi and Gómez-Morales 2017; Robertson 2018; Mattiucci et al. 2022). When detected, leads to the rejection of the product (*Decreto-Lei* no. 25/2005 of 28th of January).

c. *Staphylococcus aureus*

Staphylococcus spp., and particularly *Staphylococcus aureus*, have been found in salted fish products, and after rehydration and desalting of dry salted cod. Due to a favourable environment for bacterial growth - high humidity and low salt concentration – *Staphylococcus aureus* can reach 10^6 colony-forming units/g, threatening public health (Rodrigues et al. 2003; Pedro et al. 2004; Dias et al. 2021). Detection of this hazard relies on microbial culturing and isolation, together with polymerase chain reaction (Wu et al. 2016; Zhao et al. 2020). Recent developments of rapid methods using ELISA and CRISPR-Cas technology allowed for timed findings and control (Badiou et al. 2010; Lin et al. 2023). When detected, leads to the rejection of the product.

d. Physical, microbial, and chemical contamination

As with any other foodstuff, contamination of DSC may occur at any moment in the food chain due to microbial, chemical, and physical hazards (Hussain 2016; Nerín et al. 2016). As a hazard that is difficult to assess without further analysis and screening, prevention of public health consequences is focused on the control of the different supply chain events (Nerín et al. 2016; Kamala and Kumar 2018). When detected, leads to the rejection of the product.

e. *Clostridium botulinum* toxin

Spores of *Clostridium botulinum* are ubiquitous in sea environments and have been found in fish viscera, with the risk of toxin development being relevant when gutting is done incorrectly (Ganapathiraju et al. 2019; FDA 2021). Since these are heat resistant, control strategies rely on decreasing a_w by drying and controlling the amount of salt content, as well as maintaining refrigerated temperatures (FDA 2021). Detection of this hazard used to rely on time-

consuming analysis, such as intraperitoneal injection of mice and ELISA, but recent developments of rapid methods using molecular biology techniques, such as Loop-Mediated Isothermal Amplification, allow for timed findings and control (Sharma and Whiting 2005; Chen et al. 2021). When detected, leads to the rejection of the product.

b) Non-conformities

a. Rouge

Rouge is a storage defect characterized by reddish spots on the ventral side of DSC, caused by halophilic bacteria *Staphylococcus arlettae,* a commensal bacteria with capacity for opportunistic infections, and *Staphylococcus xylosus,* frequently used as a meat starter culture and present in fermented and salted meat products (Vilhelmsson et al. 1997; Leroy et al. 2017; Lavecchia et al. 2019). When detected, the presence of these patches leads to product rejection (*Decreto-Lei* no. 25/2005 of 28th of January).

b. Burnt

Sticky fish on the dorsal side, with disorganization of texture, resulting from excess heat (*Decreto-Lei* no. 25/2005 of 28th of January; Codex Alimentarius Commission 2018). This defect leads to product rejection, as it should not be made available for the consumer (*Decreto-Lei* no. 25/2005 of 28th of January).

c. Dun

Dun is the result of the growth of the halophilic mould *Wallemia sebi* (former *Sporendonema epizoum*) (Van Klaveren and Legendre 1965; FAO and WHO 2020) and is characterized by clusters of brown and dark spots. When detected, presence of these clusters leads to product rejection (*Decreto-Lei* no. 25/2005 of 28th of January).

d. Abnormal coloration

Presence of patches of uncharacteristic colour, not derived from the manufacturing process (*Decreto-Lei* no. 25/2005 of 28th of January; Codex Alimentarius Commission 2018). When detected, leads to the rejection of the product (*Decreto-Lei* no. 25/2005 of 28th of January).

e. Improper splitting

Not carrying public health issues, improper splitting can influence product's salting and drying period. Thickness is a parameter that can limit transfer rates during drying, as well salting time (Rodrigues et al. 2005; Oliveira et al. 2012). When detected, leads to the rejection of the product.

f. Decomposition

Fish products deterioration signs include breakdown of texture and presence of a distinctive and persistent off-odour and flavour (FAO and WHO 2020). When detected, leads to product's rejection (*Decreto-Lei* no. 25/2005 of 28th of January).

g. Foul odour

Presence of a persistent uncharacteristic odour, indicative of contamination or decomposition (Codex Alimentarius Commission 2018). When detected, leads to the rejection of the product (*Decreto-Lei* no. 25/2005 of 28th of January).

h. Sour

Cod looks cooked on its ventral surface, due to temperature and airing abuse during storage, leading to decomposition of adipose tissue and texture disorganisation. When detected, leads to product rejection (*Decreto-Lei* no. 25/2005 of 28th of January).

i. Incorrect sorting

Not carrying public health or food safety issues, incorrect sorting of DSC is relevant from an economic standpoint. Different qualities and categories are sold at different prices, with 2nd quality cod being cheaper than 1st quality. Rejection is not mandatory, with food business operators (FBO) being able to choose product's destination. Since information to the consumer must be truthful and accurate to allow for informed choices, rejections can derive from this defect (Reg 1169/2011, of 25th of October).

j. Net weight defects

Despite not carrying food safety or public health concerns, FBOs ought to comply with *Portaria* No. 1198/91 of December 18. Rejections stem from deviations larger than 1% of declared net weight.

k. Labelling flaws

Labelling, as defined by Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011, is any word/ particular/ symbol/ etc. relating to a food and placed on any accompanying document or packaging. Considering not only Regulation (EU) No 1169/2011, but also Regulation (EU) No 1379/2013 of the European Parliament and of the Council of 11 December 2013 on the common organisation of the markets in fishery and aquaculture products and Commission Implementing Regulation (EU) 2018/775 of 28 May 2018, a set of particulars that must be provided to the final consumer, and when missing can lead to rejection:

i. Name of the food
ii. Commercial designation of the species and its scientific name
iii. production method, in particular by the following words "… caught …" or "… caught in freshwater …" or "… farmed …"
iv. area where the product was caught or farmed, and the category of fishing gear used in capture of fisheries
v. List of ingredients

1. When the primary ingredient's country of origin or the place of provenance is different from the food's, it must be clear with reference to:
    a. 'EU', 'non-EU' or 'EU and non-EU'
    b. Region, or any other geographical area
    c. FAO Fishing area, or sea or freshwater body
    d. Member State(s) or third country(ies)

vi. Ingredients or processing aids causing allergies or intolerances
vii. Quantity of ingredient
viii. Net quantity
ix. Date of minimum durability or "use by" date
x. Storage conditions and/ or conditions of use
xi. FBO data
xii. Country of origin
xiii. Nutrition declaration.

1.1.2. Food safety management systems

Safe food implies that its consumption will not lead to health issues for the consumer, given that it is prepared and eaten according to its intended use (Codex Alimentarius Commission 2020). Consumers expect safe food, being usually focused on quality aspects as taste, colour, and even convenience (Baiardi et al. 2016; Stevens and Hood 2019; Petrescu et al. 2022). Considered an important public health topic, efforts should be made by FBOs to install food safety management systems (FSMS), with the aim to identify, prevent, and control hazards in the food supply chain, such as Hazard Analysis and Critical Control Point (HACCP) (Panghal et al. 2018; Stevens and Hood 2019; Codex Alimentarius Commission 2020).

Developed in the 1960s, the HACCP approach to food safety began with the endeavour of pathogen-free food for space travel (Ross-Nazzal 2001; Weinroth et al. 2018), but was readily applied to the food industry. The first HACCP guidelines published by the FAO/WHO Codex Alimentarius Commission appeared in 1993 (Huss et al. 2003) with the European Union (EU) legislating on its implementation in 2004 by publishing Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. Nowadays, a range of different FSMS is available, from ISO 22000:2018, to IFS Food and BRCGS Global Food Safety Standard, and all share a basis of hazard analysis and critical control points identification, as well as good practices implementation (BRC Global Standards 2018; ISO 2018; Rincon-Ballesteros et al. 2019; IFS Management GmbH 2021).

The application of a HACCP-based FSMS follows several steps, including prerequisite programmes (PRP), preliminary activities, and HACCP principles application.

1.1.2.1. Prerequisite programmes

FAO and WHO (2003) define prerequisite programmes (PRP) as practices and procedures that establish the foundation of a HACCP system, including Good Hygiene Practices (GHP), Good Agricultural Practices and Good Manufacturing Practices. These PRP, when operational and verified, assure a strong basis for HACCP implementation and ease the transition for further activities, focusing on raw materials and working environment hazards and cross-contamination (García-Díez et al. 2017; Codex Alimentarius Commission 2020). As such, examples of prerequisites, relevant for DSC logistical operations, include:

a) Facility design and equipment

Facility and infrastructure design are the starting point of a FSMS, as operations cannot occur without physical facilities. Poor facility layout and infrastructures lead to negative impacts on food safety and quality (Maller Jr. 2011), as they must allow for GHP, namely, maintenance, cleaning and disinfection activities, as well as protection against accumulation of dirt, mould development, and cross-contamination (Holah 2008; Codex Alimentarius Commission 2020; FAO and WHO 2020). Adequate layout must allow for the normal flow of operations, as well as personnel and material movement in the building (Donk and Gaalman 2004; Maller Jr. 2011; Codex Alimentarius Commission 2020).

Equipment coming into contact with food must be suitable for food contact and designed in such a way that it can be adequately cleaned, disinfected, and maintained. Materials must be non-toxic and durable, as well as constructed in a way that minimize residue build up, bacterial adherence, and biofilm formation, preventing contamination (Holah 2008; Faille et al. 2018; Codex Alimentarius Commission 2020; FAO and WHO 2020).

b) General hygiene

Facilities should be kept clean, as residues and dirt are sources of contamination (Reg 852/2004, of 29th of April; Sharma et al. 2022). The formation of biofilms is also a possibility when cleaning practices are not conducted appropriately, and they must be eliminated to prevent food safety risks and public health concerns (Bashir et al. 2022; Sharma et al. 2022; Zhu et al. 2022 Jun).

Cleaning methods and materials must be adapted accordingly to the processed foodstuff type, food business, and surface materials. Using an isolated method or a combination of physical and chemical methods, any cleaning or disinfection activity must assure no compromise to food safety and suitability. When using chemicals, these must be handled according to manufacturer's instructions, considering contact time, dilutions, and storage (Codex Alimentarius Commission 2020).

Additionally, besides the cleaning method and materials, another important factor to keep in mind is the timing of cleaning procedures. Cleaning during daily production has been shown to decrease the risk of contamination by microorganisms, such as *Listeria*

monocytogenes, with a “clean as you go” approach being crucial (Rørvik et al. 1997; FAO and WHO 2020). A schedule must then be drafted and followed to assure all relevant equipment and facilities are regularly cleaned (FAO and WHO 2020).

Storage of cleaning equipment and chemicals must be done separately from materials used during food processing, in a way that contamination is prevented (Reg 852/2004, of 29th of April). Cleaning material must be kept in good condition and replaced whenever necessary (Codex Alimentarius Commission 2020).

c) Personal hygiene

One responsibility of food business operators is that of assuring that personnel working with food must present an elevated sense of personal hygiene, maintaining appropriate personal health, cleanliness, and behaviour (Codex Alimentarius Commission 2020). Food handlers have been found to be the origin of food contamination with microorganisms such as *Salmonella* spp., *Escherichia coli*, *Staphylococcus aureus*, and other food safety relevant hazards (Lee et al. 2017; Nasrolahei et al. 2017; Bencardino et al. 2021; Dorotíková et al. 2022).

Personnel with symptoms such as diarrhoea, jaundice, fever, sore throat, and others, must report to management and may even be excluded from handling food (Codex Alimentarius Commission 2020; FAO and WHO 2020). Behaviours such as spitting, chewing, eating, sneezing, smoking, and coughing are not allowed near food and food areas, as they can lead to aerosol formation and contamination (Burfoot 2016; Heo et al. 2017; Codex Alimentarius Commission 2020; FAO and WHO 2020). Together with appropriate attire as protective clothing, headwear and footing, adornments such as jewellery can constitute hazards and should not be used (Codex Alimentarius Commission 2020; FAO and WHO 2020).

Hand washing is a crucial component of personal hygiene, and must be carried out according to WHO guidelines, using soap and water for a minimum of 40 to 60 seconds, following a 6-step technique (WHO 2009; Oliveira et al. 2021). Hand washing must be performed before food handling activities, when returning after breaks and after using the toilet, and after handling contaminated material (Codex Alimentarius Commission 2020; FAO and WHO 2020).

d) Temperature control

Raw materials and ingredients are to be stored in appropriate conditions, as to prevent harmful deterioration, reproduction of spoilage and pathogenic microorganisms or the formation of toxins (Reg 852/2004, of 29th of April; Reg 853/2004, of 29th of April; Codex Alimentarius Commission 2020; FAO and WHO 2020). As to ensure temperature control of the storage environment, there must be an automatic record of temperature, accessible at any

given point. Temperature fluctuations must be minimized, and chilling capacity should be adapted to the volume of stored food (Xue et al. 2014; EC 2016).

e) Traceability

Defined as the "the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution" (Reg 178/2002, of 28th of January, p.4), is a key component of a food safety management system. It is guaranteed by elements designated traceable resource units (TRU), such as batch numbers, pallets, and other elements, and must enable product recall whenever necessary through the fast identification and market withdrawal of unsafe food (Olsen and Borit 2018; Codex Alimentarius Commission 2019; Codex Alimentarius Commission 2020).

f) Training

According to Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs, FBO must ensure the supervision, instruction, and training of food handlers, with FAO and WHO (2020) considering personnel training as a fundamental component of a FSMS. Relevant employees should also be trained in HACCP principles and application regularly, and ongoing training is necessary for all levels of personnel, from food handlers to managers (Codex Alimentarius Commission 2020; FAO and WHO 2020).

Training opportunities and sessions can be focused on different topics and with various educational approaches, but suggested topics include hazards and preventive measures, food manufacturing, processing and handling, as well as food hygiene and good hygiene practices (Codex Alimentarius Commission 2020). Despite widespread, theoretical sessions may not be enough to achieve the desired knowledge, with food handlers learning more when practical training is also offered (Ovca et al. 2018; Yu et al. 2020). Specific training and vocabulary is brought by in an informal way through an active learning approach, based on working instructions and procedures, as well as tasks definition for operating personnel (Agüeria et al. 2018; Codex Alimentarius Commission 2020).

1.1.2.2. Preliminary activities

a) Establish a HACCP team

Decisions about food safety hazards and controls should be taken by a team of trained people with relevant skills, knowledge, and experience (Wallace and Mortimore 2016). The HACCP team must be comprised by multidisciplinary professionals, with different backgrounds such as quality assurance, food safety, microbiology, product development, distribution and logistics, raw material specialists, operations, and engineering (Mortimore 2001; Wallace and

Mortimore 2016; Chen et al. 2020). HACCP team members must have knowledge on HACCP application (Wallace and Mortimore 2016; Codex Alimentarius Commission 2020).

b) Describe the product

A description of products handled at the FBO must be developed, including product characteristics (pH, a_w, ingredients, allergens, etc.) composition, storage conditions, package materials, and method of distribution (Wallace and Mortimore 2016; Swainson 2019a; Codex Alimentarius Commission 2020). Grouping of similar products may be done to ease HACCP implementation and reduce documentation (Dzwolak 2017; Codex Alimentarius Commission 2020).

c) Identify the product's intended use

Description of the expected use by the next FBO and by the consumer. When the intended user is part of a vulnerable group, it may be needed to increase controls to assure high level of food safety (Wallace and Mortimore 2016; Swainson 2019a; Codex Alimentarius Commission 2020)

d) Draw up the commodity flow diagram

Outlining all steps in production or handling of a specific product, a flow diagram is drawn up, with the inclusion of every step in the process under the FBO control, from raw material selection, to processing and distribution (Codex Alimentarius Commission 2020). Designed to be accurate and as simple as possible, when too complex, these can be divided into related parts, provided this relationship is clearly defined (FAO and WHO 2020).

e) On-site confirmation of the flow diagram

Performed by adequately trained personnel, confirmation of the flow diagram is important as this tool will be used to structure hazard analysis. By comparing the flow diagram to activities under the FBO control, HACCP team members may find the need to amend steps of the flow diagram (Wallace and Mortimore 2016; Codex Alimentarius Commission 2020).

1.1.2.3. HACCP principles

Principle 1 - Conduct a hazard analysis and identify control measures

Major hazards (biological, chemical, physical) must be identified through a qualitative process performed by the HACCP team (Sperber 2001; Korada et al. 2018; Codex Alimentarius Commission 2020). An evaluation must be made to understand which hazards are likely to occur, taking into consideration not only the food business operation in question, but also the product’s intended and known unintended uses (Codex Alimentarius Commission 2020).

After identifying every applicable and relevant hazard, the HACCP team must consider control measures to prevent, eliminate, or reduce the hazard to acceptable levels (Chen et al. 2020). More than one control measure may be needed to manage one hazard (Codex Alimentarius Commission 2020).

Principle 2 - Determine the Critical Control Points (CCPs).

Critical control points (CCPs) are steps in which control can be applied, being essential for prevention, removal or reduction of significant hazards to an acceptable level (FAO and WHO 2020). Not every step of a process is considered a CCP, and their determination is supported by a logical decision process, using tools such as decision trees and expert consultation (Korada et al. 2018; Codex Alimentarius Commission 2020).

Principle 3 - Establish validated critical limits

Critical limits are defined as the maximum or minimum measurable value at which a hazard must be controlled at a CCP to prevent or reduce the hazard to an acceptable level. Their establishment must be scientifically sound and validated, as this is a criteria that separates acceptability from unacceptability (Korada et al. 2018; FAO and WHO 2020).

Examples of critical limits include measurable and observable variables such as temperature, time, moisture level, pH, a_w, available chlorine, among others. These can be based on available scientific evidence, legal documents, and third-party studies (Codex Alimentarius Commission 2020).

Principle 4 - Establish a monitoring system for CCPs

Critical limits must be regularly monitored to understand if the system is under control, and procedures must be capable of detecting variations (Korada et al. 2018; Stevens and Hood 2019; Codex Alimentarius Commission 2020). Frequency of monitoring and sampling is influenced by the nature of the hazard, possible deviations, and the likely prevalence of the hazard (Gardner 1997; Codex Alimentarius Commission 2020).

Determination of the applicable sampling can be assisted by consulting competent authorities' documents, as well as Codex Alimentarius' texts such as the *General Guidelines on Sampling* (Codex Alimentarius Commission 2004). Personnel responsible must have appropriate knowledge to monitor critical limits, assess results and clearly document them, including details such as the used methodology and the monitored parameters. These documents will then be further evaluated to assess if corrective actions are needed (Codex Alimentarius Commission 2020).

Principle 5 - Establish corrective actions to be taken when monitoring indicates a deviation from a critical limit at a CCP has occurred

Corrective actions must assure that, in the event of deviation, the affected CCP is then brought under control and that potentially unsafe food does not reach consumers, by segregating the affected product. Root cause analysis should also be conducted to identify the underlying reason(s) for deviations and minimized potential for reoccurrence, with a possible

modification to HACCP plans (Korada et al. 2018; Codex Alimentarius Commission 2020; FAO and WHO 2020).

All corrective actions must be documented in detail, including underlying cause of deviation and procedures for disposition of product. Periodic review of these documents is also highly suggested (Codex Alimentarius Commission 2020; Sadler 2020).

Principle 6 - Validate the HACCP plan and then establish procedures for verification to confirm that the HACCP system is working as intended

Validation of the HACCP plan is needed before its implementation, corresponding to the process of demonstrating the system design is effective and can control the identified hazards, CCP, critical limits, etc. Validation can be based on scientific evidence, mathematical models, validation studies, and guides by the competent authorities (Stevens and Hood 2019; Codex Alimentarius Commission 2020; Sadler 2020). Personnel responsible for this process must fully understand the HACPP and assure that registers are made (Swainson 2019a; Sadler 2020).

Verification activities include procedures and evaluations to confirm HACCP system and control measure effectiveness. The periodic assessment of adequacy of the HACCP plan is also included. These activities must be done by an external member, or at least someone that is not directly involved with monitoring and corrective actions (Codex Alimentarius Commission 2020; Sadler 2020).

Principle 7 - Establish documentation concerning all procedures and records appropriate to these principles and their application

Documentation proves that the HACCP system is working and must be appropriate and sufficient to assist verification activities. Documents that must be maintained include hazard analysis, CCP and critical limit determinations, monitoring procedures and corrective actions, raw material or product specifications, as well as guidance materials, such as work instructions and other relevant texts (Swainson 2019b; Codex Alimentarius Commission 2020; FAO and WHO 2020; Sadler 2020).

Record keeping is crucial to assure HACCP efficiency and aid verification procedures, and, as such, must be as accurate and correct as possible, whilst being easily communicable. These records must be kept for a period of time determined by the competent authorities or, when relating to foodstuffs, for a period that exceeds product's shelf-life (Korada et al. 2018; Codex Alimentarius Commission 2020).

1.1.3. The logistics of food

From farm to fork, an EU approach to ensure food safety and preserve public health throughout the supply chain, various actors play roles in handling foodstuffs and raw materials

(European Union 2020). From producers to retailers, there is a shared responsibility to ensure food safety, but management of such a large chain proves to be a challenge (Koufteros and Lu 2017).

Logistics is the integrative process and organization of the flow of materials and supplies from producer to consumer, including warehousing, distribution, as well as added value services (Kain and Verma 2018; Aday and Aday 2020; European Logistics Platforms 2022). Supply chain, on its part, is a network of organizations, people and resources that cooperate to enhance product and information flow from the producer to the end costumer at the lowest cost and highest speed (Govil and Proth 2002; Kain and Verma 2018). When raw materials are foodstuffs as meat and fish products, products that need to be refrigerated, the supply chain is referred to as a cold chain, defined as a process to preserve products at a controlled temperature, so they are fresh and available to the consumer (Hussain 2016; Khan and Ali 2021).

Starting after raw material processing, the cold chain is comprised of the refrigeration steps along the supply chain that keep perishable food in the desired temperature range (Figure 5) (Mercier et al. 2017). After processing, product is precooled before storage, which is then followed by transportation to distribution centres, where product can be stored for a period dependent on its characteristics and market. Distribution centres or logistics platforms are key components in this chain of events, as it is here that various shipments are sorted and stored. Finally, product is further transported to retail facilities, where it is exposed to the consumer, that buys the product and refrigerates it at home.

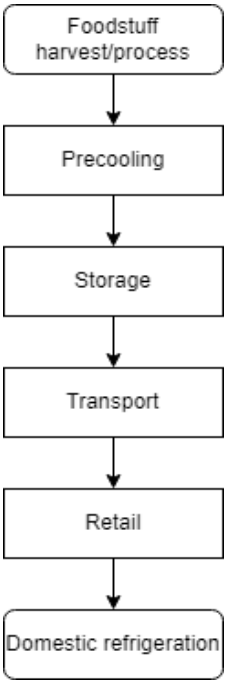


Figure 5 - Simple cold chain flow diagram (adapted from Mercier et al. 2017).

With the aim of removing heat from foodstuffs, precooling activities begin the refrigeration chain. Refrigeration continues during storage and transport, but it is during precooling that the desired temperature must be achieved, as refrigeration further down the chain is only aimed at keeping the temperature (Mercier et al. 2017).

Transport can rely on different means such as land transport by car or truck, marine transport by boat, air transport by plane, and rail transport by train. The option taken derives from reasons such as finances, time constraints, and product characteristics. Despite what is shown in Figure 5, transport can occur all throughout the chain, from harvest to precooling facilities, from storage to a different storage facility, and so on. The most common means of transport through the cold chain is land transportation and the most expensive is air transportation (Mercier et al. 2017).

Logistic platforms, fundamental for supply chain management and supply and demand balance, are an area in which transport and distribution related activities for national and international transit of goods are carried out (Abrahamsson et al. 2003; European Logistics Platforms Association 2018; Cote et al. 2021). Food Logistics Centres are a type of logistics platforms associated with foodstuffs, such as meat and seafood that are usually located near cities, with warehousing facilities for product collection (Antún and Alarcón 2014).

Assurance of adequate temperatures throughout the chain is crucial to guarantee safe and quality products, but there are times when this chain is less efficient than desired. Cold chain steps that are considered the most critical are precooling, transportation, retail exhibition and storage, and domestic fridge storage (Mercier et al. 2017). Most temperature abuses are found during loading and unloading operations, as well as at domestic refrigeration, with uncertainty regarding demand influencing being identified as a relevant cause (Sugathadasa et al. 2021; Wu and Hsiao 2021).

1.2. Internship activities

The internship occurred at a fishery products logistics platform located in Peniche, from October 2021 to February 2022. During this period, food safety and quality control activities performed by Quality Control Department technicians were closely followed.

Before onboarding, national and European food laws were studied to better understand the underlying requirements related to fishery products in general, and to dried salted cod and related products in particular.

During the internship, there was a focus on the development of product specifications, and on learning about new packaging solutions, as well as on following processing and packaging activities of prepared fish products in a fishery products production line. Monitoring procedures and activities at the reception step of fish products and dried salted cod and related products were also fulfilled, including visual and temperature assessment of incoming raw materials and products, as well as assessment and management of non-conformities,

collection of samples for microbiological and physicochemical analytical control and related results assessment, as well as determination of potable water's chlorine content, and collaboration in new staff training activities.

During the internship there was also the opportunity of accompanying an official control inspection by a Portuguese food Authority, as well as attending a training course on work hygiene and safety.

1.2.1. Company's characterization

Company X is a logistic operator located in Peniche (Leiria, Portugal) fishing port. Presenting modern facilities with 7700m^2 (Figure 6) and more than 40 workers, this food operator receives different types of fishery products, including fresh fish, prepared fish

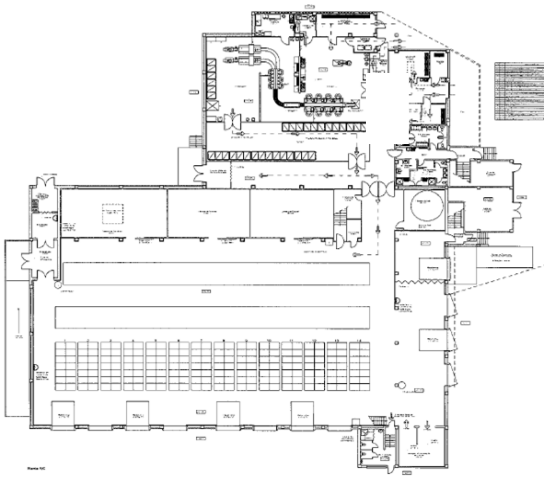


Figure 6 - Logistics' operator blueprint.

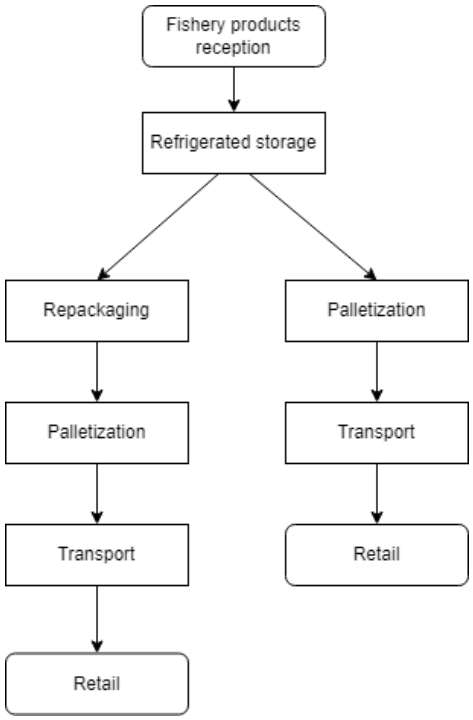


Figure 7 – Company X logistic activities schematic representation.

products, and dried salted fish products, that are temporarily stored to be distributed to retail units along the country (Figure 7). Additionally, a processing plant is also available in the facilities, in which preparation and packaging of several prepared fish products are performed.

1.3. Study aim

This work aimed to:

- assess DSC and related products non-conformities detected during quality and safety control activities performed at the reception step;
- design a practical visual guide to enhance DSC and related products quality and safety control procedures and activities at the reception step of the assessed fishery products logistic operator.

2. Material and methods

2.1. Quality and safety control activities

Quality and safety control (QC) activities of DSC and related products at the logistic operator's reception section were performed by a trained quality control technician, during regular working days. For sampling purposes, DSC and related products were selected to be verified according to an internal FSMS sampling procedure (Table 3).

Table 3 - Internal sampling criteria for monitoring activities performed at the reception step.

Batch Size (Number of boxes)	Sample Size (Number of boxes to be assessed, n)
<15	2
16-50	3
51-150	5
151-500	8
501-3200	13
3201-35000	20
>35000	32

2.1.1. Quality and safety control monitoring and sampling

In this logistic operator, quality control monitoring activities at the reception step are standardized and occur according to Table 4, following defined internal sampling criteria, applied to each delivery (Table 6). In this dissertation, one unit represents one box of DSC and related products.

Table 4 - Reception activities.

Reception activities
1. Assess transport hygiene and product stowage 2. Assess transport temperature 3. Assess pallet hygiene and product stowage 4. Organoleptic characteristics inspection 5. Temperature measurement 6. Traceability and labelling check 7. Parasite search 8. Net weight confirmation

DSC and related products' temperature checks were carried out using a PCE-IR 100 thermometer (PCE Instruments, Albacete, Spain) to ensure compliance with legal requirements set out in *Decreto-Lei* no. 25/2005 of 28th of January, establishing the commercialization conditions for salted, green, semi-dried or dried cod, and related salted, green, semi-dried or dried species, altered by *Decreto-Lei* no. 4/2006 of 3rd January (Table 5). Additionally, whole DSC's humidity was monitored by an external laboratory according to *Norma Portuguesa* 2282 (Instituto Português da Qualidade (IPQ) 1991) to ensure compliance with *Decreto-Lei* no. 25/2005 of 28th of January, altered by *Decreto-Lei* no. 4/2006 of 3rd of January, criteria. For temperature measurement purposes, the central area of the inside of the product's package was selected, to better represent its real temperature.

Considering organoleptic characteristics inspection, visual, odour, and tactile defects were verified in each of the assessed samples, according to criteria presented in Table 5. Traceability and labelling verification considered the batch number confirmation and presence and integrity of DSC and related products packaging labels, according to legal requirements (*Decreto-Lei* no. 25/2005 of 28th of January, altered by *Decreto-Lei* no. 4/2006 of 3rd January, Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004, and Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011).

Macroscopic parasites inspection in DSC and related products was also performed by visual checking (Table 5).

Finally, DSC and related products weight confirmation was carried out using a D430 Weighing Terminal scale (Societa Cooperativa Bilanciai®, Campogalliano, Italy).

2.1.2. Non-conformities analysis

When conducting monitoring activities at the reception step, the QC team followed specific criteria to assess not only transport and stowage, but also product characteristics. Different categories in each assessment group were described, and specific requirements were laid out (Table 5).

Table 5 - DSC and related products criteria used in this study.

Assessment criteria			**Requirements**
Transport	Personnel		Adequate and clean uniform.
	Hygiene and integrity		In good condition, without holes or flaws on the floor or walls.
			Walls and doors built in innocuous, waterproof, corrosion-resistant, and smooth materials.
			Materials easily cleaned and disinfected.
			No communication of the transport box with the driver's cabin.
			Floor built to prevent leakage to the outside.
	Temperature		Equipped with refrigeration equipment.
			Ability to monitor temperature.
Product Stowage	Hygiene and integrity		In good condition and clean.
			By means of adequate and clean equipment, waterproof, resistant, easily cleaned, and disinfected surfaces.
			With equipment that does not alter the smell, taste, or colour of the products.
Whole DSC	Sensory characteristics	Visual attributes	Product should not exhibit patches of uncharacteristic colouring or colouring throughout the fish that is not inherent to the technological process of production.
		Integrity	Product should be whole.
		Odour	Typical, *sui generis* odour.
		Commercial quality	1st Category – fish with no defects. 2nd Category – broken/ amputated fish or presenting the following defects: ● defective splitting with removal of the whole backbone or without removal of the anterior two-thirds of the fish; ● tears of $\geq \frac{1}{2}$ of the fish thickness in the anterior two-thirds of the fish; ● non-deep tears affecting >15% of the fish in a continuously delimited area or more than one-third of the total surface of the fish; ● blood or liver clots/ spots affecting >5% of the surface of the fish; ● exposed clavicular bones with torn muscle; ● excess of adherent salt and/or mucus on the dorsal surface of the fish due to improper washing before drying.
		Absence of defects	Defects in DSC include: ● Burnt – sticky fish on the dorsal side, with texture disorganization, resulting from excess heat; ● *Rouge* - alteration caused by halobacteria; ● Dun – alteration caused by halophilic fungi; ● Sour – alteration resulting from poor storage at improper temperature and airing, causing the adipose tissue to decompose, with total texture disorganization; ● Physical contamination – presence of foreign bodies.
		Parasites	No visible parasites.

		Commercial Category	● *Especial* – 1st category fish weighing >3 kg; ● *Graúdo* – 1st category fish weighing 2 kg-3 kg; ● *Crescido* – 1st category fish weighing 1 kg-2 kg; ● *Corrente* – 1st category fish weighing 0.5 kg-1 kg; ● *Miúdo* - 1st category fish weighing ≤ 0.5kg ● *Sortido* – 2nd category fish with the following scales: o *Sortido* > 3 kg; o *Sortido* 2 kg-3 kg; o *Sortido* 1 kg-2 kg; o *Sortido* 0,5 kg-1 kg; o *Sortido* ≤ 0.5kg
	Temperature		< 7ºC for dried salted products; < 4ºC for salted, green and semi-dried, and by-products.
	Hygiene		No evidence of lack of hygiene.
	Labelling		Labelling should be easily readable and include: ● Commercial denomination; ● Commercial category; ● Scientific name; ● Capture zone; ● Capture method; ● Batch; ● Net weight; ● Use by date; ● Nutritional information; ● Food business operator data.
	Packaging		Whole.
			No evidence of damage or humidity.
	Net weight		Admissible deviation of up to 1% of net weight.
Related products	Sensory characteristics	Visual attributes	Product should not exhibit uncharacteristic colouring, not inherent to the technological process of production.
		Absence of defects	Defects in DSC and related products include: ● Burnt – sticky fish on the dorsal side, with texture disorganization, resulting from excess heat; ● *Rouge* - alteration caused by halobacteria; ● Dun – alteration caused by halophilic fungi; ● Sour – alteration resulting from poor storage at improper temperature and airing, causing the adipose tissue to decompose, with total texture disorganization; ● Physical contamination – presence of foreign bodies.
	Temperature		< 7ºC for dried salted products; < 4ºC for salted, green and semi-dried, and by-products.
	Hygiene		No evidence of lack of hygiene.

	Labelling	Labelling should be easily readable and include: ● Commercial denomination; ● Commercial category; ● Scientific name; ● Capture zone; ● Capture method; ● Batch; ● Net weight; ● Use by date; ● Nutritional information; ● Food business operator data.
	Packaging	Whole.
		No evidence of spillage or damage.

2.2. Non-conforming results

Non-conformities (NC) were classified in minor and major, based on *Codex Alimentarius* Commission (2004, 2018) and *Decreto-Lei* no. 25/2005 of 28 January, altered by *Decreto-Lei* no. 4/2006 of 3rd January. Major non-conformities are related to defects described in legislation and standards, impacting product's commercial ability and food safety, including foul odour, *rouge*, dun, excessive humidity, parasites, physical hazards, and high temperature. Minor non-conformities do not impact the product's commercial ability and include labelling flaws, net weight defects, classification errors, as well as packaging defects (Table 6).

Table 6 – Non-conformity classification.

Type of Non-Conformity
Major
Butterfly defects **Dun** **Excessive humidity** **Foul odour** **Presence of parasites** **Physical hazard** ***Rouge*** **High temperature**
Minor
Packaging defects **Classification error** **Net weight defect** **Labelling flaws**

All products conforming with the above-mentioned criteria are accepted, while those non-conforming are rejected or, in the event of temperature abuse, conditionally accepted and readily placed in a refrigerated area.

When non-conformities occur, a specific report is filled (Annex 1), which is further assessed by the Quality Department Team for trend analysis purposes.

2.3. Development of a practical guide for DSC and related products reception

To develop a practical guide for DSC and related products reception at the logistic operator, some preliminary activities were considered, including:

- observation of quality and safety control reception activities, staff procedures, and assessment of available related documents of the internal FSMS;

- non-conforming reports and trend analysis, together with analytical control data from January 2017 to February 2022;

- photographic report using Nokia 8 TA-1004 (HMD Global, Espoo, Finland) and One Plus 9 (One Plus, Shenzhen, China) cameras.

Finally, a literature search was conducted with a focus on DSC and related products specific characteristics, production process, possible non-conformities, as well as legal requirements and sampling procedures for incoming raw materials.

Based on the *Standard for salted fish and dried salted fish of the Gadidae family of fishes* (Codex Alimentarius Commission 2018) and the *General Guidelines on Sampling* (Codex Alimentarius Commission 2004), a sampling plan was developed.

2.4. Statistical analysis

A database was prepared using Microsoft Office Excel 2019® (Microsoft Corporation, Redmond, United States of America) considering data from temperature at reception, non-conformities in DSC and related products, and humidity (%). Descriptive statistics were carried out with RStudio (RStudio Team 2022), using R version 4.1.2 (R Core Team 2021).

Fisher's exact test was conducted to assess statistical association ($p<0.05$) between type of non-conformity (major and minor) and rejection, as well as non-conformities and rejection, in all products and whole DSC in RStudio.

3. Results

3.1. DSC and related products

The assessed logistic operator receives dry salted legitimate cod, namely *Gadus morhua* and *Gadus macrocephalus*, as well as a related species, *i.e.*, *Theragra chalcogramma*. Regarding commercial presentation, products include whole and chopped DSC, cod cheeks, cod heads, cod tongues, shredded cod and shredded pollock, as well as cod *samos*.

3.2. Non-conforming results detected at reception

Shipments of DSC and related products batches were received in the incoming raw materials section of the logistic platform (Figure 8) from 11:00 to 14:00. Safety and quality control monitoring activities followed the steps outlined in table 3. After monitoring activities

were completed, the accepted batches were kept in the expedition zone at appropriate temperatures (10 to 12ºC), to be distributed to the store (Figure 9).

Whenever a NC was detected, the non-conforming product was placed in a designated area, with a warning sign mentioning its withdrawn from sale, to be returned to the supplier or Disposed as an animal by product according to the Regulation (CE) Nº 1069/2009 laying down health rules as regards animal by-products and derived products not intended for human consumption.

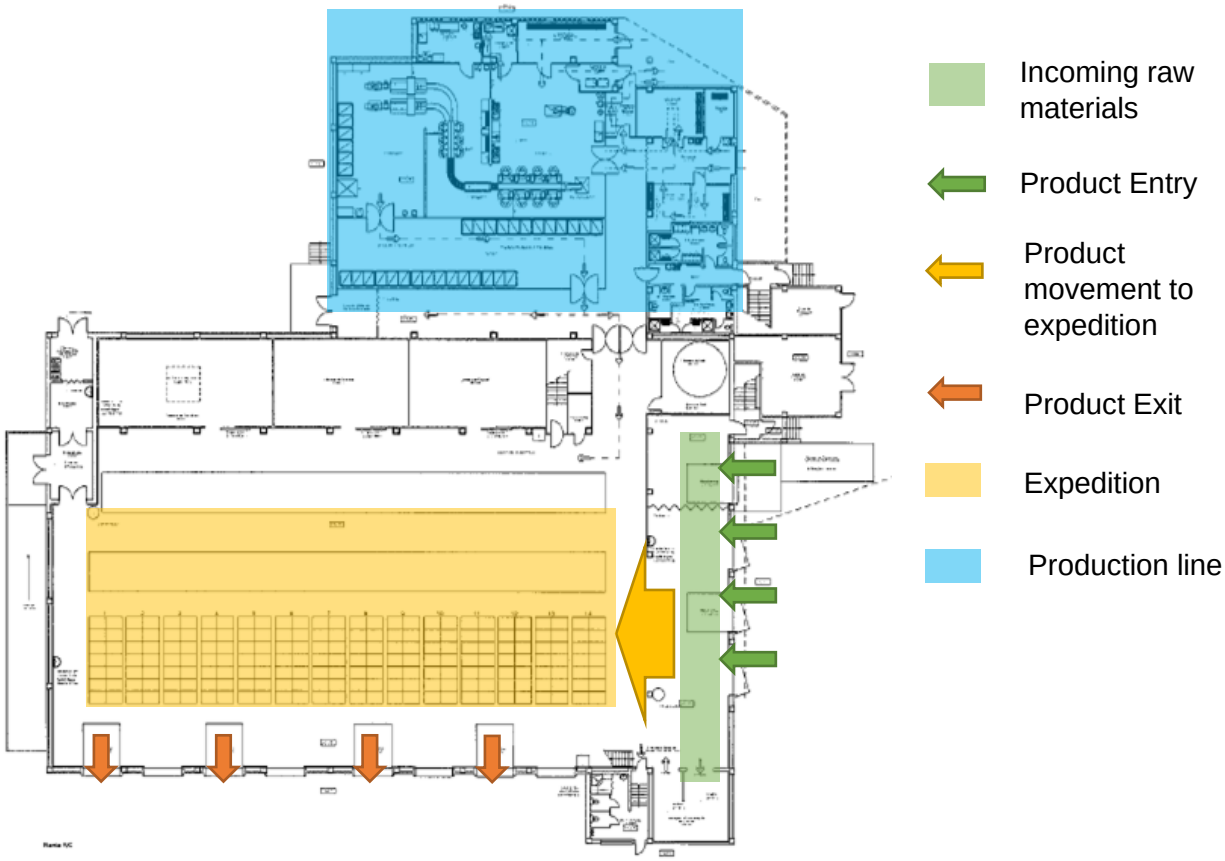


Figure 8 - DSC and related species products circuit within the logistic operator.

Figure 9 - Expedition zone exhibiting different batches of DSC before being distributed to stores.

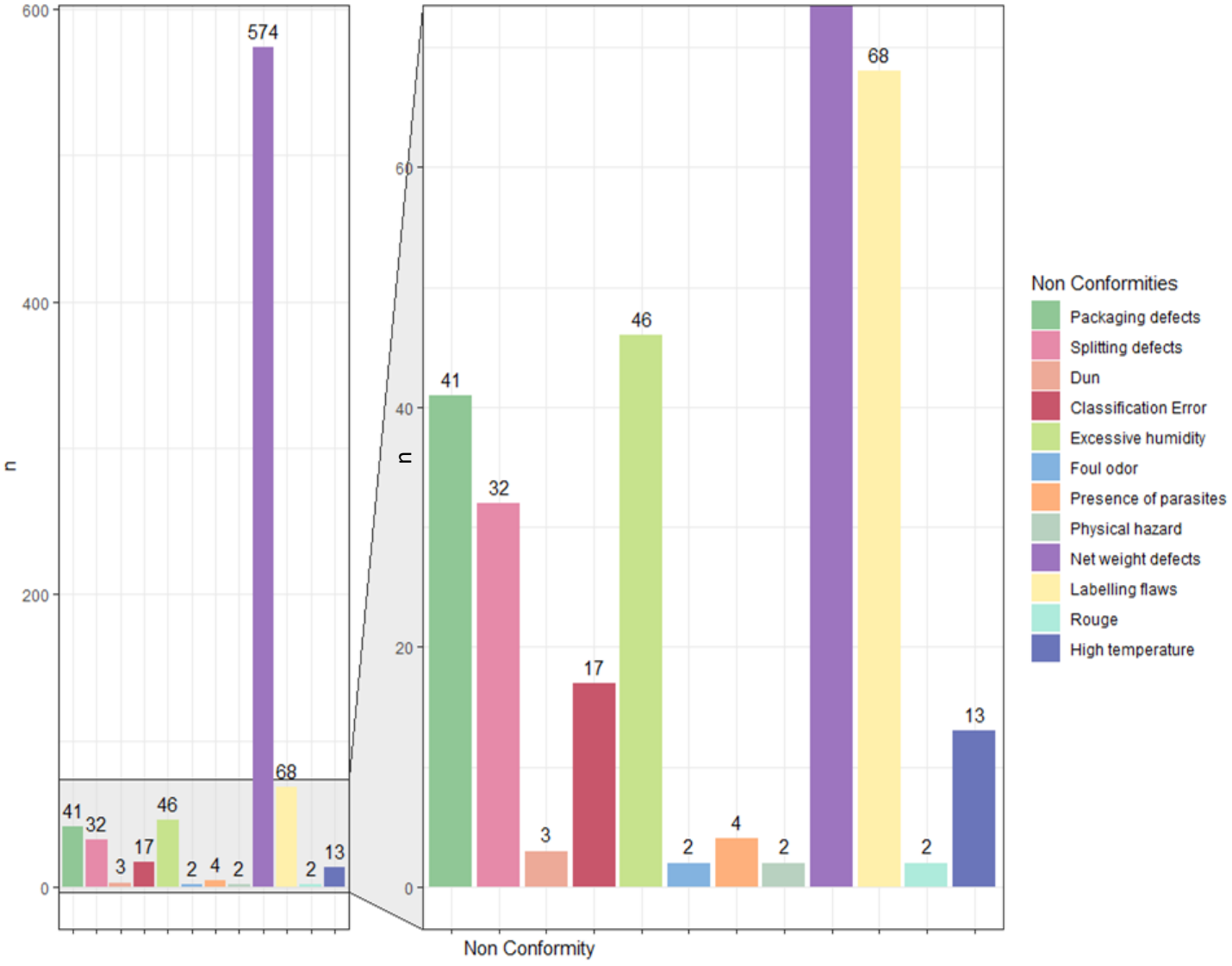
3.2.1. DSC and related products

Records of non-conformities from January 2017 to February 2022 were assessed. A total of 804 NC related to DSC and related products were recorded.

The most common NC (71.39%; n=574) was related to net weight deviations, followed by labelling flaws (8.46%; n=68), and excessive humidity (5.72%; n=46). Specific dried salted product defects, such as dun and *rouge*, represented a small number of NC over the years, with *rouge* corresponding to 0.25% (n=2) of the total occurrences and dun to 0.37% (n=3) (Graph 1 and Table 7).

Considering NC classification, minor NC were overrepresented (87.06%; n=700), while major NC accounted for 12.94% (n=104) of all NC. The higher proportion of minor NC is influenced by net weight defects, a non-conformity that has mainly economic consequences.

Graph 1- Relative frequency of NC detected in DSC and related species products in the reception step monitoring activities of the assessed logistic operator from January 2017 to February 2022.



Not all NC determined a product rejection, and 3.50% (n=28) of all non-conforming products were accepted. In the case of major NC, 15.40% (n=16) of the products were accepted, even when temperatures were above the specified temperature range for DSC and related food products, or its humidity was excessive (Table 7). In the assessed logistic operator, conditional acceptance of food products occurs, with the product being readily placed in chilled facilities to correct its temperature.

Table 7 - Relative frequency of detected NC and number of rejections in DSC and related products according to NC classification from January 2017 to February 2022.

	Non-conformities		
Type of Non-Conformity	**n; %**	**Accepted**	**Rejected**
Major	**104; 12.94%**	**16**	**88**
Splitting defects	32; 3.98%	0	32
Dun	3; 0.37%	0	3
Excessive humidity	46; 5.72%	3	43
Foul odour	2; 0.25%	0	2
Presence of parasites	4; 0.50%	0	4
Physical hazards	2; 0.25%	1	1
Rouge	2; 0.25%	0	2
High temperature	13; 1.62%	12	1
Minor	**700; 87.06%**	**12**	**688**
Packaging defects	41; 5.10%	0	41
Classification error	17; 2.11%	0	17
Net weight deviations	574; 71.39%	5	569
Labelling flaws	68; 8.46%	7	61
Total	**804; 100%**	**28**	**772**

After conducting a Fisher's exact test to check for an association between the NC classification and the decision to reject the non-conforming food product, a statistically significant ($p < 0.05$) relationship was found with an odds ratio of 10.37. Thus, the odds of a product being rejected with a minor NC is 10.37 times higher than with a major NC.

3.2.2. Whole DSC

3.2.2.1. Non-conformities

Regarding whole DSC, 717 NC were recorded in the logistic operator from January 2017 to January 2022; of these, 87 were classified as major NC, *i.e.*, 12.13% of all NC (Table 8). Similarly, to what is described in section 4.2.1, net weight deviations were overrepresented, corresponding to 79.92% of whole DSC NC. Specific dried salted product defects comprised only a small percentage of all NC, namely 0.42% were due to the occurrence of dun and 0.14% to the presence of *rouge*.

Table 8 - Relative frequency of NC detected and rejections in whole DSC from January 2017 to February 2022.

	Non-conformities		
Type of Non-Conformity	**n; %**	**Accepted**	**Rejected**
Major	**87; 12.13%**	**4**	**83**
Splitting defects	32; 4.46%	0	32
Dun	3; 0.42%	0	3
Excessive humidity	46; 6.42%	3	43
Foul odour	1; 0.14%	0	1
Presence of parasites	2; 0.28%	0	2
Physical hazard	1; 0.14%	1	0
Rouge	1; 0.14%	0	1
High temperature	1; 0.14%	0	1
Minor	**630; 87.87%**	**8**	**622**
Packaging defects	11; 1.53%	0	11
Classification error	17; 2.37%	0	17
Net weight deviations	573; 79.92%	5	568
Labelling flaws	29; 4.04%	3	26
Total	**717; 100%**	**12**	**705**

Figure 10 - Splitting defects in whole DSC.

Again, not all non-conforming products were rejected, with 1.70% (n=12) of all NC being accepted (Table 8). In the case of major NC, 4.60% (n=4) were accepted, with excessive humidity (Figure 11 and 13) accounting for 75% of these cases. A 100% rejection rate was found related to non-conformities such as parasitic presence and splitting defects (Figure 10 and 12).

Fisher's exact test to check for association between NC classification and rejection decision in whole DSC, a statistically significant ($p < 0.05$) relationship was found, with an odds ratio of 3.74. Thus, the odds of a whole DSC being rejected with a minor NC is 3.74 times higher than with a major NC.

Figure 11 - Non-rigid whole DSC.

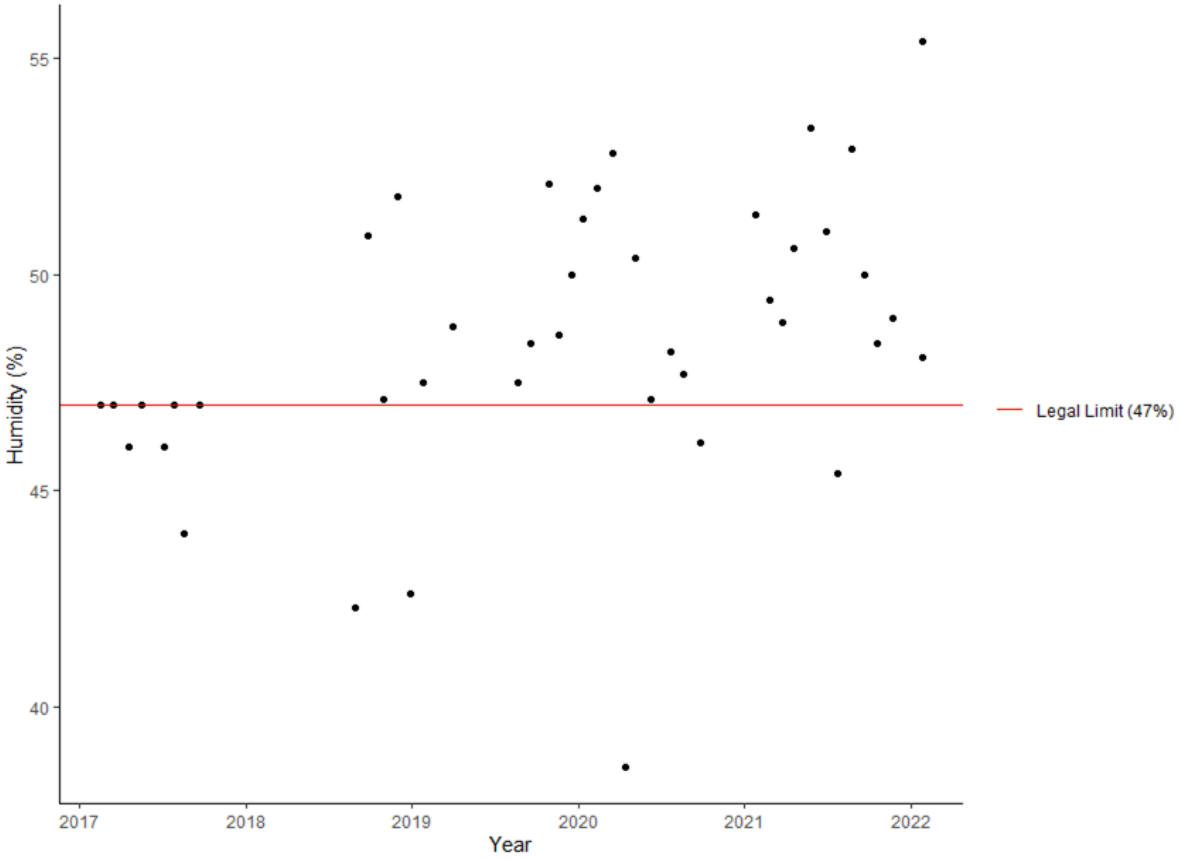
Figure 12 - Parasitic evidence (nematode larvae) in whole DSC peritoneum.

Figure 13 - Evidence of high humidity in whole DSC- visibly wet fin.

3.2.2.2. Humidity

From January 2017 to February 2022, 42 determinations of whole DSC humidity were conducted. Of these, 69.05% (n=29) of the results were non-compliant, with higher humidity values than the legal limit of 47% for dried salted cod products (*Decreto-Lei* no. 25/2005 of 28 January) (Graph 2). The median value for humidity determination results was 48.40%, which is also higher than the legal limit. This excess of water content is a recurring issue, with non-compliant results appearing since 2019, reaching a maximum of 55% in January 2022.

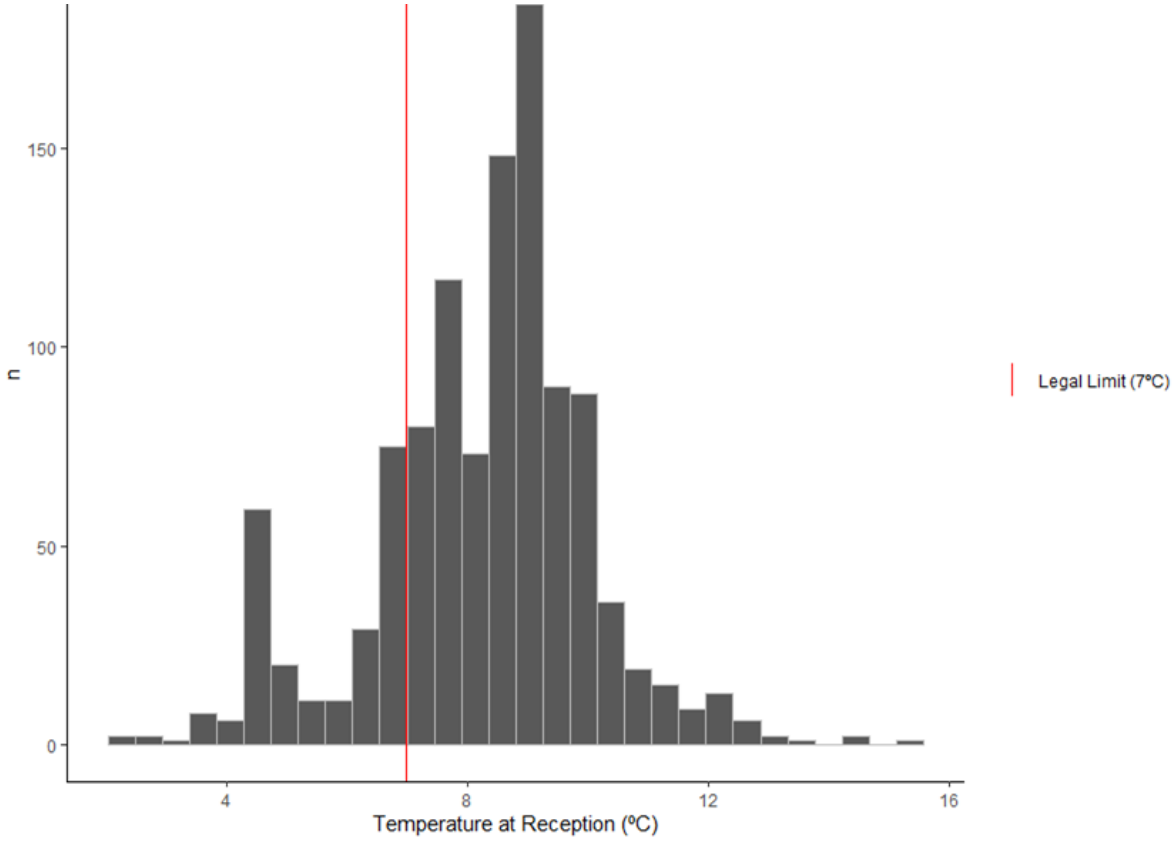
Graph 2 - Whole DSC humidity determination results from January 2017 to February 2022.



3.2.2.3. Temperature monitoring at reception

From January 2017 to January 2022, 1111 whole DSC temperature records were performed. A median temperature of 8.6ºC was obtained, with results ranging from 15.3 ºC to 2.2ºC. Of these, 79.80% (n=886) exceeded the legal limit of 7ºC (Graph 3).

Graph 3 - Whole DSC temperature monitoring results at the reception step of the logistic operator from January 2017 to February 2022.



3.3. Development of a practical guide for DSC and related products reception

After analysing NC detected in DSC and related products, there was the need to develop a visual guide to aid reception activities in the logistic operator. The aim of this document was to quickly assist the personnel responsible for monitoring activities in addressing specific non-conformities and confirming quality and safety issues (Appendix 2).

Logistics personnel included workers with education ranging from primary to secondary school level, and without specific training in food safety and quality, while the QC team presented specific food safety and quality higher education. Because trained professionals in QC activities might not be able to verify all incoming products and raw materials, logistics personnel must be able to carry out its inspection. Thus, there was a focus on keeping the guide's descriptions simple, with little or no scientific and technical jargon, accessible for every worker, regardless of their educational background.

As such, the beginning of the document focuses on stating its aim and resuming the recorded NC. The following chapters focused on explaining quality and safety control activities and detailing product's characteristics and desirable attributes, as well as eventual non-conformities, based on records. Regarding quality and safety control activities, a flow diagram

of the required tasks is shown, together with a simple description of activities, as well as a suggested sampling plan, based on *Codex Alimentarius* Commission documents (2004 and 2018). Product's expected characteristics are presented, by combining photographs and detailed descriptions based on *Decreto-Lei* no. 25/2005 of 28 January, also including salt and humidity requirements. Due to the nature of the determination methods, salt and humidity results are not readily available at the reception step, still, these attributes are needed and useful in periodical checks.

A whole chapter of the guide is dedicated to non-conformities, and because it intends to be a practical visual guide, representative pictures of several different NC were included. A small description of the defects and flaws is also provided, being particularly detailed whenever no photographic record could be displayed. Photographs were captured during the internship, but some were provided by the QC team, particularly those of *rouge* and dun (Figure 14 and 15).

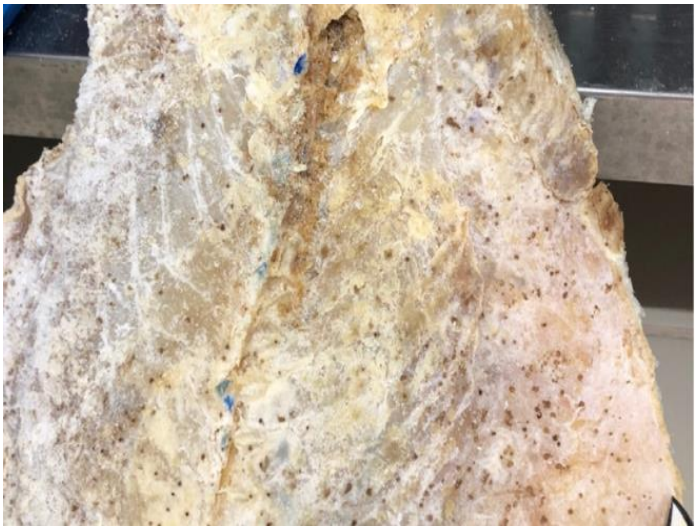


Figure 14 - Dun (private collection, courtesy of Dr. José Cordeiro).

Figure 15 - *Rouge* (private collection, courtesy of Dr. José Cordeiro).

The guide also considers sampling procedures and decisions to be made when NC are detected (Table 9). The final chapter of the guide presents a compendium of relevant European and Portuguese legislation, as well as applicable *Codex Alimentarius* Commission texts, with the purpose of providing QC personnel with further reading, whenever deemed necessary.

Table 9 - DSC and related products sampling procedure considering an AQL=6.5 and a normal inspection level (adapted from Codex Alimentarius Commission 2004 and 2018).

Pallet/Batch number of boxes	Sample size	Rejection if more than n non-conformities
2-8	2	0
9-15	3	0
16-25	5	1
26-50	8	1
51-90	13	2
91-150	20	3
151-280	32	5
281-500	50	7
501-1200	80	10
1201-1320	125	14
1321-10000	200	21

4. Discussion

4.1. Non-conformities

Non-conformities represented a small percentage considering the overall received product. The most common NC in all products and in whole DSC was net weight deviations, followed by labelling flaws in all products, and excessive humidity in whole DSC. Net weight deviations occurred mainly in whole DSC (99.80%). Despite not representing a food safety concern, net weight deviations are a relevant NC, as FBOs ought to comply with *Portaria* No. 1198/91 of December 18, with rejections happening when the product presents a deviation >1% of its declared net weight.

Labelling consists of the information of any food placed on packaging or accompanying documents and is important as the consumer must have all information concerning foodstuffs to assist them in making easier and healthier choices (Reg 1169/2011, of 25th of October; Meijer et al. 2021). This attribute represented the second highest NC in all products (8.46%) and 4.04% of whole DSC NC. Despite the possibility of commercial and public health problems ensuing from lack of or incorrections in labelling information, these occurrences are either rejected, with a rejection rate of 89.70%, or accepted and readily corrected at the logistic operator. The discrepancy in occurrences in all products versus whole DSC may arise from brine spilling and smudging of labels, leading to missing or incorrect batch numbers and other

issues related with mandatory mentions set out in Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers.

From 2017 to 2021, only 4 occurrences of parasitic presence were detected (0.50% of all NC) in the assessed logistic operator, with only 2 of these occurrences relating to whole DSC. Ramos (2011) showed a 92,90% occurrence of anisakids in DSC through visual inspection, with a range from 1 to 30 parasites and an average of more than 5 larvae per fish, and Ramos (1998) showed an 86.40% infestation rate, detected in DSC obtained in retail establishments. The findings at this logistic operator are not in line with Ramos's findings, as only a small number of occurrences through the years was documented. Because this low frequency of detection can be due to the methodology (visual assessment), a possible approach to increase parasite detection can be candling, a technique based on holding up fish to a light in a darkened room or on a light table to detect parasites (Commission Reg 2074/2005, of 5th of December; Levsen et al. 2005; Mercken et al. 2021); nevertheless, a low efficiency has been reported for this method (Bao et al. 2019), that seems to be particularly useful for the detection of heavily infested fish and in the removal of superficial parasites (Bao et al. 2020; Mercken et al. 2022). Candling's ability to detect parasites is affected by the fish's size, thickness, texture and colour of the flesh (Levsen et al. 2005), with the FDA (2017) detailing that this method is insufficient to avoid this hazard.

Rouge, meaning the red discoloration of the fish's surface, due to the proliferation of halophilic bacteria (*Decreto-Lei* no. 25/2005 of 28th of January; Codex Alimentarius Commission 2018), represented 0.25% of all NC, while dun, due to the development of halophilic mould clusters of dark colour (*Decreto-Lei* no. 25/2005 of 28th of January; Codex Alimentarius Commission 2018), represented 0.37%. These NC are responsible for the immediate and mandatory rejection of the affected product (*Decreto-Lei* no. 25/2005 of 28th of January). Dun is the result of the growth of the mould *Wallemia sebi* (former *Sporendonema epizoum*) (Van Klaveren and Legendre 1965; FAO and WHO 2020). Reddening agents *Staphylococcus arlettae* and *Staphylococcus xylosus* presented the highest countings in DSC by Vilhelmsson et al. (1997). Both dun and r*ouge* occur due to issues during conservation (Oliveira et al. 2012), and the low frequency of detection in this logistic operator can be interpreted as a sign of good practices in the supplying industry.

Commercial classification errors constituted 2.37% of whole DSC NC. These flaws relate to the classification set out in *Decreto-Lei* no. 25/2005 of 28 January, with differences between DSC 1st category and 2nd category, as well as further sorting according to weight. When a whole DSC is wrongly classified, economic losses can arise, as 1st category products are more expensive than 2nd category, with a lightweight cod being cheaper than a heavier one, no matter the category. The product's commercial ability is not impacted, as the logistic

operator is able to correctly classify and label it, with no consequences further down the supply chain. Related to these errors, splitting defects, representing 4.46% of whole DSC NC, can impact the product's commercial ability. Some splitting issues are characteristic of 2nd category DSC, such as the removal of the whole backbone of the fish or lack of removal of the front two-thirds of the fish (*Decreto-Lei* no. 25/2005 of 28th of January). Larger defects, such as a total lack of splitting, or splitting defects different from the ones set out in *Decreto-Lei* no. 25/2005 of 28 January, will lead to problems in the product's commercial ability, since they cannot be sold. Furthermore, defects in splitting can lead to issues in cod processing, as its thickness correlates to the time of salting, being a parameter that can limit transfer rates during drying (Rodrigues et al. 2005; Oliveira et al. 2012).

Packaging defects accounted for 5.10% of NC in all products and 1.53% in whole DSC. Whole DSC was packaged in cardboard boxes, while other products had different packaging solutions, such as plastic wrapping or plastic cups. European Union mandates that product packaging must not be a source of contamination (Reg 852/2004, of 29th of April; Reg 853/2004, of 29th of April) and it should protect food products from hazard introduction (Arndt 2001; Wani et al. 2014; Alamri et al. 2021), as well as allow for proper labelling (Codex Alimentarius Commission 2020). Packaging integrity is crucial for food safety and should be monitored throughout the supply chain (Lalpuria et al. 2012). In this logistic operator, all occurrences related to packaging defects led to product's rejection, since when damage occurs, protection against hazards is compromised (Mohan et al. 2020).

Corrective measures must be assured and applied, and the supplier must be informed of these non-conformities. As described in earlier paragraphs, the QC team carried out some instant corrective measures, such as correcting product's labelling, but most of the corrective measures consisted of informing the supplier and continuously monitoring the incoming product.

4.2. Humidity

Whole DSC median humidity rate in this logistic operator was 48.4%, higher than the limit depicted in *Decreto-Lei* no. 25/2005 of 28 January. This deviation leads not only to economic repercussions, with an applicable fine of € 500 to € 44 891 and possible commercial issues (*Decreto-Lei* no. 25/2005 of 28th of January), but also to quality problems such as decreased shelf-life, microbial growth and consequent spoilage (Rodrigues et al. 2003; Lorentzen et al. 2015; Swainson 2019b).

Kong and Singh (2016) detail that the relative humidity (RH) of the storage environment of a product will influence its humidity and a_w, and, as described by Doe et al. (1982), when there is a higher environmental a_w compared to salted cod a_w, the product will absorb water, causing a higher water content and weight gain. Rodrigues et al. (2003) showed an a_w in DSC

of 0.70, with fresh fish having an a_w of 0.989 (Chirife and Fontan 1982). Considering Chirife and Fontan's (1982) definition of equilibrium relative humidity (ERH), meaning the RH of the air surrounding the food that is in equilibrium with its environment, an ERH of 98.90% can be considered for fresh fish, according to the following equation:

$$ERH\ (\%) = a_w \times 100$$

According to Costa (2010), cited by Oliveira et al. (2016), DSC storage should have a relative humidity of approximately 70%. Thus, storing DSC in an area with fresh fish products will lead to an absorption of water by DSC, due to the high ERH at this area, resultant from fresh fish's a_w.

Thus, humidity determination results at this logistic operator were not unexpected, especially because the product is stored until shipping in the same area as fresh fish products, an area with a high relative humidity. Not only that, but when collecting and storing a sample for further analysis, it is stored in a fresh fish refrigeration unit overnight, without the possibility of controlling the unit's humidity. The overnight storage of analytical control samples might have contributed to disparate findings when relating non-conforming products detected at the reception step and analytical results, because only those products that were visually humid and wet at the time of reception were considered as having high humidity content, and as such was registered as a non-conformity.

Considering the assessed logistic operator, and the lack of humidity control in the expedition zone and storage units, as well as the concurrent storage of fresh fish products and DSC and related products, humidity determinations may return altered and unrepresentative values, different from the original product's humidity. FBO's must ensure adequate storage facilities, capable of keeping separated raw materials from processed products (Reg 852/2004, of 29th of April). A clear separation of DSC and fresh fish products should be sought out to prevent alterations that cause commercial problems, product depreciation and spoilage.

4.3. Temperature at reception

Despite 79.8% (n= 886) of the temperature measurements at reception being higher and non-conforming with *Decreto-Lei* no. 25/2005 of 28 January, there were only 13 records of NC related to high temperatures at reception, corresponding to 1.47% of high temperature measurements. Of these 13 occurrences, only 1 lead to product's rejection, with the other 12 being accepted conditionally and monitored hourly to ensure product's temperature would reach an acceptable value. The conditional product's acceptance and monitoring were often carried out without registering a non-conformity.

Lorentzen et al. (2015) describes the growth of halophilic bacteria and subsequent development of areas with red discoloration derived from high temperature storage of DSC loins and deterioration after more than 14 days of storage at 35ºC. Oliveira, Gonçalves, et al.

(2016) described a similar finding, with the development of red discoloration zones after 76 days at 18ºC, with samples stored at 12ºC for 76 days being close to spoilage. Also described is the contribution of water content for the duration of halophilic microorganisms' lag phase and consequent shelf-life, with product's best-by-date being negatively influenced by its water content (Lorentzen et al. 2015). The growth of halophilic mould *Wallemia sebi* is also influenced by temperature, with faster growth at 20ºC and 25º than higher temperatures (Wheeler et al. 1988; Patriarca et al. 2001).

With 79.80% of high temperature occurrences detected at reception, it is possible to speculate that further issues may occur, such as the development of *rouge*, a decrease of product's shelf-life, and spoilage (Lorentzen et al. 2015; Oliveira, Gonçalves, et al. 2016).

Despite Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs establishing that food business operators must comply with temperature requirements for foodstuffs, there is also a possibility of limited periods of time with no temperature control for handling of the product, provided it does not lead to risks to public health. As DSC and related species products are only stored for a maximum of 12 hours before being shipped to another facility, and are kept at a refrigerated temperature of 10ºC, never reaching temperatures as high as described by Lorentzen et al. (2015), the product is conditionally accepted and readily placed in a chilled area to prevent microbial growth and product deterioration.

4.4. Development of a practical guide for DSC and related products reception

The fishing sector already follows Council Regulation (EC) No 2406/96 of 26 November 1996, laying down common marketing standards for certain fishery products, that guides fresh fish's freshness assessment based on organoleptic characteristics, as skin pigmentation, gill colour and smell, eye colour and shine, as well as other visual criteria (EC 1996). As for DSC's sector, the only legal standard available is *Decreto-Lei* no 25/2005 of 28 January. Defects detailed in this legal document are predominantly visual, based on assessing the product's presentation, originating rejections and sales withdrawal. Despite carrying a detailed description of most defects, when referring to *rouge* and dun, no mention of the expected visual aspect of these defects is presented, not allowing the reader to completely understand the non-conformity.

Reception of raw materials and finished products can constitute a HACCP Critical Control Point, as this step represents the first assessment of goods. Reception activities must ensure that all incoming raw materials and goods are fit for purpose and no threat to product's quality, safety and legality is present (Swainson 2019b; Codex Alimentarius Commission 2020). The assessment of incoming product is, thus, of paramount importance. At this stage,

assessment is based mostly on the physical inspection of visual properties and temperature control (Swainson 2019b), not relying on time-consuming analytical determinations. This inspection must be carried out by adequately trained staff, with appropriate technological, human, and instrumental resources and support (Reg 852/2004, of 29th of April). Written procedures of frequency and inspection method must be available at site and references to compliant product, for comparison, must be accessible, whether by freezing samples or documented with photographs (Swainson 2019b).

HACCP implementation brings heavy documentation (Taylor and Kane 2005; Carrascosa et al. 2016), with a range of papers being drafted and archived. From procedures and work instructions to statistical analyses, food workers sometimes perceive FSMS implementation as having a high paperwork load (Luning et al. 2009; Dzwolak 2017). Documentation and record keeping are the basis of assurance activities (Luning et al. 2009; Sadler 2020), but food handlers often consider it to be excessive and a primary difficulty for implementation (Hielm et al. 2006; Galstyan and Harutyunyan 2016; Dzwolak 2017). As to not add to the immense paper load of implementing a FSMS, documentation and record keeping must be adapted according to the company's size and operation, with some flexibility being applied to small and micro food businesses (Taylor and Kane 2005; EC 2016; BIOHAZ et al. 2017).

Considering the fourth and seventh HACCP principles: effective monitoring of CCPs and record keeping of monitorization and verification activities, such as temperature control and NC occurrences (Reg 852/2004, of 29th of April; EC 2016), FBOs must ensure accurate and correct records, as this is paramount for assessment of the FSMS and the establishment of control measures (Luning et al. 2009; Dzwolak 2019). To achieve such accuracy, food workers must be trained in adequate food safety and quality terms, with training sessions adapted to its target audience. Technical knowledge gaps can be found not only in food handlers, but also in HACCP team leaders (Wallace et al. 2012; Smigic et al. 2016; Dzwolak 2019; Gruenfeldova et al. 2019; Ahmed et al. 2021). According to Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs, all employees in the business must be aware of food safety hazards, highlighting the importance of correct and universal training. As the use of a generalist description may result in errors in identifying the correct hazard (Dzwolak 2019), the use of visual aids helps overcoming language and vocabulary barriers, also allowing for the easy communication of food safety topics (Rajagopal et al. 2019).

Continuous process improvement is a focus of FSMS, with the EU regulating that FBO's management must encourage it, based on the best of current scientific and technological knowledge, as well as applicable best practices (Reg 852/2004, of 29th of April). The implementation of HACCP brings improvement in product quality and processes, due to

increased awareness of hazards and employee participation (Wallace and Mortimore 2016), but this is not enough to assure future progress. Review of any food safety management systems should be done regularly, with the intent to keep up with state-of-the-art knowledge and practices, but also focused on understanding its impact on the FBO, contributing to continuous improvement (Fraqueza and Barreto 2014; Wallace and Mortimore 2016; Stevens and Hood 2019). An area to consider while reviewing the plan is raw material control, specifically its execution, what problems have arisen in the past, its efficiency and what can be done differently (Wallace and Mortimore 2016).

The reception of DSC and related species products focuses on metrological determination of temperature and sensorial analysis of incoming goods based on a sampling plan. Despite the QC team being knowledgeable on non-conforming attributes, some NC have an extremely low frequency and can be difficult to identify without previous knowledge of their visual aspect, thus being difficult to correctly record. Following the necessity of continuous process improvement, the need for fewer documentation and Swainson's (2019) suggestion of keeping photographic examples of compliant product, this visual guide was developed with photographs of a compliant product, as well as of NC attributes to ease quality and safety control activities, accessible to any relevant personnel and of easy comprehension, no matter previous education and training.

5. Conclusion

This study revealed that most non-conformities in dried salted cod and related products detected at a logistic operator are minor NC, such as net weight defects. Major NC, with implications on product's commercial ability and safety, have fewer occurrences than minor NC.

Temperature checks at reception revealed almost 80% of product's temperatures monitored above the mandatory 7ºC. Considering product's movement to a chilled area and storage time, no problem is expected to arise from this non-conformity at this stage in the supply chain.

Similarly, during regular humidity checks, there was an elevated number of occurrences that were non-compliant with legal documents. An effort must be made to ensure storage within an appropriate environment, with adequate and controlled humidity.

The development of a practical visual guide to aid reception activities is of great importance as a source of information for the QC team and other personnel responsible for monitoring activities, a paramount step of the supply chain since it is the first opportunity for detection of non-compliant product and its rejection. Aimed as a guidance document, it can aid employees to correctly identify and register non-conforming occurrences.

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7. Annexes

7.1. Annex 1 - Internal non-conformity report form.

Date	Supplier code	Product	Supplier	Non-conformity	Ordered quantity	Rejected Quantity	Order number	Comments

7.2. Annex 2 - Practical visual guide to support control activities and decision at the reception of dried salted cod.

Practical visual guide to enhance procedures at the reception of dried salted cod

Introduction

From 2017 to 2022 several non-conformities at the reception of dried salted cod were detected at company X's logistics platform. These non-conformities include net weight defects, excessive humidity, *rouge*, dun, and even labelling flaws.

Considering company X's market position in the retail sector, it is of upmost importance to follow monitoring activities to ensure that the product sold follows all safety and quality requirements.

Aim

With the development of this practical guide, we intend to facilitate monitoring of the reception of salted dried codfish at this logistics' platform and clarify doubts that may arise in relation to detected non-conformities. The applicable legal diplomas available at the time were used as the basis for its development, as well as documents from the *Codex Alimentarius Commission* and the internal HACCP plan.

Monitoring procedures are presented in detail and as a flowchart. The characteristics and images of a compliant product are then presented, as well as the various non-conformities that may be detected and must be reported to the company's Quality Department.

Quality and safety monitoring activities

Reception of dried salted cod is done at the logistics' platform around 12:00, with possible changes due to external factors. Upon reception and during unloading, it is essential to assess the **transport hygiene and product stowage**, as well as **transport temperature**, available on the receipt printed by the transporter

After unloading, product temperature should be checked following a sampling based on *Codex Alimentarius Commission* 2018 and 2004 (Table 1) and using **PCE-IR 100 thermometer**. During the temperature check, product characteristics are also verified through sensory evaluations. This **sensory evaluation** allows the detection of visual changes in the product, as well as odour changes.

Another focus is product labelling and traceability verification. The presence of all legal labelling requirements, available in Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 and Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004, must be verified. Product traceability is verified by comparing the information on the label with the information available on the invoice.

Table 1 DSC and related products sampling procedure considering an AQL=6.5 and a normal inspection level (adapted from Codex Alimentarius Commission 2004 and 2018).

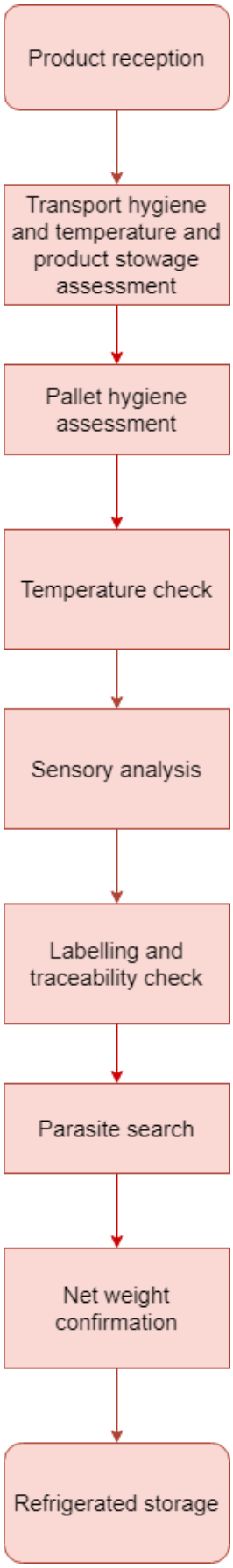
Pallet/Batch number of boxes	Sample size	Rejection if more than n non-conformities
2-8	2	0
9-15	3	0
16-25	5	1
26-50	8	1
51-90	13	2
91-150	20	3
151-280	32	5
281-500	50	7
501-1200	80	10
1201-1320	125	14
1321-10000	200	21

Finally, the last step is **net weight checking**. Different commercial types are selected and weighed on the scales. The weights of the boxes are defined in table 2, and their subtraction from the weight obtained on the scales, allows for net weight to be obtained. A minimum of 2 boxes are weighed, and if non-conformities are detected, 5 boxes are weighed

Table 2 Box Tare.

Box type	Tare (kg)
Orange cardboard box	1,200
Dark blue cardboard box	1,400
Wood box	5,240

Flow diagram of the reception process activities



Compliant dried salted cod

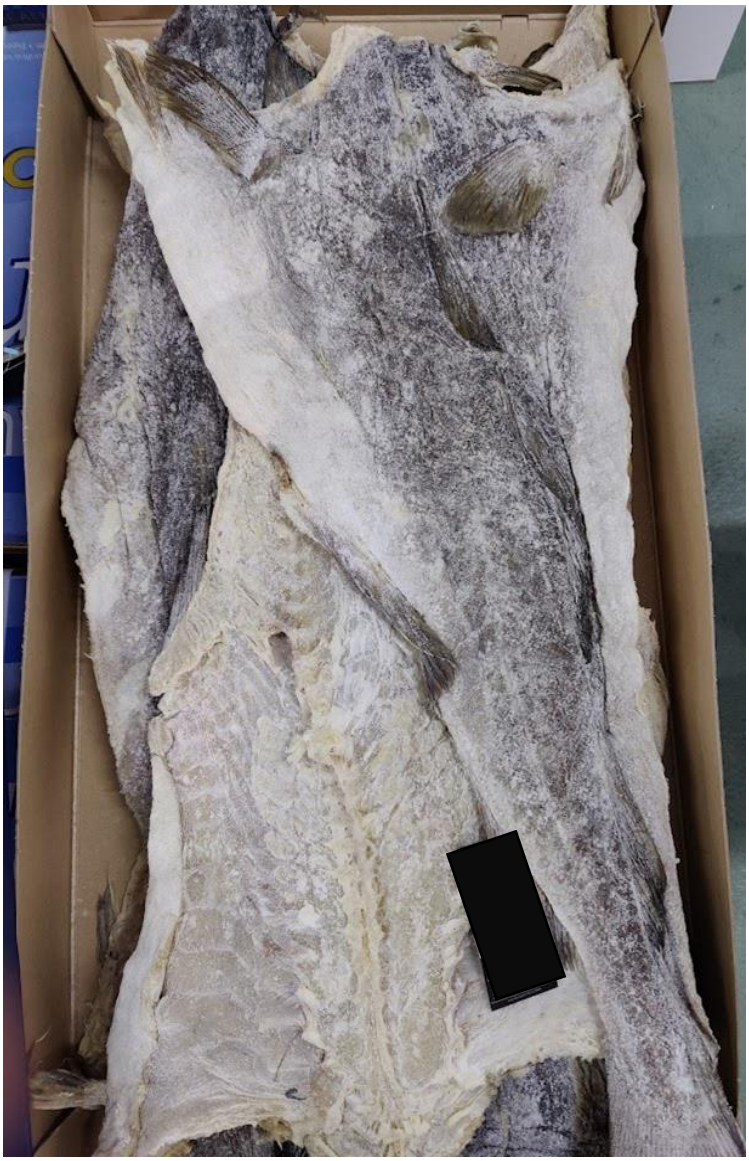


Figure 1 Compliant product.

Figure 2 Compliant product.

According to ***Decreto-Lei* nº. 25/2005 of 28 of january**, dried salted cod corresponds to a product which has been bled, gutted, headed, scaled and washed with a **humidity content of <47% and salt content of >16%**, produced with one of the 3 cod species: *Gadus morhua, Gadus ogac, or Gadus macrocephalus*.

Non-conformities

Classification errors

→ Commercial quality

1st Category – fish with no defects.

2nd Category – broken/ amputated fish or presenting the following defects:

- defective splitting with removal of the whole backbone or without removal of the anterior two-thirds of the fish;
- tears of $\geq \frac{1}{2}$ of the fish thickness in the anterior two-thirds of the fish;
- non-deep tears affecting >15% of the fish in a continuously delimited area or more than one-third of the total surface of the fish;
- blood or liver clots/ spots affecting >5% of the surface of the fish;
- exposed clavicular bones with torn muscle;
- excess of adherent salt and/or mucus on the dorsal surface of the fish due to improper washing before drying.

→ Commercial category

- *Especial* – 1st category fish weighing >3 kg;
- *Graúdo* – 1st category fish weighing 2 kg-3 kg;
- *Crescido* – 1st category fish weighing 1 kg-2 kg;
- *Corrente* – 1st category fish weighing 0.5 kg-1 kg;
- *Miúdo* - 1st category fish weighing ≤0.5 kg
- *Sortido* – 2nd category fish with the following scales:
    - *Sortido* > 3 kg;
    - *Sortido* 2 kg-3 kg;
    - *Sortido* 1 kg-2 kg;
    - *Sortido* 0.5 kg-1 kg;
    - *Sortido* ≤0.5kg

Improper splitting

Figure 3 Splitting defects in whole DSC.

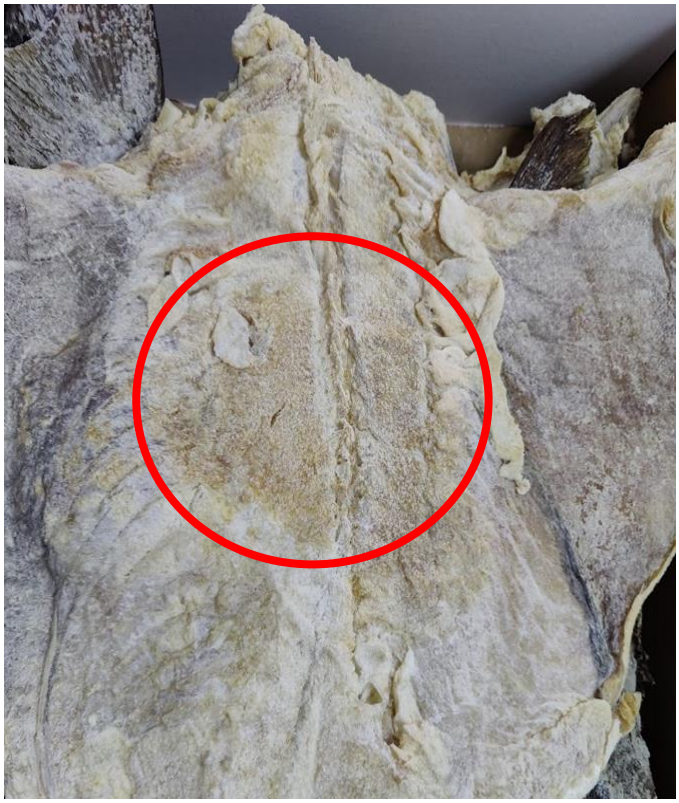


Figure 4 Liver spot

Figure 5 Exposed clavicle bones and muscle tears.

Figure 6 Blood spot.

Burnt

Sticky fish on the dorsal side, with disorganization of texture, resulting from excess heat.

Rouge

Rouge is a storage defect characterized by reddish spots on the ventral side of DSC, caused by halophilic bacteria.

Figure 7 Rouge.

Figure 8 Rouge.

Dun

Dun is the result of the growth of the halophilic mould, characterized by clusters of brown and dark spots.

Figure 9 Dun.

Figure 10 Dun.

Color or odour alterations

Presence of a persistent uncharacteristic odour.

Presence of patches of uncharacteristic colour, not derived from the manufacturing process.

Sour

Cod looks cooked on its ventral surface, due to temperature and airing abuses during storage.

Foreign bodies

Presence of foreign matter, not derived from the fish.

Parasites

Presence of parasites detectable with naked eye.

Figure 11 Parasitic evidence (nematode larvae) in whole DSC peritoneum.

High temperature

Dried salted cod must be stored at a controlled temperature of **less than 7ºC**.

Labelling flaws

Labelling should be easily readable and include:

a) Commercial denomination;
b) Commercial category;
c) Scientific name;
d) Capture zone;
e) Capture method;
f) Ingredients;
g) Batch;
h) Net weight;
i) Use by date;
j) Nutritional information;
k) Food business operator data.

Figure 12 Label.

Excessive humidity/ salt defects

Figure 13 Evidence of high humidity in whole DSC- visibly wet fin.

Figure 14 Evidence of high humidity in whole DSC.

Figure 15 Excess of adherent salt.

Figure 16 Evidence of process defects – flesh falling apart at the touch

Stowage and transportation flaws

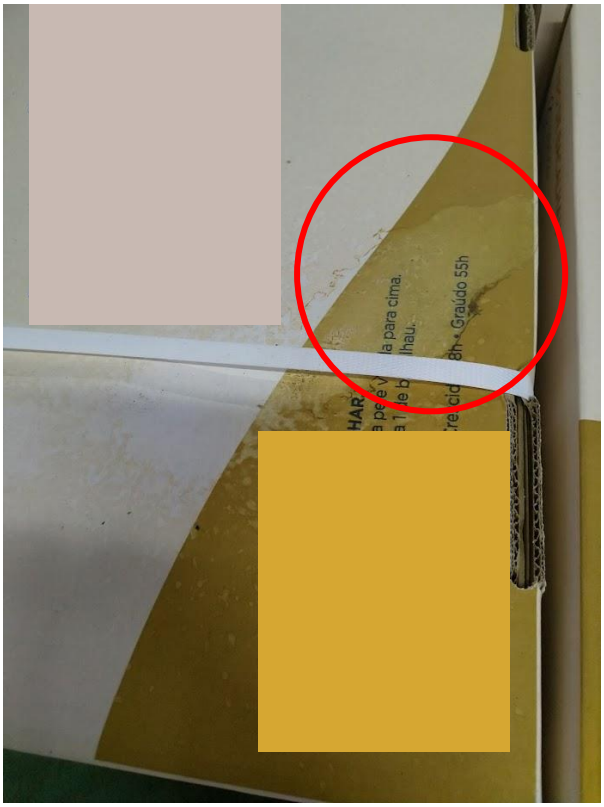


Figure 17 Packaging with traces of humidity.

Figure 18 Pallet overlapping.

Figure 19 Packaging with traces of humidity, resulting from defective transportation, with no product alteration.

Figure 20 Packaging defect.

Net weight deviations

Figura 21 Declared net weight: 25kg Determined net weight: 23,080kg (24,280 kg - 1,200kg).

Complementary reading

Codex Alimentarius Commission. 2018. Standard For Salted Fish And Dried Salted Fish Of The Gadidae Family Of Fishes. Rome: Food and Agriculture Organization of the United Nations : World Health Organization.

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7.3. Annex 3 - Electronic poster communication presented at ATAVET II. International III. National Veterinary Medicine Student Congress (2021).

DEVELOPING PRODUCT SPECIFICATIONS FOR PREPARED FISH PRODUCTS: AN ESSENTIAL PART OF THE FOOD SAFETY MANAGEMENT SYSTEMS

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Product specifications are key elements in a food industry's food safety management system

Study aim:
Develop product specifications for prepared fish products processed in an industrial fresh fishery products processing industry

STORAGE CONDITIONS	Store between 0 ºC and 2 ºC
LABELLING	- Commercial Designation - Scientific Name - Production Method - Catch area - Size - Net Weight - Batch - Best before date - dd/mm/yyyy - Food Business Operator data (NCV, Address)

13 prepared fish product specifications have been published

MICROBIOLOGICAL CRITERIA	Maximum levels for this product: *E. coli*: $5x10^3$ ufc/g *Enterobactereaceae*: 100 ufc/g *Salmonella*: Not detected in 25 g Coagulase positive *Staphylococcus aureus*: $1x10^3$ ufc/g
PHYSICAL-CHEMICAL CRITERIA AND CONTAMINANTS	Maximum levels, in compliance with Regulation (CE) nº1881/2006: Cadmium: 0,05 mg/kg Lead: 0,3 mg/kg Mercury: 0,50 mg/kg
ALLERGENS	Fish, molluscs, crustaceans
NUTRITIONAL INFORMATION	Nutrition information per 100g Energy value 908 kJ / 220 kcal Fat 15,7 g of which saturates 3,46 g Carbohydrates 1,7 g of which sugars <0,5 g Protein 19,7 g Salt 0,167 g

Shelf-life and nutritional information were obtained through laboratory analyses
The remaining information was determined by the quality team or adapted from regulations
Other product specifications and the HACCP plan will be reviewed

References
Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs
Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs
Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs
Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin
Regulation (EU) No 1379/2013 of the European Parliament and of the Council of 11 December 2013 on the common organisation of the markets in fishery and aquaculture products

ATAVET II International III National Student Congress, Atatürk Üniversitesi, Online, December 15-16 2021

7.4. Annex 4 - Electronic poster communication presented at Chapter 4-Conference on Food Science, Nutrition & Public Health (FNPH-2022).

DEVELOPING A VISUAL GUIDE TO ENHANCE QUALITY CONTROL PROCEDURES AT THE RECEPTION OF DRIED SALTED COD IN A LOGISTIC OPERATOR

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Dried salted cod is a traditional food product with a long history of consumption in Portugal

Study aim: create a practical visual guide to aid quality control operations and the identification of non-conformities

120 batches → **0% Non Conformities**

- Product Reception
- Transport hygiene and product stowage assessment
- Temperature measurement
- Sensory analysis
- Labelling and traceability check
- Net weight Audit
- Sort by store

6,7% with quality issues

- 3,3% Excessive humidity
- 0,8% Parasite presence
- 0,8% Splitting defects
- 0,8% Incorrect stowage
- 0,8% Packaging defect

Pallet/Batch number of boxes	Sample size	Rejection if n Non Conformities
2-8	2	0
9-15	3	0
16-25	5	1
26-50	8	1
51-90	13	2
91-150	20	3
151-280	32	5
281-500	50	7
501-1200	80	10
1201-1320	125	14
1321-10000	200	21

Any issues/ non conformities that arise during quality control activities at reception are expected to be quickly clarified by using this guide

References

Decreto-Lei no 25/2005 de 28 de janeiro. Diário da República no 20/2005 – I Série A. Ministério da Agricultura, Pescas e Florestas. Lisboa.
FAO and WHO. 2004. General Guidelines on Sampling. Rome
FAO and WHO. 2018. Standard for Salted Fish and Dried Salted Fish of the Gadidae Family of Fishes. Rome.
FAO and WHO. 2020. Code of Practice for Fish and Fishery Products. Rome
Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin

Chapter 4-Conference on Food Science, Nutrition & Public Health (FNPH-2022) February 24-25th, 2022 Lisbon, Portugal